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

GEOLOGICAL SURVEY
W. H. COLLINS, DIRECTOR

Summary Report, 1932, Part B

CONTENTS

OTTAWA
J. O. PATENAUDE, ACTING KING'S PRINTER
1933

No. 2329

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

GEOLOGICAL SURVEY
W. H. COLLINS, DIRECTOR

Summary Report, 1932, Part B

CONTENTS

OTTAWA
J. O. PATENAUDE, ACTING KING'S PRINTER
1933

No. 2329

WATERTON LAKES-FLATHEAD VALLEY AREA, ALBERTA AND BRITISH COLUMBIA

By G. S. Hume

CONTENTS

Illustrations

INTRODUCTION

In southwestern Alberta and southeastern British Columbia is an area mainly of Precambrian strata (Figure 1) extending from east of Waterton Lakes to Flathead Valley and from the International Boundary northward for 25 miles to North Kootenay Pass, 13 miles south of Corbin. The southeast part of this area, extending west to the interprovincial boundary along the Rocky Mountain summit and for 12 miles north of the International Boundary, lies within Waterton Lakes Park. This area is noted for its scenic beauty and has long been of interest to the geologist because of the structure of the mountain front and the unusual association of oil seepages with rocks of Precambrian age. Seepages of oil and gas are known from several localities and were visited and described by Selwyn[1] in 1891, following some prospecting activity that resulted from their discovery. At that time Selwyn, following Dawson's[2] reports of 1875 and 1885, regarded the oil seepages as occurring in Cambrian rocks. In 1902 Willis,[3] studying Lewis and Livingstone Ranges in Montana, discovered the great Lewis overthrust fault where strata of Late Precambrian age are overthrust onto Cretaceous rocks. The Late Precambrian of Lewis and Livingstone Ranges was correlated by Willis with Dawson's section and this correlation was definitely established by Daly[4] in 1912 who ascribed all the Precambrian rocks to the Lewis series.

[1]Selwyn, A. R. C.: Geol. Surv., Canada, Ann. Rept., vol. V, pt. I, pt. A, p. 9 (1890–91).
[2]Dawson, G. M.: British Boundary Comm. Rept., pp. 67, 68 (1875); Geol. Surv., Canada, Ann. Rept., vol. I, pt. B, p. 39 (1885).
[3]Willis, Bailey: Geol. Soc. Am., Bull., vol. 13, pp. 305-352 (1902).
[4]Daly, R. A.: Geol. Surv., Canada, Mem. 38 (1912).

SCOPE OF WORK AND ACKNOWLEDGMENTS

For some years intermittent drilling has been done in Sage Creek area on the east side of Flathead River Valley. In one well, in which drilling was being continued in 1932, a depth of 3,260 feet had been reached and shows of oil and gas had been reported from what were believed to be Precambrian strata. These interesting results had given rise to repeated requests to the Geological Survey for information on this area and accordingly the writer was instructed to devote part of the field season of 1932 to an examination of the stratigraphy and structure with a view to determining the prospects for oil and gas, if any. A reconnaissance study of six weeks spent in the area between Waterton Lakes and Flathead Valley, with detailed work in Sage Creek area, proved inadequate for the solution of all the geological problems encountered, but considerable data were collected which it is hoped may prove advantageous in further exploration.

The writer wishes to acknowledge his appreciation of the kindness and help given him by Mr. Herbert Knight, Superintendent, and the various officials of Waterton Lakes Park. Thanks are also due Mr. John Gloyn of Pincher Creek who put at the writer's disposal his extensive knowledge of the area and pointed out to him the various seepages on Cameron and Lineham Brooks. In Flathead Valley Mr. James Fisher gave much valuable assistance and the various officials of the Crowsnest-Glacier Oil Company put all information regarding drilling at the writer's disposal and, as well, provided every possible means for the prosecution of the work.

The writer also wishes to acknowledge his indebtedness to his assistants, C. O. Hage, C. E. Michener, and S. Tabacchi, whose co-operation at all times was much appreciated and whose industry added greatly to the knowledge acquired.

ACCESSIBILITY OF AREA

Waterton Lakes may be reached by good gravel roads from Macleod, Cardston, or Pincher Creek. Within the park, the Parks Branch has constructed good roads up Blakiston (Pass) Brook and up Cameron Brook to Cameron (Summit) Lake on the International Boundary, 9 miles south and west of the town of Waterton. A narrow but fair road leaves Cameron Brook road about ½ mile north of Cameron Lake and crosses the Rocky Mountain divide through Akamina Pass. It can be followed to the Akamina Valley Oil Company's property 6½ miles northwest of the interprovincial boundary. From the Akamina Valley Oil Company's property a pack trail can be followed westward along Kishinena Creek to Flathead River in Montana. About a mile northeast of the point where this trail crosses the International Boundary another trail leads northwestward out of Kishinena Valley and across Elder and Fisher Creeks to Sage Creek. Originally a trail led up Sage Creek and across the divide to the headwaters of Blakiston Brook. This trail is now passable for a pack train for only 4 miles above the well sites on Sage Crek. There is a good automobile road from Montana up Flathead Valley to the Sage Creek well locations, but this area is inaccessible from any point in Canada except by pack train. From Sage Creek a pack trail leads across Flathead Valley to the old Corbin wagon road. This road is now passable by pack train only as far as a ford on Flathead River south of the Flathead townsite or about 14 miles south of Corbin. A poor automobile road leads southward from Corbin to the Flathead townsite.

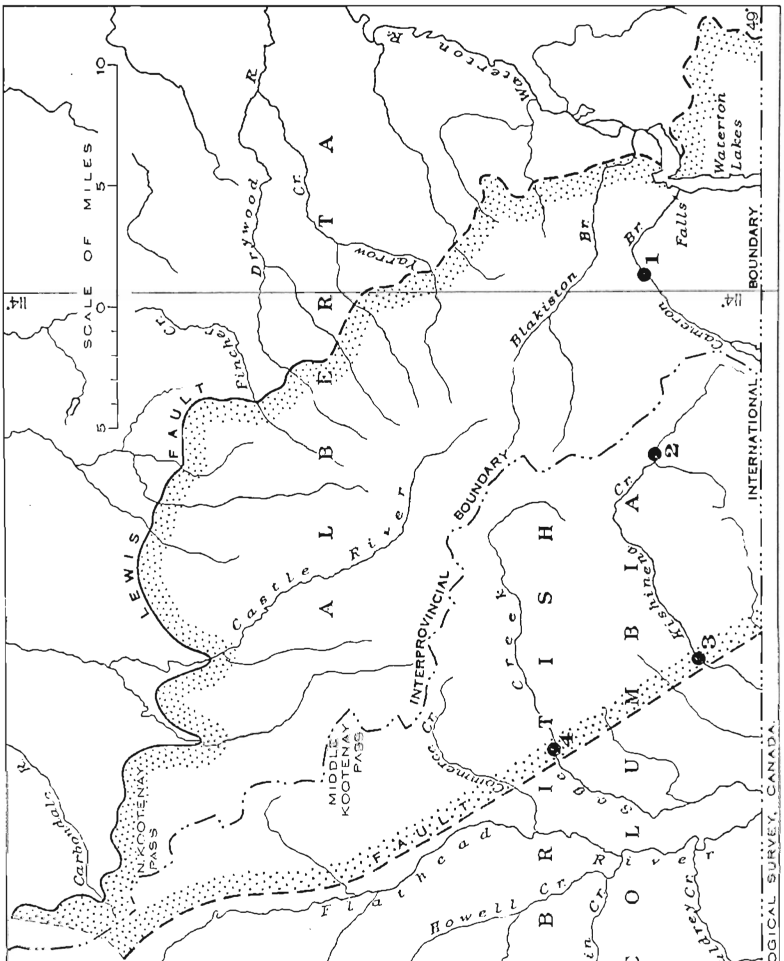


Figure 1. Waterton Lakes-Flathead Valley area, showing outline of area of Precambrian strata. 1, Cameron Brook petroleum seepages at "Oil City"; 2, Akamina Valley Oil Company; 3, Kishinena dome; and 4, Sage Creek dome.

From Flathead townsite a good trail goes east over North Kootenay Pass to the headwaters of Carbondale Creek and down this stream 11 miles to the forest ranger's station where it joins a fair automobile road that leads out to the main highways. The trail on the west side of North Kootenay Pass is fairly steep and the pass has an elevation of 6,774 feet.

The middle Kootenay Pass is said to be impassable owing to fallen timber. It can be approached fairly closely, however, from the east side up the west fork of Castle River. The trail from Beaver Mines up the main branch of Castle River and down Blakiston Brook is in good condition and was the trail followed in taking the party's pack train to Waterton.

PHYSICAL FEATURES

The mountains in southern Alberta that comprise the Clark Range are sharply separated from the eastward flanking plains, above which they rise abruptly several thousand feet. The town of Waterton on upper Waterton Lake is in a sharp angle of the mountain front where the trend of the mountains changes from westerly to northerly and the lake southward from the narrows at the town lies in a deeply incised trench within the mountains. North of the narrows, however, the lake turns easterly and lies on the plains in front of the east-west trending mountains. From Waterton Lakes northward many eastward flowing streams have cut deep valleys through the mountains and divide them into massive, steep-sided peaks and ridges. Within the mountains are many picturesque cirque lakes and the topography is rugged with the mountains rising 2,000 to more than 3,000 feet above the valley bottoms. The tops of the mountains are, as a rule, above timber-line, although the flanks are well timbered with fir, spruce, larch, etc.

The western edge of the Clark Range at Flathead Valley is almost as abrupt as the eastern edge at the plains, the mountain slopes descending sharply to a broad flat through which runs the north fork of Flathead River. Much of the flat is covered by boulder, gravel, and sand deposits, underlying which are gently tilted Tertiary deposits that were laid down in a lake in the valley and hence are much younger than the structural features to which the valley owes its origin.

STRATIGRAPHY

The following succession of formations occurs within Waterton Lakes-Flathead area.

Recent		
Tertiary	Eocene?	Kishinena formation
Mesozoic	Cretaceous	
	Jurassic	
Palæozoic	Pennsylvanian	
	Mississippian	
	Devonian	
	Silurian	
	Cambrian	
Precambrian	Lewis series	Kintla formation
		Sheppard formation
		Purcell lava
		Siyeh formation
		Grinnell formation
		Appekunny formation
		Altyn formation
		Waterton formation

Clark Range is composed mostly of Precambrian rocks warped into a broad, synclinal basin in the central part of which are Cambrian and younger Palæozoic rocks. Palæozoic, Mesozoic, and Tertiary strata occur in Flathead Valley west of Clark Range and Mesozoic and possibly Palæozoic strata underlie the Precambrian rocks of Clark Range as a result of thrust faulting on a tremendous scale. The Precambrian area has a maximum width of 24 miles along the International Boundary. Its eastern and northern limit is the outcrop of the plane of the great Lewis fault, but 25 miles north of the boundary, just beyond North Kootenay Pass, the area narrows to a point and the Precambrian beds disappear under younger rocks.

The stratigraphy along the International Boundary has been described in detail by Daly[1] and will be only briefly outlined here.

Waterton Formation. This formation exposed, according to Daly, at Cameron Falls, on Cameron Brook near its mouth, consists of thin-bedded dolomite and argillite of grey-brown and purple colour. Its total thickness is unknown. A well drilled near Cameron Falls penetrated the Lewis thrust underlying the Waterton at 1,233 feet.[2] The dip of the beds near the well is about 55 degrees, but the general dip in this area is only 15 to 30 degrees. It is probable, therefore, that the total stratigraphic thickness drilled was not more than 1,000 feet. Daly reports 200 feet of Waterton dolomite exposed at Cameron Falls and vicinity. It is probable, therefore, that at Cameron Falls the greatest thickness of the formation to the Lewis thrust is about 1,200 feet.

Altyn Formation. This formation consists of white or light grey magnesium limestone, quartzite, and argillite. Daly gives the thickness as 3,500 feet. This is approximately the thickness of the exposed beds, but it is believed these are repeated somewhat by faulting. The thickness, however, is very great.

Appekunny Formation. The contact between the Altyn and Appekunny formations is well defined, the top bed of the Altyn containing Cryptozoans in some abundance. The base of the Appekunny consists of yellow weathering, argillaceous sandstones and limestones passing upward into a very hard and thick, gritty limestone, the quartz grains on the weathered surface giving the rock almost the appearance of a fine conglomerate. Above the limestone are white quartzite bands as much as 30 feet thick, alternating with argillite and limestones. Above these beds there are about 1,100 feet of grey argillites with one prominent zone of red argillites. The total thickness as measured on Ruby Ridge is 2,020 feet. In Sage Creek area the thickness is more than 3,000 feet. In this area the white quartzite beds are particularly prominent, but no prominent series of red argillite beds was observed below the Grinnell formation.

Grinnell Formation. The Grinnell consists of red argillites with white and red quartzite bands near the top and bottom of the formation. The thickness as measured on Ruby Ridge is 1,025 feet.

---

[1]Daly, R. A.: Geol. Surv., Canada, Mem. 38, pt. 1 (1912).
[2]Johnston, W. A.: Geol. Surv., Canada, Sum. Rept. 1931, pt. B, p. 75.

Siyeh Formation. The Siyeh formation consists mainly of yellowish weathering, somewhat argillaceous limestones with some quartzites and argillites. In Waterton Lakes area the thickness is estimated to be about 3,200 feet, although Daly gives a thickness of 4,000 feet along the International Boundary. This thinning was also noticed in other formations and seems to become much more pronounced northward, the total observed thickness in North Kootenay Pass area being much less than farther south. The Siyeh formation contains a prominent diorite sill about 25 feet thick on the face of Mount Lineham, but only 9 feet thick in North Kootenay Pass area. Towards the base, the formation carries a limestone member, 40 to 50 feet thick, composed wholly of Cryptozoans. The Siyeh is a very prominent cliff-forming member and its yellowish colour on weathering is in striking contrast with the red of the underlying Grinnell and the black of the overlying Purcell lava.

Purcell Lava. Overlying the Siyeh is the Purcell lava, a dark greenish or purplish amygdaloidal basalt with an estimated thickness of 200 to 300 feet. The lava appears to be conformable on the Siyeh formation and seems to thicken to the northward rather than thin like the sediments.

Sheppard Formation. The Sheppard is composed of yellowish weathering, siliceous limestone, quartzites, and argillites. In certain areas it contains a relatively thin lava flow below which are thin-bedded, red argillites and sandstones. In other areas both the red sediments and the lava flow are absent. The total thickness is 400 to 600 feet, thinning to less than 100 feet in North Kootenay Pass area where heavy, reddish quartzites occur near the base of the formation.

Kintla Formation. The Kintla can readily be divided into four divisions which in order of age, from youngest to oldest, are as follows. (4) Grey argillites with small amounts of red argillites and containing at least three porphyrite sills. The thickness is not less than 2,000 feet and may be as much as 2,500 feet in some areas. The thickness is dependent on the amount of erosion, as the top of this formation is everywhere an erosional unconformity. In North Kootenay Pass area this member is lacking. (3) Red quartzites breaking into very massive blocks. The thickness is about 400 feet. (2) Grey and greenish argillites, 150 feet thick. (1) Red argillites and quartzites, 1,200 feet thick. Evidently this lower member was the only one observed by Daly along the International Boundary where it forms the tops of many of the ridges and hills and is very conspicuous on account of its deep red colour.

Cambrian. Above the Kintla formation, and in erosional unconformity with it, are thin, coarse-grained quartz sandstones or quartzites of white or pink colour and probably Cambrian in age, although no fossils were found in them. In the area north of the Akamina Valley Oil Company's property on Akamina Brook, 17 miles west of Waterton Lake, these sandstones rest on the upper member of the Kintla formation, but elsewhere they rest on the next lower member, the Kintla red quartzites. The thickness of the sandstone is not definitely known, but is thought to be between 50 and 100 feet. Above the sandstone are shales of red, green, and grey colours, and these contain abundant trilobite remains at certain horizons. The thickness of these beds is not known as the upper contact with overlying limestones was not seen. In one area only a few hundred feet were present, but in another area a much greater thickness was suspected. It is possible that there is another erosional unconformity above these beds, although this has not been definitely demonstrated.

Silurian. Above the Cambrian shales, in the area north of the Akamina Valley Oil Company's property, is a series of hard and gritty, massive limestones. In this area about 600 feet of these beds form a massive mountain in the centre of the Waterton Lakes-Flathead Basin structure and farther north it seemed as if a much greater thickness occurred. The limestones contain many poor corals and although these are difficult of definite determination they indicate a Silurian age. None of these beds was proved to be present in the vicinity of North Kootenay Pass, as the lowest beds of the limestone-shale series above the Cambrian yielded Devonian fossils. No Ordovician fossils were seen and it is possible that there is a large erosional break at the top of the Cambrian as these beds seemed much thicker in some areas than in others. Such an erosional interval would account for the complete absence of the Ordovician with Silurian limestones overlying the Cambrian shales in the Waterton Lakes-Flathead synclinal basin.

STRUCTURE

The rocks exposed in Clark Range between Waterton Lakes and Flathead Valley are mostly Precambrian, but have been thrust over much younger strata of Mesozoic and Palæozoic ages. The fault, known as the Lewis thrust, was described by Willis[1] from Montana where it has a northwest trend and a southwest dip of 3 to 7¾ degrees. On Chief Mountain in Montana, near the International Boundary, according to Willis the fault has an elevation of between 7,000 and 8,000 feet. In the vicinity of Waterton Lakes (elevation 4,202 feet) the fault plane is completely concealed under outwash and drift material in front of the mountains. A well drilled several years ago near Cameron Falls, in what is now the town of Waterton, penetrated the fault at an elevation of slightly more than 3,000 feet or 1,233 feet below the surface (elevation of well 4,239 feet). In the vicinity of Waterton Lakes the elevation of the fault plane where it comes to the bedrock surface beneath the drift cannot exceed the level of the lakes, i.e., 4,200 feet. As the fault plane apparently dips west the difference in elevation of 2,800 to 3,800 feet of the fault plane at Chief Mountain and at Waterton Lakes may be due to the fact that there is a deep re-entrant of the mountain front at Waterton, but there is also a possibility that the fault plane is warped, as has been stated by Willis[2], who pointed out that the change in strike and dip of the Lewis thrust in Montana indicated a warped surface for the fault plane. No study was made by the writer of the Lewis thrust along the mountain front in Canada except in the vicinity of North Kootenay Pass, 40 miles northwest of Waterton. Here another sharp, local change in the trend of the mountain front occurs. North of the pass, on North Kootenay

[1]Willis, Bailey: Geol. Soc. Am., Bull. 13, p. 330 (1902).
[2]Willis, Bailey: Geol. Soc. Am., vol. 13, p. 332 (1902).

Mountain, the Lewis fault plane has a maximum elevation of more than 6,900 feet, a westerly dip of 21 degrees, and a strike of north 20 degrees west in conformity with the trend of the mountains. Three miles to the southeast on Mount McCarty the trend of the mountain front is east and west and the Lewis fault plane with a maximum elevation of 6,480

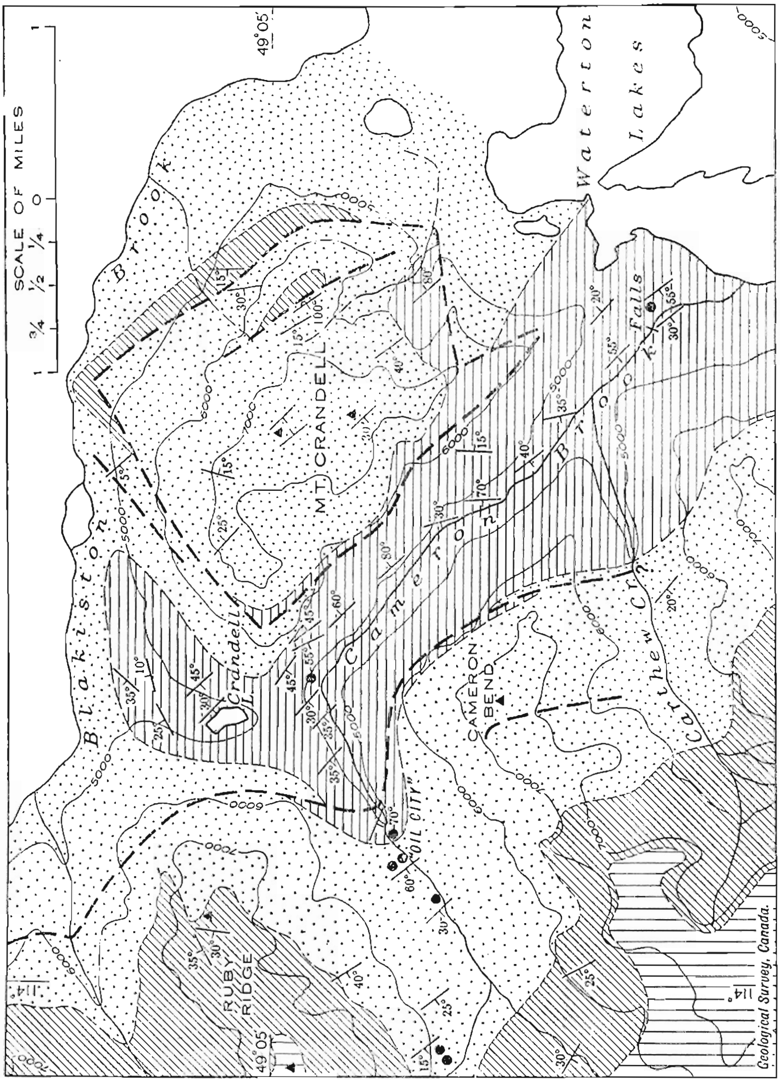


Figure 2. Sketch map of Mount Crandell and vicinity. Siyeh formation shown by vertical ruling; Grinnell formation by diagonal ruling; Appekunny formation by stipple pattern; and Altyn and Waterton formations by horizontal ruling. Bore-holes shown by solid circle, and faults by heavy pecked line.

feet shows a strike of south 80 degrees west and a southerly dip of 13 to 14 degrees. This change in strike of 80 degrees with accompanying changes in direction of dip suggests, as in Montana, warping of the fault plane subsequent to faulting.

Direct evidence of folding subsequent to faulting can be seen on Mount Crandell at Waterton (*See* Figure 2). Here the top of the upper part of the mountain is cut by a thrust fault whose outcrop trace encircles the mountain and can be seen to be folded with the strata. The fault is most easily traced from the northeast face of the mountain to the west face above Crandell Lake. In part of this distance Appekunny grey argillites are overthrust onto a relatively thin slice of red argillites and quartzites of the Grinnell formation and in many places the fault plane can be observed and its strike and dip measured. On the west face of the mountain the outcrop of the fault is well above the level of Crandell Lake (Figure 2) and the fault can be seen again on the east face of Ruby Mountain to the west of Mount Crandell, the intervening area showing Altyn limestones below the plane of the fault. Similarly, the fault on the southwest and south side of Mount Crandell can be again observed on Cameron Mountain across the valley of Cameron Brook and southeast of the narrows at the south end of upper Waterton Lake on Sheep Mountain where Appekunny strata are overthrust onto a relatively thin band of red Grinnell sediments that wedge out westward. This wedge is quite obviously the same as that which occurs on the northeast and north faces of Mount Crandell and which shows a wedging out on the east face of this mountain. The structure on the east face of Mount Crandell appears at first sight to be highly complicated. This is due to the fact that the fault itself is folded, but when the fault is traced the major structure can be seen to be relatively simple.

This evidence of folding subsequent to faulting presented by the fault just described and the evidence given by the Lewis thrust itself are highly suggestive of folding of this major fault, which if true is of great importance in regard to the prospects for oil and gas in the area under consideration.

West of the mountain front, where the faults above described occur, there is very little faulting in the Lewis series which forms most of Clark Range. The regional structure between Waterton Lakes and Flathead Valley is a broad syncline the axis of which in British Columbia is nearly parallel to Akamina Brook, a tributary of Kishinena Creek from the southeast. This syncline crosses Cameron Brook at the northeast end of Cameron Lake on the International Boundary 6 miles west of Waterton, trends northwesterly for several miles, beyond which it appears to turn more northerly. It plunges to the north and west and northwest of the Akamina Valley Oil Company's wells, 17 miles from Waterton, is occupied by Cambrian and later Palæozoic limestones that rest on an eroded surface of the upper beds of the Lewis series. The west limb of the syncline is occupied by beds dipping 25 to 30 degrees northeast and the whole sequence from the top of the Kintla to the lower part of the Appekunny is exposed between the syncline and Flathead Valley. Along the east side of Flathead Valley the Lewis series is faulted against younger strata, but the nature of this fault has not been absolutely determined. Daly[1] and Mackenzie[2] both thought it was a normal fault with downthrow to the

[1]Daly, R. A.: Geol. Surv., Canada, Mem. 38, p. 90 (1912).
[2]Mackenzie, J. D.: Geol. Surv., Canada, Mem. 87, p. 1 (1916).
See also Roy. Soc., Canada, vol. 16, pt. IV, p. 108 (1922).

west. Link[1] in a more recent paper pointed out the possibility of underthrusting and from regional information this explanation seems to the present writer to be much more logical. Such an explanation, however, does not fit all the facts observed by the writer during the reconnaissance trip of 1932. For the most part the fault is obscured by outwash or glacial materials and by Tertiary beds deposited subsequent to faulting. This is particularly the case from Sage Creek south to the International Boundary. A short distance north of Sage Creek, on Commerce Creek, Devonian[2] limestones dipping easterly at 45 degrees were observed in a long, narrow ridge only a short distance west of the outcrops of the Lewis series. Nowhere, however, was the position at the fault closely located except directly south of North Kootenay Pass, but owing to difficulty of travel the whole of the intervening area was not traversed. South of North Kootenay Pass, on a northeast facing mountain, Siyeh beds dipping 25 degrees northwesterly occur. About 50 feet in elevation above the highest outcrop of these beds Palæozoic limestone thought to be of Mississippian age occurs, also dipping 25 degrees in the same direction. Within a short distance southwards the Palæozoic limestones display the same relation to the Grinnell and possibly the Appekunny formations. This contact of the Palæozoic limestones with the apparently underlying Precambrian cannot mark an erosional unconformity and overlap of the Palæozoic because only 2 miles north the complete succession of the Precambrian, Cambrian, and younger Palæozoic formations is exposed. The only possible explanation seems to be that the Palæozoic strata have been thrust from the west over the beds of the Lewis series. The writer could arrive at no satisfactory explanation of this peculiar anomaly of younger beds thrust over older, and, consequently, instead of solving the problem of faulting, has only found facts that make it more confusing. It has always seemed remarkable that normal faulting which results from tension should occur in an area where thrust faulting is predominant and it does not seem logical, therefore, to expect normal faulting on any large scale in Flathead Valley. Mackenzie, however, believed the evidence on the west side of Flathead Valley indicated normal faulting and this problem was investigated by the writer on Cauldrey Creek.[3] West of the outcrops of Tertiary on Cauldrey Creek occur a series of brown sandstones and limestones underlying undoubted Mississippian rocks. Mackenzie, therefore, mapped these beds as Devono-Carboniferous and drew a normal fault between them and a large area of Mesozoic rocks occurring to the north of them. A careful search for fossils, however, revealed the fact that these so-called Devono-Carboniferous beds in reality are Jurassic and the sediments are strikingly similar to the Fernie as exposed elsewhere. It is, therefore, quite apparent that the Mississippian beds on Cauldrey Creek are overthrust onto the Fernie and such preliminary investigations as were made by the writer lead to the deduction that the Mesozoic strata occur in an embayment of the fault front from which the overthrust Palæozoic rocks have been removed by erosion. This, then, eliminates the possibility of normal faulting on the

[1] Link, T. A.: Am. Ass., Pet. Geol., vol. 16, No. 8, p. 786 (1932).
[2] The age is based on fossil determinations by E. M Kindle.
[3] *See* Geol. Surv., Canada, Map No. 182A, accompanying Mem. 87.

west side of Flathead Valley and no evidence was found to support the contention that normal faulting is present on the east side.

As already pointed out there is a sharp descent from the mountains of Clark Range to Flathead Valley. This abrupt change is accompanied by a reversal of the direction of dip of the strata from east to west, giving anticlinal forms within the Lewis series along the mountain front. This anticlinal arrangement is, however, quite strongly modified by east-west cross folds which throw the strata into a series of domes. Three of these domes were observed, namely: on Kishinena Creek, on the headwaters of Fisher and Elder Creeks, and on Sage Creek where drilling is being done. Others are reported to be present, as on Starvation Creek[1] south of Kishinena Creek, and no doubt a thorough examination would reveal several more along the mountain front. In each of the three observed domes the Appekunny formation forms the lowest beds exposed, but the Kishinena and Sage Creek domes are eroded about 2,000 feet deeper than the Fisher-Elder Creek dome. The Fisher-Elder Creek dome lies midway between the Kishinena and Sage Creek domes and is slightly east of a line joining the other two. It is thus higher up the flank of the mountain range, thereby accounting for the fact that the strata exposed in it are not so low stratigraphically as in parts of the others where valleys in each case have been eroded through the domes.

It has already been stated that the character of the fault along the east side of Flathead Valley is unknown. Since oil seepages escape through the Precambrian, in which it is highly improbable that oil could originate, it seems necessary to postulate an origin in younger rocks underlying the Precambrian strata and in faulted contact with them. It is unknown whether this fault is the westward extension of the Lewis thrust or an east-dipping fault along the east side of Flathead Valley, as suggested by Link. If it is the Lewis thrust then Flathead Valley would be a window through the fault as has been suggested.[2] The known facts, however, do not seem to fit such a theory, nor on the other hand are they altogether in harmony with the east-dipping or under-thrust fault as suggested by Link. In the present state of our knowledge, therefore, it seems impossible to go further than to state that a fault probably underlies the Precambrian in Sage and Kishinena Creeks areas and that the oil as found in the seepages comes from below this fault.

In the vicinity of North Kootenay Pass the Lewis thrust was observed in several places and in each it was associated with the coal series of the Kootenay formation. This is similar to the conditions found in the foothills north of Highwood River where all known low-angle faults of large displacement are associated with coal beds. Not only are these coal beds less competent than the enclosing sediments and hence readily broken by faulting, but the coal seems to act as a lubricant in large displacements of this character. The reasons for this are perhaps obvious when it is remembered that coal and graphite are essentially similar in composition and that graphite is a splendid lubricant for certain types of mechanical uses. Where the Lewis thrust plane was observed the coal

[1]Daly, R. A: Geol. Surv., Canada, Mem. 38, p. 90 (1912).
[2]Kirkham, V.: Private report for an oil company.

had been ground into a gouge a foot or more thick lying directly under the hard beds of the Lewis series and in contact with them. In a few places the Kootenay beds were lying above the basal Blairmore conglomerate over which they may have been thrust. The conglomerate in turn was overlying other Blairmore beds and it is considered that in certain places the relationships were due to slicing, whereas in others the beds were overturned. In other places, huge masses of Palæozoic limestone occurred surrounded by Kootenay coal-bearing beds and directly below the strata of the Lewis series. An individual mass of Palæozoic limestone of this kind seen on Mount McCarty was at least 100 feet long and 50 feet thick and it was suspected that much larger masses occurred, but it could not be proved that they belonged to one block because exposures were not continuous. These masses of Palæozoic rocks undoubtedly have been dragged along the fault and hence presumably there are areas where the fault plane must cut the Palæozoic limestones from which the masses have been torn. The assumption is, therefore, that both Mesozoic and Palæozoic rocks occur in contact with the Lewis series in various places under the Lewis thrust. Since similar Mesozoic and Palæozoic rocks are believed to be capable of generating oil, and oil and gas have been produced from them in various places in Alberta, it seems probable that rocks of the same type underlie Sage Creek and Kishinena Creek areas and that the oil has been generated and accumulated in them and is escaping from the reservoir rocks in them through fracture zones in the overlying Precambrian strata.

OIL SEEPAGES AND OIL AND GAS PROSPECTS

Cameron Brook Area

Seepages of oil on Cameron Brook, 5 miles west of Waterton Lakes, were visited by Selwyn in 1891. These seepages are still to be seen, although since Selwyn's visit they have been somewhat changed by pits dug to collect the oil. The seepages seen by the writer are at " Oil City " east of the location of the present Oil City Royalties No. 1 (Patrick Oils, Limited) well and the small derrick said to be the site of the Original Discovery Oil well. By digging in the gravel at several places along the edge of Cameron Brook and throwing the gravel into the water, an iridescent film of oil can be seen and a strong odour of oil can be detected. Also, small pits will collect a thin scum of oil in a short time and a large pit several feet deep dug on the south side of the brook and some distance from it contained at the time of the writer's visit a few gallons of water with a considerable amount of heavy, black, viscous oil. This pit is said to represent a genuine seepage, although its character might lead a sceptical observer to have some misgivings. There is no doubt, however, that genuine oil seepages occur at this place and in the early days considerable quantities of oil are said to have been collected by a man named Aldridge by digging trenches and skimming the oil off the water at the level of the brook. The so-called " Original Discovery " well drilled in 1902 and claimed to be the first well drilled for oil in Alberta, still has a small derrick over it. This well is reported to contain considerable quantities of drilling and fishing equipment and has defied all efforts to clean it out. Government records contain an affidavit by John Lineham, at that time president of the Rocky Mountain Development Company, the company that drilled the well, to the effect that the well produced 8,000 gallons (about 230 barrels) of crude oil of which 700 gallons were sold. At the time of the writer's visit only a very thin film of oil was present on the water, filling the casing to within a few feet of the surface. Another well between one-fourth and one-half mile west, however, shows quite a thick scum of oil on the surface of the water filling the casing.

Other seepages were seen on Lineham Brook a short distance northwest of the Cameron Lake road. Here in a canyon in hard, dense Appekunny argillites a small amount of oil with water is seeping from the rocks along bedding planes and cracks and is dripping slowly into the water of the creek, where the oil quickly forms an iridescent film. The odour of petroleum is quite evident even before the seepages are seen.

The seepages near " Oil City " on Cameron Brook (*See* Figure 2) can be quite definitely related to structure. East of the Original Discovery well location is a fault, the plane of which is almost parallel to the bedding plane of the strata. Nearer the wells the strata are quite highly tilted, suggesting minor faulting, and it is believed the oil that forms the seepages at this place is migrating along the fracture zones of these faults and so escaping to the surface. The angle of dip of the fault plane is not absolutely known, but it is thought the Original Discovery well penetrated the fault zone at about the horizon where oil was encountered, namely at 1,020 feet. The chances of obtaining any steady or commercial flow from such a fracture zone do not seem very good, although, no doubt, a few barrels of oil might be obtained, as happened in the case of the " Original Discovery " well. At a considerable distance north and east of this location is the Cameron Brook anticline, but as far as could be learned no seepages occur near the crest of the anticline which roughly parallels Cameron Brook for about 4 miles from the falls at Waterton Lake northeast to the bend in the brook a short distance east of " Oil City." The seepages are, as stated above, a considerable distance down the southwest flank of this anticline, but the migration of the oil up the fracture zones of the faults towards the anticlinal axis is quite in harmony with the anticlinal theory of oil concentration. A number of shallow wells have been drilled in the Waterton-Cameron Brook area, but only one near Cameron Falls made a test of the oil prospects. This well, at a depth of 1,233 feet, penetrated the Lewis thrust and below it passed into Mesozoic strata. There are conflicting reports as to whether the well contained any oil, but if oil was present it was in very small quantities. The site of the well is now covered by a house, but the stand-pipe of an old water well adjoining the oil well is still to be seen.

The prospects of obtaining oil in any quantity either on the Cameron Brook anticline or on its western flank at " Oil City " are dependent on two factors, namely: (1) the presence of suitable porous horizons to act as reservoir rocks; and (2) favourable structure to cause a concentration of any oil present. It is inconceivable that the Lewis series could have acted as source rocks for oil and gas, since these rocks are too highly metamorphosed. Hence it is believed the origin of the oil is in the Mesozoic strata underlying the Lewis thrust and any concentration of this oil in the Mesozoic strata is dependent on the Cameron Brook anticline extending downward across the fault into them, since the Precambrian strata are too dense and hard to act as reservoir rocks except where they are excessively shattered by faulting. Any oil in the shattered Precambrian rocks, however, would seem to have been derived from a concentration below the fault plane or in a favourable anticlinal structure in the Mesozoic rocks under the Cameron Brook anticline. Such a condition assumes that the Lewis thrust has been folded subsequent to faulting and, as has already been pointed out, there is evidence to support such an hypothesis. Prospects of obtaining oil in commercial quantities, therefore, are dependent either on finding highly shattered zones in the Precambrian where a sufficient porosity has been developed by fracturing, or by drilling through the Precambrian into the anticlinal structure of the Mesozoic rocks where there is a possibility of the presence of porous reservoir rocks. No predictions can be made as to the exact age of the strata likely to be encountered under the Lewis thrust at this place, other than the probability that they will be Mesozoic. In a well at Cameron Falls where the Lewis thrust was penetrated the strata are thought to belong to the Crowsnest volcanics and these beds in themselves would not be expected to be very porous except so far as they contain fracture zones. Thus, though there appears to be a possibility that below the Lewis thrust where it passes beneath the Cameron Brook anticline the strata may also lie in an anticline and in the vicinity of the thrust be so broken as to be a potential reservoir for oil, no direct evidence that is so exists and although the seepages of oil at "Oil City" indicate that a certain amount of oil is present, there is no proof that commercial quantities are present.

At "Oil City" where drilling is proposed by Oil City Royalties (Patrick Oils, Limited) the elevation is approximately 1,000 feet above the well at Cameron Falls where the fault plane was penetrated at 1,233 feet. The fault is known to have a general westerly dip, but the amount is unknown. The minimum observed dip on the Lewis thrust is 3 degrees and if this amount be postulated between the well at Cameron Falls and "Oil City," Oil City Royalties well could hardly be expected to penetrate the Lewis thrust at less than 4,000 feet. If the dip of the fault plane is somewhat steeper the depth will be still greater. If, as is probable, the Lewis thrust approaches a bedding plane fault then it may be assumed that about the same horizon of the Precambrian will occur at Oil City immediately above the fault as at Waterton where the depth to the fault plane and the approximate thickness of the strata above it are known. The Oil City Royalties well location is on Appekunny strata close to the Altyn-Appekunny contact. In this area Daly believed the Altyn formation to be 3,500 feet thick, although the writer would consider the thickness to be slightly less owing to repetition by faulting. Below the Altyn is the Waterton dolomite not less than 1,200 feet thick. The stratigraphic thickness of beds above the Lewis thrust at "Oil City" is, therefore, not less than 4,500 feet and the best that could be hoped would be a degree of dip of these strata of not less than 30 degrees. Thus the drilling depth to the Lewis thrust would be expected on this basis to be in excess of 5,000 feet. It is believed by the writer that a fair test of the prospects for oil should include a well drilled through the Lewis thrust, as dependence on fracture zones within the Precambrian is likely to lead to disappointing results, although it must be admitted a lucky site might yield some results from fracture zones above the fault.

The seepages on Lineham Brook northwest of "Oil City" are farther removed from the Cameron Brook anticline than are those at "Oil City" and any well drilled in this locality would commence in strata near the top of the Appekunny formation with the prospect of having to drill at least 2,000 feet more of Precambrian beds than at Oil City.

Akamina Valley Oil Company's Property

Several shallow wells have been drilled on Akamina Brook in British Columbia, 17 miles west of Waterton Lake. In some of these, oil shows occurred and at certain times of the year one seepage is reported[1] to yield oil. As has been already stated, the valley of Akamina Brook is in a broad syncline and at the Akamina Valley Oil Company's wells Kintla strata outcrop. It is, therefore, obvious in this area if the same horizons in the Precambrian occur above the Lewis thrust as at Waterton, then the thickness of Precambrian above the Lewis thrust is not less than 10,000 feet. This is considered a minimum rather than a maximum because it is thought the Lewis thrust, like many thrust faults in the foothills, is likely to cut deeper stratigraphically in the direction from which the thrust originated. At North Kootenay Pass the strata immediately above the Lewis thrust belongs to the Siyeh formation, whereas at Waterton the beds immediately above the same fault are nearly 8,000 feet lower stratigraphically in the Precambrian. This, then, is evidence that lower stratigraphic beds are cut by the Lewis thrust from north to south in Canada, and since there was apparently an eastward as well as a northward movement to the overriding mass of Precambrian strata above the Lewis thrust it is probable the beds above the Lewis thrust in the area of the Akamina Valley Oil Company's wells are as low, if not lower, stratigraphically, than at Waterton. The thickness of the Precambrian is thus too great in this area to warrant drilling through them and although the synclinal surface structure may not be indicative of the structure in the beds below the fault, from which any oil must be derived, yet there is no evidence to show favourable structure for oil accumulation is present in the lower beds, even though they were within reach of the drill. It is thus inferred that the prospects for oil in this area are negative and if any oil seepages do occur they could readily be explained as a concentration of a small amount of oil by waters following bedding planes and fractures toward the central part of the basin structure, and hence have no significance as indicating probable commercial quantities of oil at depth in this locality.

Sage Creek, Fisher-Elder Creeks, and Kishinena Creek Domes

Sage Creek, Fisher-Elder Creeks, and Kishinena Creek domes lie within the Precambrian on the east side of Flathead Valley. All these

[1] Personal communication from Mr. John Gloyn.

domes appear to be of the same general character, although only the Sage Creek dome has been studied in any detail (*See* Figure 3).

The Sage Creek dome lies within the valley of Sage Creek between high, precipitous walls which rise nearly 3,000 feet above the valley floor, here about 1 mile wide. The structure is essentially a dome with some minor wrinkles or folds. On the north side, high up on the mountain slope, are evidences of a fracture zone in a narrow area less than 100 feet

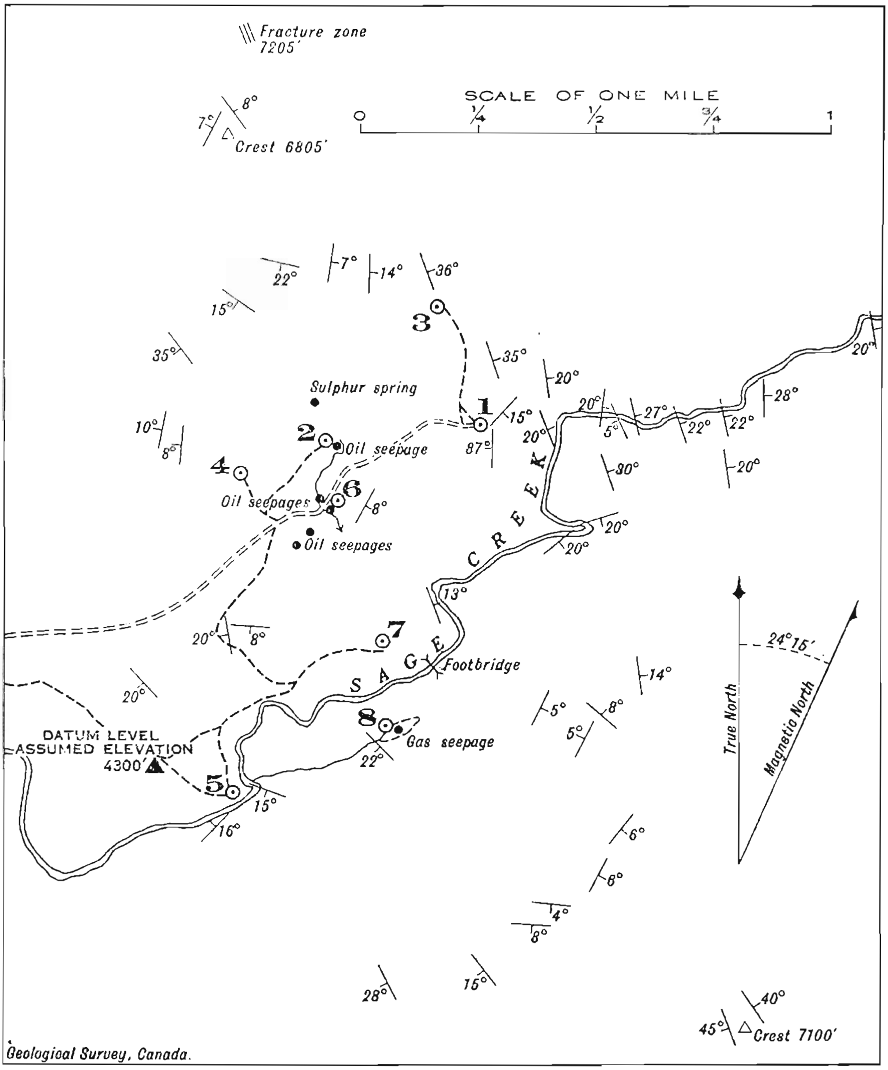


Figure 3. Sage Creek dome—wells: 1, Crowsnest Glacier No. 1; 2, Crowsnest Glacier No. 2; 3, Crowsnest Glacier No. 3; 4, Crowsnest Glacier No. 4; 5, Flathead No. 1; 6, Flathead No. 2; 7 and 8, British Columbia Oil and Coal Development Company.

across in which the strata are highly tilted or even slightly overturned, and yet outside this zone on both sides of it the beds dip at angles of only a few degrees. Other fracture zones were also seen and there seems little doubt that the seepages are connected with one or more of these.

The seepages are very remarkable and consist of both oil and gas. In order to arrive at some definite conclusion in regard to the amount of flow, one seepage was bailed morning and night for a period of six days. This seepage occurs in gravel into which a steel barrel with the bottom removed has been sunk. Water comes with the oil and gas, but the oil is so light that it can be readily separated from the water by allowing the latter to flow out through a small aperture in the bottom of the container. The record of this seepage was as follows:

Date	Amount of oil recovered a day
August 12, 1932	8 gallons (approximate)
" 13, 1932	3 " "
" 14, 1932	1·25 " "
" 15, 1932	1·5 " "
" 16, 1932	1·5 " "
" 17, 1932	1·25 " "

It is thus considered that the settled flow of the seepage amounts to $1\frac{1}{4}$ to $1\frac{1}{2}$ gallons a day. The amount of oil obtained was somewhat dependent on the time taken to remove the last small quantity of oil and water from the hole, because when the head of water amounting to several gallons had been removed there was always a strong ebullition of gas with oil and a minimum amount of water flowing into the hole. The larger amounts recovered on the first and second days, however, were the accumulated supply over a period of several days prior to bailing, the oil, previous to our visit, having been periodically taken from this hole for general purposes of camp use at the drilling site of the Crowsnest-Glacier Oil Company. It is said that in wet weather or in the spring the amount of oil that occurs in this seepage is much larger. This is undoubtedly true, as other seepages in the immediate vicinity also contained oil, and oil occurred on the water of a small stream nearby. The movement of the water through the gravel would no doubt carry the oil and gas with it and more oil would find its way to the seepage in time of high water flow. The position of the seepages can be seen on Figure 3. The seepage that was bailed was close to the road, but north of it and east of the small stream shown. It can be seen that the amount of oil escaping from the several seepages is considerable, but perhaps even more impressive than the oil seepages are the strong gas flows evident in several places, indicating a reserve volume under pressure.

As already explained in the case of the "Oil City" seepages on Cameron Brook, it seems inconceivable that this oil could have originated in the Lewis series which here forms the surface outcrops. The observed fracture zones offer a logical means of escape from depth, presumably from Mesozoic or Palæozoic rocks underlying the overthrust Precambrian Lewis series. It has been suggested by Mackenzie[1], although considered highly improbable, that the oil in Sage Creek area may have been derived from the Kishinena formation of Tertiary age. A detailed study of conditions shows that this cannot be so unless the Kishinena formation

[1]Mackenzie, J. D.: Geol. Surv., Canada, Mem. 87, p. 48 (1916).

occurred under the Precambrian. Mackenzie, however, recognized that the Tertiary beds were deposited subsequent to the faulting that formed Flathead Valley and that the Kishinena strata overlapped onto the Precambrian. At the present time no Tertiary strata occur in the immediate vicinity of the oil seepages and yet fairly strong gas flows are found with the oil seepages, and gas, sufficient to blow the mud fluid from the hole, was encountered in the Crowsnest-Glacier well. There is no obvious way in which this gas with the accompanying oil could have migrated from the Tertiary strata into the Precambrian. The Tertiary beds, moreover, were deposited under freshwater conditions, as is evident from the abundant fossil remains found in them and it is highly improbable that they are capable of producing more than small quantities of oil or gas, if any. On the other hand, there seems no reason to doubt that the seepages on Cameron Brook and at Sage and Kishinena Creeks are of the same type and the only possible source seems to be from beds that although younger, yet, due to faulting, underlie the Precambrian rocks.

It is unfortunate that the direction and dip of the fault plane on the east side of Flathead Valley are unknown, because lacking this knowledge no accurate prediction of the thickness of the overlying Precambrian can be made. The reversal of dip along the west side of the Precambrian mass is in harmony with underthrusting as suggested by Link, but as already pointed out the only evidence observed, namely that in the area south of North Kootenay Pass, is not in accord with this hypothesis. The beds exposed in the valley of Sage Creek on the Sage Creek dome belong to the base of the Appekunny formation and the formations that underlie strata of the same age in Waterton Lakes area are the Altyn and Waterton formations, the thickness of which is considered to be about 4,500 feet. If the fault under the Sage Creek dome is an underthrust, that is an eastward dipping fault as suggested by Link, it may cut off the Lewis series at a higher horizon than the Lewis thrust does at Waterton. If the fault is the Lewis thrust and if, as is believed, it cuts strata at progressively lower horizons in the direction from which the thrust originated, then lower Precambrian horizons are probably present in Sage Creek area than at Waterton, in which case the depth to the fault will exceed 4,500 feet by an unknown amount.

Lacking the seepages in the Precambrian rocks east of Flathead Valley, this area would never have been considered as an oil or gas prospect on account of the character of the rocks through which the seepages must come. The seepages and the associated domed structure, however, suggest accumulations of oil and gas at depth and it is impossible to understand how this oil could have got into the Precambrian rocks, unless the younger rocks under the fault lie in a structure such as would favour concentration of oil. East and west folds were found to be present in Sage Creek area and this suggests that the domed structure of the Precambrian may be later than the faulting, since, as already shown, folding subsequent to faulting took place in Waterton Lakes area. If this is so then the folding also extends down into the younger rocks underlying the fault and hence the conditions in these beds would favour a concentration of any oil there present. The escape of small amounts of this oil through fractured zones such as are known to be present in the Precambrian rocks would be an expected result of the action of gas pressure in the oil reservoir rocks.

Only one other factor has a bearing on possible oil production provided the structure is favourable at depth and the fault is within drilling depth. This is the amount of porosity likely to be encountered in the productive horizon. Beds of Jurassic or Palæozoic age might have sufficient porosity to act as oil and gas reservoirs, or if not the very great fracturing of the strata below the fault plane is a favourable factor.

Several shallow wells have been drilled in Sage Creek area. The only well being operated at present is that of the Crowsnest-Glacier Oil Company which at the time of the writer's visit was being drilled with a diamond drill at a depth of 3,259 feet. In some of the old, abandoned wells a considerable amount of gas occurs and in one well east of Sage Creek and on the northwest edge of a beaver dam lake, a small quantity of water-white oil occurs. This oil is regularly collected and is used in kerosene lamps. It burns without giving off any smell or soot. The well of the Crowsnest-Glacier Oil Company (No. 1) periodically yields sufficient volumes of gas to clean the hole of water with which some oil is ejected. A small quantity of non-inflammable sulphur gas is escaping from a well drilled by the British Columbia Oil and Coal Development Company. At present most of the leases on the Sage Creek dome are said to belong to the Amalgamated Oil Company.

Summing up the prospects of the Sage Creek dome it may be said that it is quite apparent that oil and gas are undoubtedly present in this area, as is shown by the seepages and to a less extent by drilling. The surface structure is a dome in Precambrian strata and if this dome persists to depth into younger rocks below the Precambrian, the prospects for production would appear to be favourable. The oil doubtless originated in these younger rocks and is now escaping through fracture zones in the Precambrian. The depth to the younger rocks under the Precambrian is not known. It does not seem probable that it can be much less than 4,500 feet and may be somewhat more.

A preliminary examination of the Kishinena dome on Kishinena Creek seems to show that this structure is essentially like the Sage Creek dome. Only one seepage was observed and this is issuing from gently inclined Appekunny strata. The oil is slightly more bluish than the oil from the Sage Creek seepages and is thought to be of slightly heavier gravity, although sufficient was not collected to make a test. The drilling depth in the Kishinena dome would, presumably, be approximately the same as at the Sage Creek dome and if the latter is found to be productive the former would warrant a test by drilling. Up to the present no wells have been drilled on it.

The dome at the headwaters of Fisher and Elder creeks is intermediate in position between the Sage Creek and Kishinena domes. On account of the higher elevation, however, it would require approximately 2,000 feet deeper drilling. It is much more difficult of access than the others and as far as known yields no seepages. Tests are not warranted on this structure until the merits of either the Sage Creek or Kishinena domes have been proved.

A great part of the southern end of Flathead Valley in Canada has been leased for oil and gas. The area is to a considerable extent covered by Tertiary freshwater deposits, but on the west side of the valley in the vicinity of Howell, Cabin, and Cauldrey Creeks is an area of Mesozoic rocks bounded on the northwest and south by Palæozoic rocks and on the east by the Tertiary of Flathead Valley. The Palæozoic rocks are overthrust onto the Mesozoic and such Mesozoic strata as now outcrop owe their exposure to erosion of the Palæozoic rocks that formerly covered them. The Mesozoic rocks thus appear as an embayment through the fault plane and are thus bounded by the overthrust Palæozoic rocks on three sides. As has been shown by Mackenzie[1] these Mesozoic beds appear to dip in one direction only and hence provide no closure for oil or gas fields. The structure of the whole Flathead Valley, excluding the Tertiary beds which are an overlap, is not as simple as the structure of the exposed Mesozoic beds might lead one to suppose, because on the east side of the valley on Commerce Creek, a short distance north of Sage Creek, is a long ridge exposing Devonian limestones. No structures in the Mesozoic or Palæozoic rocks favourable for oil and gas accumulations have so far been demonstrated in Flathead Valley proper, and the outcrop of these beds would provide a ready means of escape for any oil or gas they may have originally contained.

The Tertiary beds belonging to the Kishinena formation, as already stated, are an overlap onto all older beds. For the most part these Tertiary beds have an easterly dip and so far as known no folds suitable for oil accumulation have been found, although a certain amount of folding is present and it cannot be said favourable structures are not present since outcrops are few and very scattered. The Tertiary sediments, however, are of freshwater origin and although they might yield small shows of oil or gas, it seems highly improbable they could give rise to commercial quantities of these materials. Only one well is at present drilling in Flathead Valley proper, namely the Canadian Kootenay well at the bridge over Flathead River about 4 miles north of the International Boundary. This well is drilling in Tertiary beds which as far as known dip only in one direction, namely, easterly. As the Tertiary beds overlap onto the Mesozoic on Cauldrey Creek west of the well location, the base of the Tertiary must come to the surface, although it is concealed by gravel and drift. It is impossible to see, therefore, how this well has any merit as an oil or gas prospect, unless it should penetrate favourable structure in the Mesozoic strata under the Tertiary overlap, a condition concerning which no data are available.

Drilling Equipment. The Precambrian rocks are very dense and hard and much difficulty has been experienced in drilling them with standard cable tools due to the shearing of pins on the bits and other mechanical breakages. Several wells have been lost in Sage Creek area due to tools lost in the hole and excessive drilling costs have resulted for small amounts of footage drilled. The writer had the opportunity of seeing a diamond drill at work on the property of the Crowsnest-Glacier Oil Company and although the equipment was not in good condition its effectiveness for drilling the highly metamorphosed rocks was amply demonstrated. It is recommended, therefore, that operators should at least consider this type of drilling equipment before launching on any extensive drilling program in these Precambrian strata.

---

[1]Mackenzie, J. D.: Geol. Surv., Canada, Mem. 87, Map 182 A.

GEOLOGY AND COAL DEPOSITS OF CROWSNEST PASS AREA, ALBERTA

By B. R. MacKay

CONTENTS

Illustrations

INTRODUCTION

Crowsnest Pass, Alberta, is one of the more important steam-coal producing districts in the province. The coal deposits belong to two geological ages, some occurring in the Kootenay formation of Lower Cretaceous age and others in the Allison (Belly River) formation of Upper Cretaceous age. The Kootenay deposits are by far the more important and are easily accessible, being exposed in a series of narrow, northerly trending bands that are crossed by the Crowsnest Branch of the Canadian Pacific Railway seven times in a distance of 12 miles (*See* Figure 4). These coals are of bituminous rank and range in quality from poor coking to strongly coking. They belong to the same series of deposits as occurs in the Crowsnest section of southeastern British Columbia and forms the southern section of a coal belt that extends along the eastern slope of the Rocky Mountains from near the International Boundary northwesterly to beyond Peace River, a distance of 650 miles.

The coal deposits of the Allison (Belly River) formation are of small extent. The only deposits at present being developed in the area occur at a point 2 miles south of Sentinel station near the top of the Allison formation and within a half mile of the Rocky Mountain overthrust. The Allison formation outcrops in a belt varying from 1 to 4 miles in width, and extends along the front of the Rocky Mountains from Waterton Lake northward to Mount Bishop at latitude 50° 25′, a distance of over 100 miles. Small coal seams have been observed in it at several localities, as immediately north and south of Crowsnest Lake, on the eastern slope of Crowsnest Mountain, and west of the entrance to Waterton Lakes Park. The deposits occurring south of Sentinel are the only ones that have proved to be of sufficient commercial importance to be worked. These deposits are correlated with the Belly River deposits which cross Crowsnest River at Lundbreck, 24 miles to the east. At Lundbreck the coals are non-coking and of sub-bituminous rank, but in Sentinel area they have been raised by dynamic metamorphism to bituminous rank and show a tendency to coke.

The coal production of Crowsnest district, Alberta, has been practically wholly derived from its Kootenay coal deposits. Production began in 1899 and rapidly increased in importance, reaching its first peak in 1910 with a production of 1,608,205 tons. The maximum output of 1,769,807 tons was made in 1920. Since then there has been a falling off in production as shown on the accompanying table, the output of the past year being the lowest since 1911, due largely to curtailment in railway traffic and industries, and in part to strike conditions that existed during the past summer. Figures of production for the years prior to 1910 are not available. During the earlier years, they were merged in those giving the combined production of Alberta and Saskatchewan. From 1905 to 1909, inclusive, they were included in the total output of Alberta to which, it is estimated, they contributed more than 50 per cent of the annual production. This annual production of the province, as stated in the Annual Reports of the Department of Public Works, Alberta, was as follows:

Year	Short tons
1905	811,228
1906	1,385,000
1907	1,834,745
1908	1,845,000
1909	2,174,329

For 1910 and succeeding years, figures of production for the district are available and are given in the table, page 24. The figures for 1910 and 1911 are from the Annual Report, Department of Public Works, Alberta; those for 1912 to 1917 inclusive from "Mineral Production of Canada"; those for 1918 to 1920, from Mines Branch, Ottawa, Bulletin 567; and those for 1921 to 1932, inclusive, from "Coal Statistics for Canada".

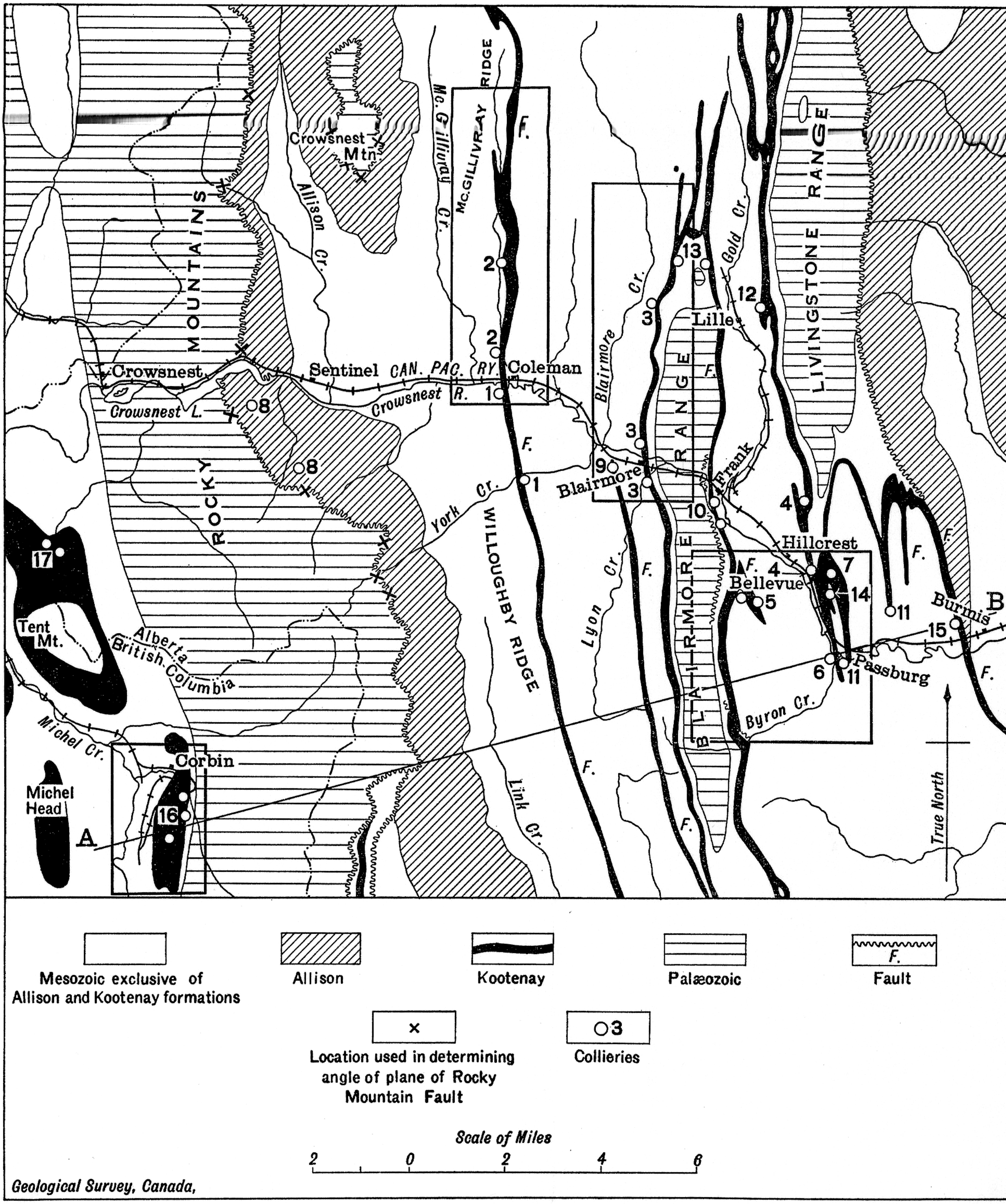


Figure 4. Index map of Crowsnest Pass area, Alberta. For geological section along line AB, *See* Figure 6; areas of detail mapping shown by rectangles; collieries are shown by numbers, for list *See* page 23.

LIST OF COLLIERIES (*See* Figure 4)

Operating Collieries, Kootenay Coal Deposits, Alberta

1. International Coal and Coke Company mines.
2. McGillivray Creek Coal and Coke Company mines.
3. West Canadian Collieries, Greenhill mines.
4. West Canadian Collieries, Bellevue mines.
5. Hillcrest Collieries mines.
6. Byron Creek Collieries mine (temporarily closed).
7. Mohawk Bituminous Mines.

Operating Collieries, Allison (Belly River) Coal Deposits, Alberta

8. Canadian-American Coal Company mines.

Abandoned Collieries, Kootenay Coal Deposits, Alberta

9. Cartwright and Thomason Sunburst mine.
10. Franco-Canadian Collieries mine.
11. Leitch Collieries mine.
12. West Canadian Collieries, Lille mine.
13. West Canadian Collieries, Grassy Mountain mines.
14. Maple Leaf Coal Company mine.
15. Burmis Mining Company mine.
17. Spokane and Alberta Coal and Coke Company mines.

Operating Collieries, Kootenay Coal Deposits, British Columbia

16. Corbin Collieries mines.

Coal Production, Crowsnest Pass District, Alberta

Year	Short tons
1910	1,608,205
1911	528,119
1912	1,500,594
1913	1,772,575
1914	1,208,342
1915	919,383
1916	1,399,782
1917	1,188,456
1918	1,595,662
1919	1,175,535
1920	1,769,807
1921	1,282,571
1922	1,025,771
1923	1,602,292
1924	912,550
1925	1,132,661
1926	1,452,023
1927	1,443,161
1928	1,639,358
1929	1,553,716
1930	1,133,891
1931	951,948
1932	714,884

The existence of valuable coal deposits in Crowsnest district was first brought to the attention of the public by G. M. Dawson in his report on the "Region in the Vicinity of the Bow and Belly Rivers"[1] and is referred to again by him in his report on the Rocky Mountains between latitudes 49° and 51° 30′.[2] Little exploratory work was done on these deposits, however, up to 1899 when the Crowsnest Branch of the Canadian Pacific Railway was constructed. In 1902 W. W. Leach was detailed to a geological investigation of this field and his report[3] summarizes the results of his investigations of the stratigraphy, structure, and coal deposits of the district. Leach's report is accompanied by a geological sketch map of part of the Blairmore-Frank coal fields supplemented by three generalized structure sections.

The importance Crowsnest Pass district had reached in 1910 as the largest producer of bituminous coal in the province made it expedient that the Geological Survey undertake a more detailed survey of the area. To serve as a base for this investigation a topographic map of an area measuring 17 miles north and south and 12 miles east and west, with its centre near Blairmore, and designated the Blairmore map sheet, was started in 1911 and completed in 1912. In September, 1911, W. W. Leach began a revision of the geological mapping of the area, which he continued in 1912. Leach's preliminary report[4] summarizes the stratigraphy and general structure of the district and his preliminary geological map[5] outlines the major features of the area. Leach died before concluding his investigation and in 1915 the work of revision was completed by B. Rose.[6]

The Blairmore geological map, on which was combined the work by Leach and Rose, was published in 1920 and is accompanied by a battery

[1] Geol. Surv., Canada, Rept. of Prog. 1882-84, pt. C, p. 100.
[2] Geol. Surv., Canada, Rept. of Prog. 1885, pt. B, p. 58 and p. 69.
[3] Geol. Surv., Canada, Ann. Rept., vol. XV, pt. A, pp. 169-181 (1907).
[4] Geol. Surv., Canada, Sum. Rept. 1911, pp. 192-200.
[5] Geol. Surv., Canada, Sum. Rept. 1912, Map. 107 A, p. 234.
[6] Rose, B.: Geol. Surv., Canada, Sum. Rept. 1915, p. 110; 1916, pp. 107-114.

of seventeen structure sections along east-west lines at intervals of a mile. The map and sections have proved of incalculable value for general use, but their small scale (1 mile to 1 inch) does not permit of them being used as bases on which to plot details necessary for the solution of the many geological difficulties encountered in mining the coal deposits.

These difficulties arise from three main causes, the most formidable of which are the folding and faulting that characterize most of the deposits of the Rocky Mountains. In many instances the continuations of seams cut off by faults have been recovered by following the small coal stringers along the fault planes, but in a number of areas the displacements are of such magnitude as to have caused a termination of mining operations with a great loss of invested capital which would probably have been saved had the structural conditions affecting the area been more fully appreciated. Other difficulties encountered arise through the existence of "wants" in the coal seams, due either to non-deposition of the coal-forming vegetation or its removal prior to the deposition of the capping sediments. In still other instances mining operations have been discontinued owing to the coal seams becoming too high in ash to permit of the deposits being profitably developed.

RECENT DETAIL WORK

The need of detailed geological maps has long been felt and repeatedly voiced by those engaged in the development of the coal deposits, and in 1931 detailed investigations were commenced in Crowsnest Pass district, Alberta. An area 4 miles square, having Hillcrest as the principal mining camp, was the first to receive attention. This was followed in 1932 with the mapping and study of two other areas each 2 miles in width and 6½ miles in length. One of these areas covered the coal deposits under development in the vicinity of Blairmore, and the other the coal deposits being mined mainly to the north of Crowsnest River at Coleman. All three areas were mapped on a scale of 800 feet to an inch. The topographic base map for the Hillcrest investigation, having a 25-foot contour interval, was made in 1930 by J. A. Macdonald of the Topographic Division of the Geological Survey. The topographic base maps for the investigation of Blairmore and Coleman areas were made by photographically enlarging to the required scale portions of the Blairmore topographic manuscript made in 1912 on a field scale of 4,000 feet to an inch and with a contour interval of 100 feet. Township-section grids of the areas to be mapped were drawn to the same scale, and to them was transferred the topography as obtained from the enlarged maps. The culture was brought up to date, and where necessary the topography was revised. These revised topographic base maps were used and although somewhat less accurate than the Hillcrest map as regards topographical detail, are nevertheless believed to be sufficiently accurate to satisfactorily fulfil all requirements.

The geological maps of the three areas are each accompanied by a series of E-W geological structure sections drawn on a natural scale across the area at intervals of one-fourth mile. These sections show the surface profile and all essential surface and underground geological data and mine workings. The data shown have been checked by transferring each of the structure sections to a glass plate where the detail on one section can be compared with those of the adjacent sections. At the close of the field seasons each of the operating companies concerned was supplied with a hand-coloured copy of the geological map and a set of cross-sections of its respective area. Hand-coloured copies of these detailed maps and batteries of sections may be obtained at a reasonable charge on application to the Director of the Geological Survey. The main features of these areas are shown on the simplified sketches (*See* Figures 7, 8, and 9).

Further assistance was rendered the coal companies by supplying them, at a nominal charge covering cost of material and outside help, with celluloid structure section models of their respective fields (*See* Plates I, II, and III). These models consist of the series of structure sections cut out of celluloid sheets, on which are plotted formations, boundaries, coal seams, faults, mine levels, and bore-holes. These sections are geologically coloured and erected in their proper position on a hand-coloured geological map base and the whole is encased in a mahogany glass frame. The models are proving of incalculable value to the mining company officials, in their planning of mining operations, and in sizing up the economic possibilites of areas under development.

The writer desires to record his appreciation to the officials of the various mining companies concerned for assistance rendered during the course of the investigations, for office and housing accommodation furnished, and for information and office material supplied. Among those deserving special mention are the following: Wm. Stevenson, General Manager, and W. Hutchison, Engineer, Hillcrest Collieries, Limited; G. A. Vissac, General Manager, J. R. Smith, Business Administrator, L. P. Robert, General Superintendent, and R. G. Foot, Assistant Engineer, West Canadian Collieries, Ltd.; George Kellock, General Manager, A. E. Graham, Engineer, McGillivray Creek Coal and Coke, Ltd.; J. McIntyre, Manager, Mohawk Bituminous Mines, Ltd.; G. A. Campbell, Manager, Blairmore Iron Works. Of these the writer's thanks are especially due to Messrs. G. A. Campbell, R. G. Foot, A. E. Graham, and Wm. Hutchison, Engineers, for technical assistance rendered in the draughting and fabrication of the structure models and geological columnar sections supplied their respective companies.

The writer's thanks are also due to numerous other residents of the district for courtesies received which greatly assisted in the progress of the work, and added to the comfort of the party. Among these he is especially indebted to Rev. Father Harrigan and Mr. A. Greig, Manager, McLaren Lumber Company.

The following student assistants were attached to the party: D. J. MacNeil, H. N. Hainstock, H. H. Fraser, R. Thompson, D. Campbell, J. C. Pratt, H. H. Beach, and W. R. Roxborough. The first five mentioned served with the party two years and the four last mentioned one year. The writer's thanks are due to each of these assistants for the highly satisfactory manner in which he carried out the duties assigned him. Special recognition is accorded to the two senior assistants, D. J. MacNeil and H. N. Hainstock. Mr. MacNeil in 1931 was entrusted with the mapping and investigation of the Hillcrest area to be used as a basis for a doctorate thesis, and in 1932 he carried out similar work on the Blairmore coal area.

H. N. Hainstock in 1931 was engaged mainly in a study of the Mesozoic-Palæozoic contact, and in 1932 was assigned to the detail mapping of the McGillivray Creek coal area.

GENERAL GEOLOGY

The area dealt with in this report measures approximately 18 miles in a north-south direction and 22 miles in an east-west direction (*See* Figure 4). It extends from the eastern boundary of Range 3 in the vicinity of Burmis westward to beyond the summit of Crowsnest Pass at Crowsnest Station, and in a north-south direction from Township 6 to Township 9, inclusive. Within this area the topography ranges from rolling to mountainous. The mountainous territory is largely confined to the areas underlain by Palæozoic rocks, namely: (1) Livingstone Range which lies altogether north of Crowsnest River; (2) Blairmore Range which comprises Bluff, Turtle, and Hillcrest Mountains; (3) Crowsnest Mountain which is an erosion remnant of the main Rocky Mountain Range; and (4) the main range of the Rocky Mountains. The highest elevations attained in each of these areas are: Mount Ptolemy of the main range with an elevation of 9,234 feet; Crowsnest Mountain with an elevation of 9,138 feet; Centre Mountain of Livingstone Range, with an elevation of 8,355 feet; and South Peak of Turtle Mountain with an elevation of 7,236 feet. The channel of Crowsnest River drops from an elevation of 4,419 feet at Crowsnest Lake to 3,950 feet at Burmis, giving a relief ranging from 3,200 feet at the eastern side to 4,800 feet at the western side of the area.

The country east of Livingstone Range falls off rapidly in elevation and merges into the rolling topography of the foothills. The area between the outlying ranges of Palæozoic rocks and the main range of the Rockies is characterized by a series of less pronounced, northerly trending ridges separated by broad, drift-covered valleys. The most conspicuous of these ridges is Willoughby or Ash Ridge. This ridge, which is capped by resistant volcanic rock, crosses Crowsnest Valley 1 mile west of Coleman and reaches its maximum elevation of 7,266 feet on Ma Butte 6½ miles north of Coleman. Most of the other high ridges in the area owe their relief to protection from erosion by reason of the presence of some resistant layer such as the prominent conglomerate bed that marks the base of the Blairmore formation.

The subdued outline of the tops of the ranges indicates that the area was completely covered by the Cordilleran ice cap. A tongue from this glacier advanced down the valley of Crowsnest River, scouring out Summit, Island, and Crowsnest Lakes at the Alberta-British Columbia divide. Evidence of ancient alpine glaciation is to be seen in the well-developed, knife-edge ridges, truncated spurs, cirques with their precipitous walls, rock steps, and rock-basin lakes which characterize the higher peaks of both the main Rocky Mountains and Livingstone Range. Except in the higher areas bedrock is largely obscured by a veneer of boulder clay, the character of which shows it to be largely formed from rocks of local origin.

The hillsides, up to an elevation of 7,000 feet, are largely covered with a growth of scrub spruce and jackpine, much of which has been recently reduced by forest fires that have swept the district.

Crowsnest Valley forms a prominent topographic depression that cuts in an east-west direction transversely across the rock structure. At the height of land marking the British Columbia-Alberta boundary, the valley bottom is 4,438 feet above sea, and at Burmis, 24 miles to the east, it lies at an elevation of 4,000 feet, giving a gradient of 18 feet to the mile. The gradient of the stream, however, is not uniform throughout. It is steeper where the river is actively engaged in cutting its channel through the more resistant rock formations, as at the outlet to Crowsnest Lake and at Frank, where it crosses Palæozoic limestones, and at a mile west of Coleman where occur the Crowsnest volcanics. At these localities, also, the valley is comparatively narrow and steep-sided, whereas in the intervening areas the valley is low and broad; and the valley slopes rise gently from the channel of the river to its watershed about 7 miles distant. The pre-Glacial configuration of Crowsnest Valley and its tributaries, Byron and Drum Creeks, was very much the same as at present except that parts traversing the softer rocks were probably gouged out during the Glacial period, so that the streams are now engaged in cutting their channels across the harder rocks of Blairmore Range.

Crowsnest Valley from Crowsnest Lake eastward to beyond Burmis is largely floored by alluvium, the original surface of which is believed to have been that of an outwash plain formed in front of the retreating valley glacier. Near Crowsnest Lake the surface of this deposit is irregular on account of morainic deposition by a glacier that advanced down Allison Creek Valley; but farther down the valley it has a plain-like surface with a gradient slightly less than that of Crowsnest River. At Sentinel this surface lies about 50 feet above the river at an elevation of 4,450 feet, and at Burmis it lies at an elevation of 4,200 feet or about 300 feet above river-level. In some places the alluvium has deeply buried the bedrock, whereas in other places only a slight veneer caps rock spurs. The surface of this flood-plain is characterized by a number of isolated, conspicuous, roughly-circular depressions which have been formed by the melting of large blocks of ice that became buried in the outwash from the valley glacier.

On the retreat of the ice, the drainage of Crowsnest Valley appears to have been damned somewhere east of Burmis and the water caused to rise to a height of approximately 300 feet above the present channel level, forming a long, narrow lake. The numerous tributary streams issuing into this lake built at their mouths alluvial fans since dissected or in places largely removed by later erosion. Remnants of such fans are to be seen near the mouths of most of the larger tributary streams, such as the stream entering Crowsnest River from the south at Burmis, Byron Creek, Drum Creek, Blairmore Creek, and Nez-Percé Creek. Post-Glacial erosion by Crowsnest River has cut the original outwash plain into a series of terraces. The uppermost terrace begins near Crowsnest Lake at an elevation of 4,419 feet and has an elevation of 4,150 feet at Burmis. Another terrace begins east of Coleman at an elevation of 4,350 feet and drops gradually to an elevation of 4,100 feet at Burmis, and a third terrace begins at 4,200 feet at Blairmore and has an elevation of 4,010 feet or about 20 feet above river level at Burmis. The main and tributary streams in eroding their new valleys have in places cut into projecting rock spurs.

One of the most recent physiographic events in the district is the rock slide that occurred at Frank on April 29, 1903, when a large mass of Turtle Mountain broke away, rushed down the mountain slope, swept across Crowsnest Valley for a distance of almost 2 miles climbing up on the opposite side to a height of over 4,540 feet or 385 feet above the river channel. Evidence of a smaller rock slide which had occurred in prehistoric times is to be seen on the east side of Bluff Mountain, 2 miles directly north of Frank, at an elevation of 5,500 feet.

STRATIGRAPHY

The various formations exposed within Crowsnest area, with their main characteristics and their thicknesses at their western and eastern exposures, are given in the table, page 30. For more detailed data the reader is referred to previous reports on the district, the latest of which deals with the Mesozoic-Palæozoic contact and associated sediments, and appeared in Summary Report 1931, part B. The main revision here made is that the 37-foot thick quartzite zone, including at the base a breccia quartzite conglomerate exposed in the Rock Creek section of Livingstone Range and equivalents elsewhere in this and Blairmore Range, are, on the basis of lithological similarity, correlated with the Triassic Spray River beds of the Crowsnest Lake section instead of being grouped with the Jurassic sediments. The thicknesses of several formations have also been slightly revised as a result of measurements made during the past year.

The main features brought out in the following geological table are: (1) the alternation of marine and terrestrial deposits and the occurrence of volcanic deposits in the Upper Cretaceous; (2) a remarkable thinning of all the formations from west to east; (3) the absence of Tertiary formations; (4) the existence of three unconformities of considerable magnitude, (*a*) the disconformity indicated by Devonian sediments resting upon Middle Cambrian sediments, observed in the North Kootenay Pass section, (*b*) the erosional unconformity between the Palæozoic and the overlying Mesozoic rocks, and (*c*) the erosional unconformity of less magnitude between the Kootenay and Blairmore formations.

Table of Formations

Age	Formation	Characteristics	Thickness, feet West	Thickness, feet East
Upper Cretaceous.....	Allison (Belly River)	Soft, light-coloured, fresh-water sandstones interbedded with minor amounts of fresh-water, grey and black shales, and an occasional lens of conglomerate and at least two coal seams near top of formation. Non-marine, in part brackish water....................	4,000	2,500
	Colorado...........	Soft, dark, marine shales with thin, arenaceous beds and concretions of ironstone. Two horizons of hard, resistant, quartzitic sandstone occur near base of formation and probably represent the Cardium bands of areas farther north. Marine..........................	3,250	3,000
	Crowsnest Volcanics	Volcanic ash, tuff, and agglomerate of various colours and textures. Largely non-marine...............	1,800	600
Lower Cretaceous.....	Blairmore..........	Light-coloured, shaly sandstones and sandy shales alternating with red and green shales and with massive, hard conglomerate or coarse sandstone at base and loose, cherty conglomerate at top. At least one bed, and possibly several beds, of shaly, freshwater limestone in lower part of formation. Non-marine..........................	2,300	2,150
	Erosional unconformity			
	Kootenay..........	Coarse, hard sandstone alternating with black shales, with six coal seams. Non-marine..............	650	360
Jurassic...............	Fernie..............	Thin-bedded, grey-black and black, fissile, marine shales with thin-bedded, brown sandstone, fossiliferous calcareous grits, and in places a phosphate bed at base containing gryphæ. Marine........	900	700
Triassic..............	Spray River........	Shaly quartzite and quartzite breccia conglomerate. Marine............	350	50
Erosional unconformity				
Pennsylvanian........	Rocky Mountain quartzite	Fine-grained, light grey quartzites.. Marine	1,118	550
Mississippian..........	Rundle.............	Interbedded, finely crystalline and coarsely granular, compact, grey limestone and bands of chert with beds containing crinoids, corals, and brachiopods. Marine.........	4,988	1,550
	Banff...............	Fine and massive-bedded limestone with layers and nodules of chert and beds with strong odour of hydrogen sulphide. Fossiliferous.	1,070	540

Table of Formations—Concluded

Age	Formation	Characteristics	Thickness, feet	
			West	East
Devonian............	Minnewanka........	Dark grey, finely crystalline and coarsely granular limestone with chert lenses and bands; dark, calcareous shale at top. The limestones are fossiliferous. Marine....	2,600	?
Disconformity				
Cambrian...........	Flathead quartzite..	Hard, white and reddish quartzites with beds of quartzitic shale and conglomerate lenses containing trilobite remains.................	300	....

GENERAL STRUCTURE

The west part of the area is a fault block composed largely of westerly dipping Palæozoic sediments that plunge beneath the Mesozoic beds of Fernie Basin. This block has been thrust eastward 25 or more miles along a westerly dipping fault plane and along it Devonian limestones may be observed lying upon westerly dipping sediments of the Allison (Belly River) formation of Upper Cretaceous age that normally occur 17,000 feet higher in the stratigraphic column. Another major northerly trending and westerly dipping fault occurs at Burmis at the eastern boundary of the area. The horizontal displacement along this fault plane is small as compared with that of the Rocky Mountain fault. It is nevertheless of such magnitude that Kootenay and Jurassic sediments, and farther north Mississippian limestones, have been thrust eastward so that they now lie upon westerly-dipping sediments that have been designated Allison, but which further investigation may prove to be considerably younger. They hold the Burmis placer iron deposit. An analogous deposit in the Blackfeet Indian Reserve, Montana, is of St. Mary River age.

The area between these two major faults is 13 miles in width. In its eastern part occur two prominent, northerly trending and overlapping anticlinal ranges of Palæozoic strata separated by a synclinal trough 1 to 2 miles wide, underlain by Lower Cretaceous sediments. The more northerly and easterly of these ranges is the Livingstone Range. This starts about 1 mile northeast of Bellevue, and extends northward a distance of 28 miles. It has a maximum width of 2 miles, and over much of its length consists of a double-crested asymmetrical anticline with both axial planes dipping to the west. It is bounded on the east by the major eastern fault referred to above.

A mile northeast of Bellevue the Palæozoic rocks forming the southern nose of Livingstone Range plunge southward beneath Mesozoic sediments and the anticlinal fold divides into two, narrow, compressed, asymmetrical anticlines which, ½ mile east of Bellevue, are capped by beds of the Kootenay formation. These two folds extend southward to beyond Byron Creek and are separated by a shallow, gently southward-plunging syncline 1,000 to 1,300 feet in width, floored over most of its distance with sediments of the Blairmore formation.

The area lying between this double anticline and the major fault which runs along the eastern base of Livingstone Range is designated the Passburg-Burmis area. It is underlain by Blairmore and Kootenay rocks which have been folded into two major southward-plunging basins rimmed with the Kootenay formation, the Passburg basin on the west and the Burmis basin on the east. The Passburg basin is a single, asymmetrical fold, approximately a mile wide, opening out to the south and retaining its identity beyond the map-area. From the latitude of Bellevue southward it is cut by a southerly-trending, westerly-dipping thrust fault along which the beds on the west have been thrust upward and eastward over younger sediments. The Burmis basin is more complicated and consists of two structural troughs separated by a tongue of Kootenay rocks which extends for 1½ miles from the northern rim southward along the western side of a westerly dipping fault. The trough on the west side of this fault, as defined by the Kootenay measures, is ½ to ¾ mile in width.

Blairmore Range crosses Crowsnest River between Frank and Blairmore and extends from there for a distance of 4 miles to the north and 7 miles to the south of the river. It attains its maximum width of less than 1½ miles on Bluff Mountain, 2 miles north of Crowsnest River. Over much of its length the eastern limb of the anticlinal fold of Palæozoic strata constituting this range is characterized by a thrust fault along which Palæozoic sediments have been thrust eastward upon Lower Cretaceous Kootenay beds. In Crowsnest River Valley erosion of the limestones above the westerly dipping fault plane has exposed a small window of vertical Jurassic sediments. The fault dies out several miles to the north and south of the river, and from there to the north and south extremities of the fold the Palæozoic and Mesozoic formations outcrop in their natural sequence.

It was on the eastern side of Turtle Mountain, the segment of the range immediately south of Crowsnest River, that the great Frank rockslide of 1903 occurred. This slide was due to a combination of causes among which (*See* Figure 5) are: (1) the tightly compressed and overturned asymmetrical form of the fold; (2) the presence of two, and in places three, prominent thrust faults; one along the crest in which there is only a slight displacement; a second on the slope of the range 1,600 feet east of the crest and 1,300 feet below the summit of Turtle Mountain in which there is a considerable displacement within the limestone formation; and a third near the eastern base where Mississippian limestones have been thrust over incompetent Jurassic and Kootenay sediments; (3) rain and frost action operative in the crevices of the crushed centre of fold; (4) undermining of the eastern flank of Turtle Mountain by the erosion of Crowsnest River; and (5) slumping caused by the underground mining of the steeply dipping coal seam which skirts the eastern base.

The most unstable part of Turtle Mountain is believed to be South Peak which is almost completely surrounded by fissures and is being under-

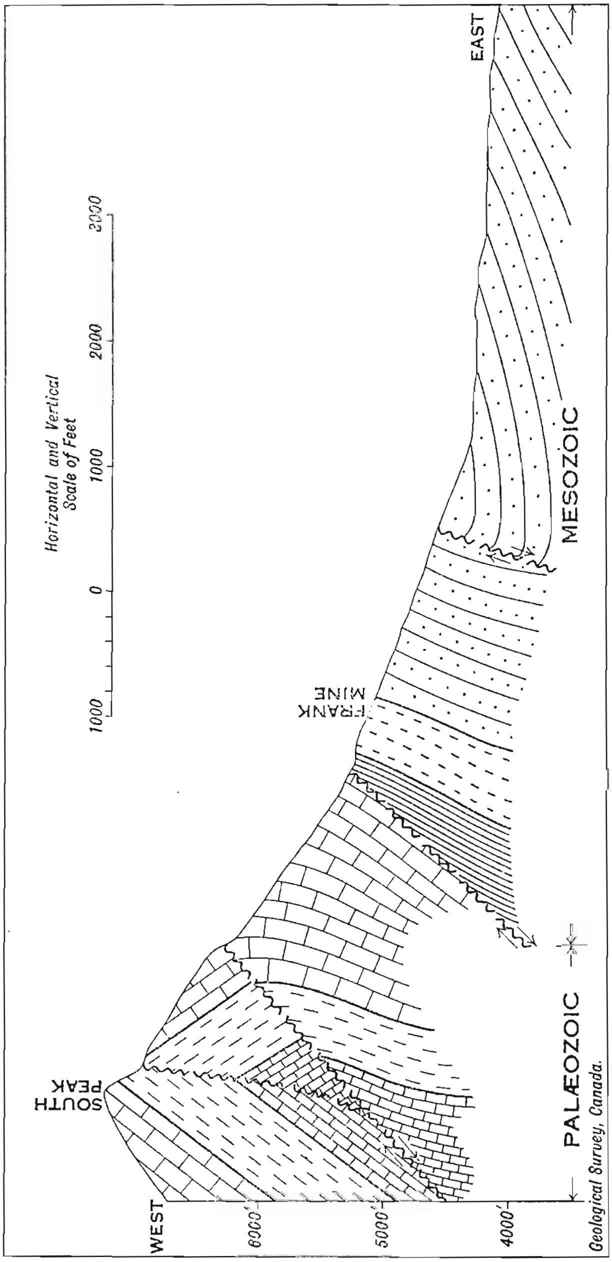


Figure 5. East-west section through South Peak, Turtle Mountain.

mined along the present rockslide scarp by wind, rain, and frost action. An investigation, carried out by the writer in 1931, revealed that at this point there is still danger of a considerable block of rock falling, but the possibility of a second large rockslide occurring is being reduced by the continuous breaking off of small portions through natural weathering agencies. A small, prehistoric rockslide occurs almost directly east of the highest part of Bluff Mountain 2 miles directly north of Frank. Here considerable Palæozoic limestones cap a small knoll with an elevation of 5,500 feet, formed largely of Kootenay measures.

The Cretaceous trough between Livingstone and Blairmore Ranges opens northward and southward into broad synclinoria which are cut by several southerly-trending faults and minor folds. The absence of coal deposits of commercial quality in the northern area has resulted in little work of a detailed character being carried out there, whereas in the southern area the presence of commercial deposits made detailed work a necessity. At the latitude of Hillcrest Station the Cretaceous synclinorium has a width of $1\frac{1}{2}$ miles. It consists of two troughs separated by a low, southeasterly-trending, asymmetrical anticline which crosses Crowsnest River at Hillcrest Station and Byron Creek about a mile above its junction, beyond which it gradually dies out. The trough on the east averages less than $\frac{1}{2}$ mile in width and that on the west ranges from $\frac{3}{4}$ to 2 miles in width (*See* Plate III). Both troughs are asymmetrical in form with their western flanks either steeply dipping or overturned to the west, and their eastern flanks gently inclined. The eastern trough is cut along its synclinal axis by a westerly dipping thrust fault along which there has been a small displacement. The western trough is cut by several thrust faults of large displacement; one of these extends from the eastern base of Turtle Mountain southeasterly to cross Byron Creek $1\frac{1}{2}$ miles above its junction with Crowsnest River; another fault branches from the former a mile west of Hillcrest Station at the eastern border of the Turtle Mountain rockslide, runs southerly, crosses Drum Creek $1\frac{1}{4}$ miles west of Hillcrest, continues along the eastern base of Hillcrest Mountain, and cuts Byron Creek $2\frac{3}{4}$ miles above its junction with Crowsnest River; a third thrust fault branches off the main eastern fault near where it crosses Falls Creek a mile south of Hillcrest townsite, runs southerly and apparently intersects the western fault which skirts the base of Hillcrest Mountain at a point about $\frac{1}{2}$ mile south of Byron Creek. An examination of the Hillcrest structure section model (*See* Plate III) will show that the segment of the western trough known as the Hillcrest basin and which is surrounded by the three abovementioned faults, has been raised and thrust northward thousands of feet with relation to the adjacent parts of the trough. It is in this basin that the Hillcrest Collieries is carrying on their present mining operations.

Between Blairmore Range and the Rocky Mountain escarpment is an area 10 miles in width that is underlain by Cretaceous strata having a westerly dip. These sediments are cut by two, and in places three, prominent, northerly trending and westerly dipping faults. The beds on the west side of each of the faults have been thrust over those on the east for distances of several thousands of feet. As a result the coal-bearing Kootenay beds that outcrop along the western flank of Blairmore Range and cross Crowsnest River at Blairmore are repeated twice, first in a belt that extends from a point on Crowsnest River $\frac{1}{2}$ to $\frac{3}{4}$ mile west of Blairmore south to South Fork Branch, a distance of 12 miles, and then again in a much longer belt that crosses Crowsnest River at Coleman. In the first of these blocks the beds have an average westerly dip of 45 degrees to 60 degrees and in the Coleman fault block, 30 degrees to 35 degrees. Details of the structure of these two areas are given in the section on economic geology.

The area between the Coleman Kootenay band and the Rocky Mountains is underlain by Colorado marine shales and Allison freshwater sediments. These have a fairly uniform westerly dip averaging 32 degrees. The Colorado shales are approximately 3,000 feet thick and Allison formation 4,000 feet thick.

Five miles west of Coleman, at Crowsnest Lake, the Allison formation is over-ridden by the westerly dipping Palæozoic limestones that form the main range of the Rocky Mountains. The fault contact runs due north from Crowsnest Lake, but 5 miles north of the railway and $2\frac{1}{4}$ miles to the east of this contact occurs Crowsnest Mountain, the upper 2,000 feet of which consists of Palæozoic sediments. From Crowsnest Lake the fault contact trends southeasterly for a distance of $4\frac{1}{2}$ miles to where it turns and assumes an almost due south course. If this south course is projected northwards it will be found to coincide almost exactly with the eastern outcrop of the fault plane in Crowsnest Mountain. There appears to be little doubt that the fault scarp formerly occupied this position, and that at Crowsnest river it has been eroded back $3\frac{1}{2}$ miles to its present location. During the summer of 1932 a number of observations were made of the position and elevation of the fault contact on spurs and re-entrants, both on Crowsnest Mountain and along the main fault contact over a distance of 12 miles. These locations are indicated on the index map, Figure 4, and with them it was possible to construct a series of triangles by which to calculate the strike and dip of the fault plane. These calculations, with but one exception, indicated angles of dip of from 5 to 9 degrees, and an average westerly dip of 6 degrees. The average strike of the fault plane is north 10 degrees west astronomic.

The Palæozoic sediments of the western fault block have a combined thickness of 9,800 feet. In Crowsnest Pass they have a regular westerly dip of from 45 to 60 degrees and are cut by only a few faults of slight displacement. Here the outcrop has its minimum width of $2\frac{1}{2}$ miles. Five miles to the south in the latitude of Mount Coulthard and Mount Ptolemy, where the Alberta-British Columbia boundary line trends in an east-west direction, the Palæozoic rocks are folded and faulted, and the outcrop has a width of approximately 5 miles.

Immediately west of this range lies a north-south trending structural trough along which flows Alexander Creek. This trough is floored by Mesozoic sediments except for a short interval 4 to 5 miles above the junction of Alexander Creek with Michel Creek, where a neck of Palæozoic rocks connects the main range with a small, northerly trending range of Palæozoic strata lying between Alexander Creek and Elk River. From the locality where the Palæozoic strata cross Alexander Creek the trough plunges to the south and to the north, opening southward into Fernie basin, and northward into Elk River basin. Several erosion remnants of the Kootenay coal measures lie along the eastern rim of Fernie basin, among which the following fall within the areas described: Tent Mountain coal area, Michel Head coal area, and Corbin coal area; each of these is described in the following section. The geological structure of the area from Corbin to Burmis is shown on the accompanying section (Figure 6).

ECONOMIC GEOLOGY

Coal mining constitutes the main industry of Crowsnest Pass district. The coal deposits in this part of Alberta belong to two horizons, the Kootenay formation of Lower Cretaceous age and the Allison formation of Upper Cretaceous age. These two coal horizons are separated by over 10,000 feet of sediments and as the coals of the two formations are of different characteristics they are considered separately.

Kootenay Coal

The Kootenay coal deposits are by far the most important, being the source of practically the whole output of Crowsnest Pass district. The general character of the Kootenay formation is given in the columnar table and its distribution shown on Figure 4.

The Kootenay formation varies in thickness from 584 to 800 feet at Coleman to less than 400 feet at Burmis. Five seams occur in the formation, but only three are of sufficient thickness to merit attention, and nowhere are more than two of the seams being worked. In fact, over much of the area only one seam is of sufficient purity to yield a commercial product without elaborate preparation. The stratigraphic horizons of the three main coal seams, their thicknesses, the numerals by which they are designated at the different collieries, and the relative extent to which each is mined are given in the following table.

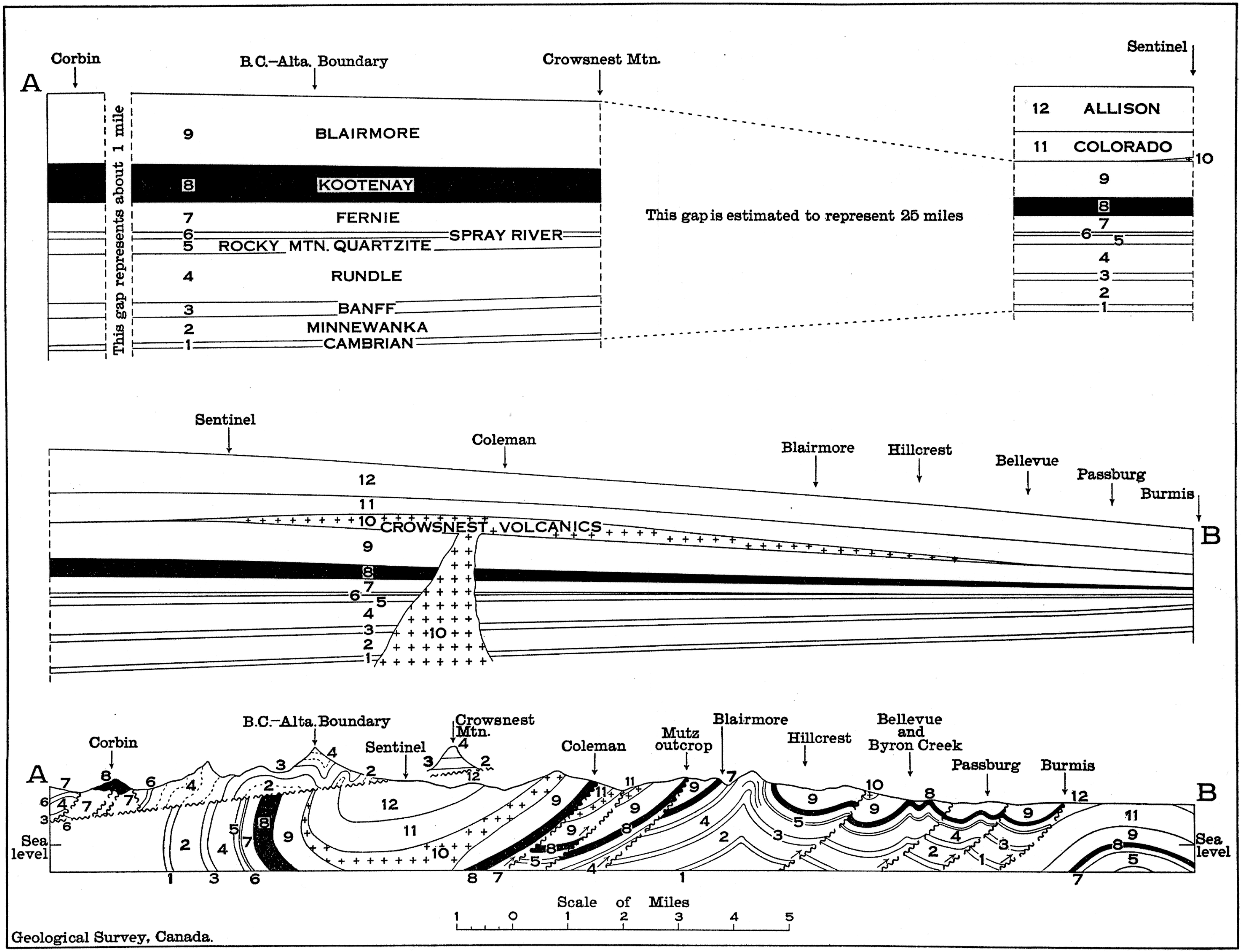


Figure 6. Section from Corbin to Burmis before and after the Rocky Mountain revolution. (*See* Figure 4 for the line of section and location of collieries).

Principal Coal Seams of the Kootenay Formation, Crowsnest Pass Area, Alberta

Thickness of Coal Seams, Their Local Numerical Designations, and the Stratigraphic Intervals at Different Collieries

—	International Coal and Coke Company, Coleman	McGillivray Creek Coal and Coke Company, Carbondale	West Canadian Greenhill Mine, Blairmore	Franco-Canadian Company, Frank	Hillcrest Collieries, Hillcrest
	Feet	Feet	Feet	Feet	Feet
Thickness as obtained from mine workings:					
Interval to top of formation	0–22				
Coal seam	No. 1: 0–3				
Interval	30	30	0–4	0	0
Coal seam	No. 2: 4–17[1] Av. 14½	No. 2: 5–17[1] Av. 9½	No. 1: 0–17[1] Av. 12	No. 1: 10–25[1] Av. 12	No. 1: 0–18[1] Av. 12
Interval	5–90	85	40–85	38	34–53
Coal seam	No. 4: 7–10[2]	No. 4: 4–10[2]	No. 2: 10[2]	No. 2: 6	No. 2: 9–13
Interval	220	230	230	125	135
Coal seam	No. 5: 5–17[3]	No. 5: 5–20[3]	No. 4: 4–6[3]	No. 3: 7[3]	No. 3: 6–13[3]
Interval	300–450	300–450	225	220	220
Estimated total thickness of formation from outcrop	584–800	650–800	560	450	430

—	West Canadian Collieries, Bellevue	Maple Leaf Collieries No. 1 mine, Maple Leaf	Leitch Collieries and Byron Creek Collieries, Byron Creek	Mohawk Bituminous Mines	Burmis Mining Company Mine No. 153
	Feet	Feet	Feet	Feet	Feet
Thickness as obtained from mine workings:					
Interval to top of formation	0	0			
Coal seam	No. 1: 4–14[1] Av. 12	No. 1: 0–8[1]	No. 1: 0	0	No. 1: 3¾
Interval	35–50	56	35	35	40
Coal seam	No. 2: 5–16[2]	No. 2: 5–14[2]	No. 2: 4–10[1] Av. 6	No. 2: 6–12[1]	No. 2: 4½[1]
Interval	125	135	110	110	100
Coal seam	No. 4: 7[3]	No. 4: 8½[3]	No. 3: 7	No. 4: 7[2]	No. 5: 5½–8[3]
Interval	220	210	220	200	200
Estimated total thickness of formation from outcrop	430	425	380	360	360

[1]Principal coal seam which has been or is being mined.
[2]Coal seam partly mined.
[3]Impure coal prospected but not mined.

An examination of the accompanying table in conjunction with Figure 4, showing the wide distribution of the collieries referred to, supports the inference that the two lower coal seams have an areal extent comparable with that of the Kootenay formation. Whether this is so has not been definitely proved, since the non-commercial quality of these coal seams, in many of the areas where they have been opened up, did not warrant further prospecting of a detailed character solely for the purpose of determining their distribution. The attractive quality of the uppermost thick seam, i.e., No. 2 seam of the Coleman area and No. 1 seam of the Blairmore, Hillcrest, Bellevue, and Burmis areas, and its extensive development, have resulted in this horizon being much more thoroughly prospected than any other. This work has shown that over large areas the seam is either absent, or present only as thin lenses or isolated patches. Where present the seam varies in thickness from mere stringers up to 18 feet, and in a few places it is separated from the overlying Blairmore basal conglomerate by a thin lens of shale. From these characteristics it is inferred that this deposit, at the time of its formation, was much more extensive than at present, and was removed from much of the area by erosion prior to the deposition of the conglomerate.

In addition to the seams listed in the table there are several thin seams as well as numerous stringers of coal which grade rapidly into carbonaceous shale. In the former class are No. 1 and No. 3 seams of the Coleman area, each of which has a maximum thickness of 3 feet. Numerous prospect pits and trenches along the outcrops at these horizons reveal in some places narrow, unworkable coal seams, whereas a short distance away the same horizons are composed altogether of black shale. In such circumstances adjacent sections of the Kootenay are found to vary in respect to the total number of coal seams, and the number listed by the different collieries depends on the interpretation given by the investigator to the carbonaceous lenses.

CHEMICAL COMPOSITION

The following table of analyses gives a fair indication of the quality of the coal seams that are either now being mined or have been mined in different parts of Crowsnest Pass area, Alberta. With one exception all analyses are of channel samples and must be considered as indicating the quality of the coal at the particular spot at which the seam happened to be sampled rather than the average run of the seam. The seams are known to vary greatly in quality even within short distances, and to obtain a representative sample of the deposit being mined at any colliery would require a large number of samples being taken from widely separated parts in the mine. As an example of the wide variation in the quality of a seam may be given the proximate analyses of two channel samples of No. 2 seam, Coleman, from different parts of the mine, both taken by a Federal officer and both analysed under the supervision of the same government chemist.

Table of Proximate Analyses of Kootenay Coal Seams Mined in Crowsnest Pass District, Alberta, as Analysed by Fuel Research Laboratories, Mines Branch.

Laboratory number	Colliery and location	Basis[1]	Moisture	Vol. mat.	Fixed carbon	Ash	S	Calories	B.T.U. per lb.	Fuel ratio	Coking properties
	Coals from the Kootenay Formation										
	International Coal and Coke Co., Mine 88, Coleman										
	No. 2 seam. Average of two channel samples, one taken by E. Stansfield, 1909, and one by G. P. Connell, 1930.	R	1·4	25·7	58·8	14·0	0·5	6360	12745	230	Good
		D		26·1	59·6	14·2	0·5	6450	12925		
M2034	No. 4 seam taken by E. Stansfield, 1909.......	R	2·4	22·3	57·0	18·3	0·5	6570	11820	255	Good
		D		22·9	58·4	18·7	0·5	6730	12110		
	McGillivray Creek Coal and Coke Co., Mine 104, Carbondale										
11570	No. 2 seam, 5 counter entry south, taken by B. R. MacKay, 1932	R	1·6	24·6	61·5	12·3	0·7	7310	13160	250	Fair
		D		25·0	62·5	12·5	0·7	7425	13360		
11571	No. 4 seam, 8 entry 3 pillar, taken by B. R. MacKay, 1932	R	2·8	24·0	58·0	15·2	0·6	6920	12460	240	Fair
		D		24·7	59·7	15·6	0·6	7125	12830		
439	West Canadian Collieries, Ltd., Greenhill Mine 396, Blairmore	R	1·2	23·1	56·2	19·5	0·5	6530	11750	2·45	Fair
	No. 1 seam, taken by F. A. Spence, Mine Inspector, 1914	D		23·4	56·9	19·7	0·5	6600	11880		
367	Franco-Canadian Collieries, Ltd., Frank No. 1 or shaft seam	R	1·2	26·0	56·3	16·5	0·6	6850	12330	2·15	Good
		D		26·3	57·0	16·7	0·6	6930	12470		
9887	Hillcrest Collieries, Ltd., Mine 40, Hillcrest....	R	1·4	27·0	52·5	19·1	0·5	6670	12010	1·95	Fair
	No. 1 seam face workings 860 ft. level near fault, taken by B. R. MacKay, 1931	D		27·4	53·2	19·4	0·5	6765	12180		
2048	Leitch Collieries, Ltd., Mine 126, Byron Creek, taken by E. Stansfield, 1909	R	1·1	28·4	52·6	17·9	1·4	6710	12090	1·85	Fair
		D		28·7	53·2	18·1	1·4	6790	12220		
322	West Canadian Colleries, Ltd., Mine 87, Bellevue	R	1·3	20·8	60·9	17·0	0·3	6710	12070	2·95	Good
	No. 1 seam taken by A. N. Scott, Provincial Mine Inspector, 1914	D		21·0	61·8	17·2	0·3	6790	12230		
2028	West Canadian Collieries, Ltd., mine, Lille......	R	1·5	24·9	58·1	15·2	0·6	6910	12430	2·30	Good
	No. 1 seam, taken by E. Stansfield, 1909......	D		25·3	58·9	15·8	0·6	7010	12620		
	Mohawk Bituminous Mines, Ltd., Mine 133, Maple Leaf	R	2·2	24·1	53·4	20·3	0·6	6405	11530	2·20	Poor
	No. 2 seam, 13 crosscut, 34 chute, taken by B. R. MacKay, 1931	D		26·1	54·6	20·7	0·6	6550	11790		
305	Leitch Collieries, Ltd., North Passburg mine	R	1·1	25·8	52·8	20·3	1·7	6480	11670	2·05	Poor
	No. 1 seam, mine main gangway, taken by A.N. Scott, Mine Inspector	D		26·1	53·4	20·5	1·7	6560	11800		

NOTE. The above analyses are, with one exception, based on single channel samples, a number of which were taken many years ago, and are, therefore, not to be assumed as representing the average commercial product now being marketed by the said collieries. This is regulated by the purchaser's specifications.

[1]Basis. R = Fuels as received. D = Fuels dried at 108° C.

No. 2 Seam, International Coal and Coke Company, Mine 88, Coleman

—	Year sample taken			
	1930		1909	
	R	D	R	D
Proximate analyses				
Moisture	1·4	....	1·4	....
Volatile matter	28·2	28·6	23·3	23·7
Ash	7·2	7·3	20·9	21·2
Fixed carbon	63·2	64·1	54·4	55·1
S	0·4	0·5	0·5	0·5
Calorific value				
Calories per gramme gross	....	....	6,360	6,450
B.T.U. per lb. gross	14040	14240	11450	11610
Fuel ratio	2·25	....	2·35	....
Coking properties	Good	....	Good	....

R=Fuels as received; D=Fuels dried at 108° C.

The writer has at his disposal the analyses of many prospect samples of deposits not yet worked and of a number of commercial car-load shipments from the larger operating collieries in the district, that indicate the quality of the coals to be considerably higher than those given in the table of proximate analyses. These analyses have been purposely omitted as the writer is of the opinion that the fresh face samples, a number of which were obtained when mines, now abandoned, were in operation, give a more accurate picture of the relative quality of the deposits in different parts of the district. Exception may be taken to the inclusion of analyses that are high in ash as compared with the average of the deposit being mined by any particular colliery. To this the writer would answer that he has been limited in his choice to the relatively small number of seam channel samples that have been taken and analysed to date by officers of the Federal Department of Mines, even though some of them were taken many years ago. In no case must any of the analyses given be taken as representing the average commercial product now being marketed by the operating collieries. The quality of this product is regulated by the purchaser's specifications. Those interested in the analyses of commercial car-load shipments from the larger operating collieries of the district are referred to Report 725 "Investigations of the Fuels and Fuel Testing, 1930 and 1931," part IV, pages 67-79, Mines Branch, Department of Mines, Ottawa.

Allison (Belly River) Coal

The Allison (Belly River) formation of late Cretaceous age carries coal at several horizons in the upper part of the formation. The number of seams vary laterally in short distances. In some sections only an occasional thin seam of doubtful quality was observed, whereas in other sections the formation is said to carry several seams of commercial value. Owing to the heavy cover of boulder clay and alluvium and the growth of jackpine that characterizes the hillslopes along the front of the Rocky Mountains, the coal-bearing horizon of the Allison formation is largely concealed, and the number and thickness of seams present can be determined only by extensive surface prospecting or drilling. Present conditions in the coal industry do not warrant the incurring of the heavy expenditure that would be necessary to obtain the necessary data. Several thin seams at different horizons have been uncovered at a number of localities at a distance from the railway, but at only one locality is there a coal seam of sufficient thickness, quality, and accessibility to induce the owners to develop their deposit under present conditions. This locality is the Canadian American Coal Company mine located 1,347 feet north of the centre post of the southern boundary of Sec. 34, Tp. 7, Range 5, W. 5th Mer., or 2 miles south of Sentinel Station on the Canadian Pacific Railway. Company officials claim to have uncovered six seams on their property; but it is possible that some of these seams may be faulted segments of the same seam. The measures strike north 66 degrees west, and dip 27 degrees west and from the position of the prospect pits there appears to be at least two seams. Stadia measurements across the Allison measures placed the seam being mined, the uppermost seam of the series, at an horizon of 3,800 feet above the base of the formation, and within a few hundred feet of the fault plane of the Rocky Mountain overthrust. It is possible that the measured thickness may be found to be greater than the actual thickness, due to the presence of hidden thrust faults that have caused a duplication of the beds.

The seam being mined by the Canadian-American Coal Company is 5 feet 2 inches thick and a section taken at the working face, at left crosscut, 400 feet from the mouth of the slope, on August 8, 1931, is as follows:

	Feet	Inches
Roof: carbonaceous shale		
Clean coal	1	5
Hard coal		4
Canneloid coal		5
Hard, white, sandy clay		3
Carbonaceous shale		1
Hard coal	2	8
Floor: Carbonaceous shale		

A channel sample of the seam and a sample of the 5-inch canneloid bench were taken and submitted to the Fuel Research Laboratories, Department of Mines, for analyses. The results are given in the accompanying table.

Table of Proximate Analyses of Allison Coal, Crowsnest Pass, Alberta

Canadian American Collieries, Sentinel, Alberta, Sec. 34, Tp. 7, Range 5, W. 5th Mer.

Lab. No.	Location	Basis[1]	Moisture	Vol. matter	Fixed carbon	Ash	S	Calories	B.T.U. per lb.	Fuel ratio	Coking properties
9795	Channel sample of 5 ft. 2 in.-seam Room on east side near bottom left crosscut, 400 feet from mouth of slope	R	5·0	32·5	45·7	16·8	1·1	6410	11540	1·40	Fair
		D		34·2	48·1	17·7	1·2	6740	12140		
9819	5-in. canneloid bench from 5 ft. 2 in.-seam	R	3·7	31·9	37·5	26·9	2·3	5895	10060	1·15	Poor
		D		33·1	38·9	28·0	2·4	5800	10440		

[1]Basis: R = Fuel as received. D = Fuel dried at 108° C.

The coal seam being mined at Sentinel lies within ½ mile of the Rocky Mountain fault scarp which from the alinement of the edge of the Palæozoic rocks to the south with Crowsnest Mountain, formerly stood 3 miles farther east than at present, overriding this seam for a distance of at least 2½ miles. A number of observations made along the fault contact on the main range and Crowsnest Mountain determine the fault plane tc have an average dip of 6 degrees west. The fault plane would lie, accordingly, only a few hundred feet above the present outcrop of the seam being worked. The proximity of the seam to this fault plane and the intensity of the westerly thrust (the Palæozoic block has been thrust eastward approximately 25 miles) has raised these Upper Cretaceous coals, which at Lundbreck and elsewhere are of much lower rank, to almost the same rank as the Lower Cretaceous Kootenay coals which are many millions of years older. On the other hand, the intense folding, faulting, and crushing to which the measures have been subjected have proved to be the greatest obstacle to the profitable mining of these deposits.

An interesting discovery in the Sentinel coal deposit being mined was a tooth of a carnivorous dinosaur and several bone fragments embedded in the coal at the top of the seam.

Comparison of Allison (Belly River) Coals and Kootenay Coals

All coal seams are made up of a series of layers of vegetal materials. A single bed of coal may yield several types of coal from different bands or layers composing it, but generally the different coal-forming substances occur intimately distributed through the innumerable layers forming the seam. The coaly material varies greatly in its degree of compactness and the relative proportion of the different chemical constituents. Coals are at present divided on the basis of their physical and chemical characteristics into four large groups or ranks: lignite, sub-bituminous, bituminous, and anthracite. Each of these ranks is a measure of the heat and pressure to which the coal has been subjected. Other things being equal the older the coal deposit the longer have the coals been under pressure and subjected to heat and the more compact should be their layers. So, also, other things being equal the closer the coal deposit to the seat of thrusting, the greater the pressure, and the higher should be the rank of the coal. Of these two factors that of intensity of mountain thrust is by far the more effective in raising the rank of the coal. That age is an important factor is obvious from a comparison of the coal deposits at Coleman and at Sentinel. The Coleman deposits of Lower Cretaceous age lie 5 miles from the Rocky Mountain fault plane, whereas the Sentinel deposits of Upper Cretaceous age, some millions of years younger, lie within a half mile of the fault scarp. Based on proximity to the Rocky Mountain thrust the Sentinel coal should be of higher rank than the Coleman coal, but a comparison of their chemical analyses will show that such is not the case. The difference is attributed to difference in age. That proximity to the mountain thrust is the main determining factor in raising the rank of coal may be confirmed by a comparison of the chemical analysis and physical character of either the Sentinel or Kootenay coals with coals of the same horizon farther away from the Rocky Mountain front.

The proximity of the seam being mined at Sentinel to the fault plane and the intensity of the thrust from the west have raised these coals considerably higher in rank than are the coals of the same horizon at Lundbreck, 24 miles to the east, and elsewhere along the Foothills belt. These coals, in turn, are of higher rank than are other coals of Upper Cretaceous age in the plains area farther east. So, also, the Kootenay coals of Crowsnest Pass and other mountain fields are of the same age as the Lower Cretaceous coal deposits of northern Ontario, but the former are of medium volatile bituminous rank, whereas the latter are still in a low lignitic stage. In the flat-lying lignitic deposits such as those of Ontario and the western plains, the bright and dull constituents of the coal occur in broad, open layers, whereas in the mountain regions they are compressed into narrow bands. In the central plains the coals are characterized by shrinkage cracks or farther west, where jointing is developed, the cleavage planes are widely spaced, and lie at 45 degrees to the direction of mountain thrust, and normal to the bedding; in the foothills belt the coals are characterized by a strong development of diagonal jointing with the bisector of the obtuse angle in the direction of the mountain thrust, and with both cleavage planes lying at an angle to the bedding; in the highly folded mountain areas there are several sets of cleavages, often very closely spaced, so that in some deposits it is impossible to procure a single large block of coal and each small piece of coal shows a wedge-shaped form developed by the intersections of the several sets of cleavage planes. It has been observed in some of these deposits that where high ash partings exist in a coal seam, diagonal jointing is not developed in these layers, though it may be conspicuously developed in the coaly layers both above and below the more competent bed. In some places where the high ash layer has a thickness of several inches, there is developed in it a rectangular cleavage, whereas in the coal layers on both sides of it is a diagonal cleavage. The intersection of the diagonal cleavages on the bedding planes of the coal produces a roughened surface in the form of a diamond-shaped lattice grid. In places some of the intersecting cleavage planes have been folded and slickensided by later movement.

Coal Areas and Mining Development

KOOTENAY COAL DEPOSITS

Immediately following the construction of the railway, mines were opened at the most accessible points on most of the outcrops, but owing to the dirty character and thinness of the seams a large number of these mines were shortly afterwards closed and abandoned. Several attempts have been made to work some of these abandoned properties, but most of them have proved unsuccessful.

Mining is being carried on at the present time by the International Coal and Coke Company, and the McGillivray Coal and Coke Company, in Coleman area; by the West Canadian collieries at Greenhill and at Bellevue; by the Hillcrest Collieries at Hillcrest; and by the Mohawk Bituminous Mines one-half mile east of Bellevue. The Byron Creek Collieries mine located at the junction of Byron Creek and Crowsnest River is temporarily closed awaiting a return of normal conditions to the coal industry. Among the collieries dismantled and abandoned are the following: the Burmis Coal Company colliery and its predecessors at Burmis; the Leitch collieries at Old Passburg and New Passburg; the Maple Leaf colliery near Bellevue; the Franco-Canadian collieries at Frank; the West Canadian collieries at Old Passburg, Lille, Grassy Mountain, and on the south side of Crowsnest River at Blairmore; and the Thomason and Cartwright mine located on the south side of the river, three-fourths mile west of Blairmore, on the Kootenay outcrop locally known as the Mutz limb.

For convenience in discussing the Lower Cretaceous coal resources of Blairmore district the Kootenay outcrops may be grouped into three main areas, on each of which considerable detailed geological mapping has been done. These are: (1) the Western or Coleman area; (2) the Central or Blairmore area, which embraces the Blairmore, Mutz, and Grassy Mountain-Kootenay outcrops; and (3) the Eastern area which embraces all the Kootenay outcrops lying to the east of the Blairmore range.

Western or Coleman Area

The most westerly outcrop of the Kootenay formation crosses Crowsnest River at the west side of Coleman townsite. It trends in a north-south direction along the east slopes of Willoughby, Ash, and McGillivray Ridges. It extends south of Crowsnest River for 13 miles to near Carbondale River, and can be traced north of the river for 50 miles. Throughout its course the formation varies in thickness from 564 to 800 feet and has an average westerly dip of 30 degrees to 32 degrees, this dip being modified in a few places by local folds. York Creek is the only locality within the western area where the base of the formation is exposed; elsewhere it is cut off by a pronounced thrust fault along which the Kootenay beds have been thrust eastward over the Allison sediments of Upper Cretaceous age. Even in the York Creek section the exact thickness of the Kootenay is not obtainable as the uppermost beds of the formation had been eroded away prior to the deposition of the overlying Blairmore, and some of the beds in the section are greatly crushed and crumpled. The section of the Kootenay formation obtained at this locality measured 584 feet, but from a series of determinations using the width of outcrop and dip of the beds the formation is estimated to be at least 650 feet thick, and to have a maximum thickness of approximately 800 feet. The only way in which the actual thickness of the Kootenay can be definitely determined is by diamond drilling. The section obtained on York Creek measured downwards from the base of the overlying Blairmore conglomerate to the top of the underlying Fernie is as follows.

Kootenay Section on York Creek

	Feet
Light grey weathering, coarse, dark brown and grey, massive-bedded sandstone	24
Thin-bedded, brownish black shale	15
Light brown, fine-grained sandstone	3
Light brown, thin-bedded, fissile shale and shaly sandstone	15
Coal and coaly shale (No. 2 seam)	16
Carbonaceous shale	9
Coal	4
Shale	4
Coal	4
Concealed interval	20
Brown weathering, grey sandstone	2½
Carbonaceous shale	3
Coal (No. 4 seam)	2
Carbonaceous shale	3
Brown weathering sandstone	4
Black shale and shaly sandstone bands	65
Grey weathering, brownish grey, fine sandstone (measures are folded here)	6
Fissile, black shale	4
Massive, grey sandstone	108
Dark grey sandstone with beds of shale	9
Coarse, dark grey, massive sandstone	5
Brown weathering, thin-bedded, fissile, black shale	6
Orange weathering sandstone	1
Coal	3½
Grey, sandy shale and orange weathering, shaly sandstone	28
Coal	2½
Brown weathering, carbonaceous shale	9
Coaly shale	2
Grey, carbonaceous shale much slickensided	30
Coaly shale and shale	3
Brown weathering, grey shale	24
Coal	8
Concealed interval, coal 8 feet thick (No. 5 seam)	12
Massive, grey sandstone	30
Coaly shale	2
Massive, light grey sandstone	6
Carbonaceous shale	2
Grey sandstone	3
Greenish grey shale and grey sandstone	45
Reddish weathering, grey shale	28
Grey, slickensided sandstone	12
	584½

The Kootenay outcrop has been prospected over most of its length, and has been found to carry five seams designated by numbers, the highest seam being No. 1. Over most of the area seam No. 1 is missing and only two of the seams, i.e., Nos. 2 and 4, are sufficiently pure and thick enough to warrant being mined. These two seams are being developed by the International Coal and Coke Company, and the McGillivray Creek Coal and Coke Company. The boundary between these two companies' holdings is the north boundary of Sec. 8, Tp. 8, Range 4, W. 5th Mer., the former company owning the area to the south and the latter to the north (*See* Figure 7). The development work and prospecting carried on by these two companies have shown that the coal seams and associated sediments vary greatly along the strike both in character and thicknesses. For example, No. 1 seam has been observed only near the mouth of the International Coal and Coke mine, where it is less than 3 feet thick and is so dirty as to have no commercial importance. It lies immediately beneath the basal conglomerate of the Blairmore formation, and passes laterally into a carbonaceous shale.

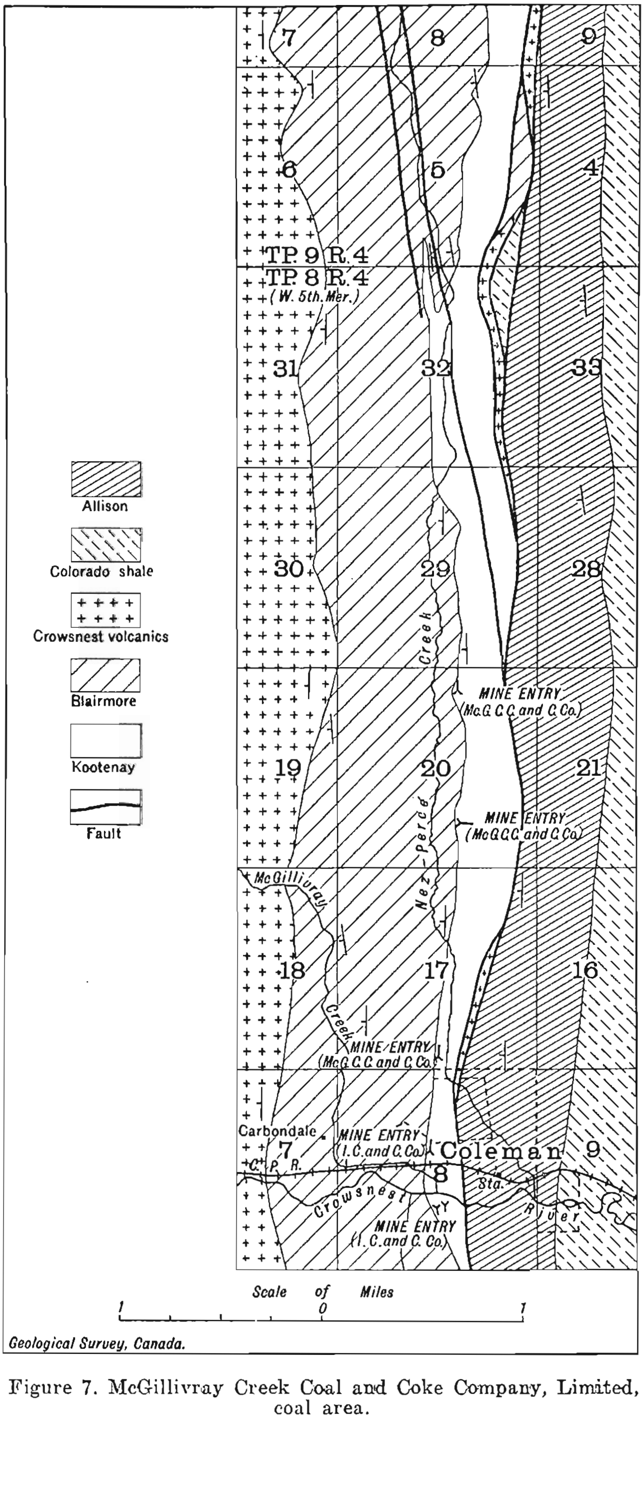


Figure 7. McGillivray Creek Coal and Coke Company, Limited, coal area.

No. 2 seam is the principal seam being developed in Coleman area. It varies from 4 to 17 feet in thickness and has an average thickness of 15 feet. In places the seam is characterized by the presence of sulphur balls and in other places by a 3 to 4-inch thick shale parting that occurs along about the middle of the seam. The seam lies from 15 to 50 feet below the base of the Blairmore conglomerate.

No. 3 seam is a thin seam, in few places more than 3 feet thick, and lies about midway stratigraphically between seams No. 2 and No. 4. It is very impure and in places approaches in character a carbonaceous shale.

Seam No. 4 ranges from 4 to 20 feet in thickness and has an average thickness of 5½ feet. It varies also greatly in ash content. A cross-section of No. 4 coal seam as obtained in No. 12 tunnel of the International Coal and Coke Company is as follows:

	Feet	Inches
Dirty coal	4	9
Bony coal		10
Rocky parting		6
Very dirty coal	4	9
Rock parting	2	6
Bone	2	0
Coal	3	0
Total thickness	18	4

Another section of No. 4 seam at an outcrop near the centre of Section 17, Township 8, on the property of the McGillivray Creek Coal and Coke Company, is as follows:

	Feet	Inches
Fair coal	1	6
Shale	1	9
Very dirty coal	2	3
Friable rock	1	9
Good coal	4	6
Total thickness	11	9

No. 5 seam varies in thickness from 5 to 20 feet, but is so dirty that it approaches in character a carbonaceous shale. It has been prospected by both companies at a number of localities, but nowhere has it been found to be of a quality to warrant it being mined.

The stratigraphic interval between No. 2 and No. 4 seams shows a considerable variation in thickness along the strike. Over the 4-mile distance prospected by the McGillivray Creek Coal and Coke Company (*See* Figure 7) the thickness of the inter-seam sediments varies from 80 feet to 90 feet. In the area developed by the International Coal and Coke Company the variation is much greater. Thus, 1,200 feet south of the north boundary of Section 8, the interval is 110 feet; at the south boundary of Section 8 the interval is 70 feet; 1,300 feet south of the north boundary of Section 5 at B level tunnel No. 19, it is 50 feet; 4,200 feet south of the north boundary of Section 5, B level tunnel No. 67, it is 40 feet, and 1,500 feet north of the south boundary of Section 29 at room 161 there is only 6 feet of sediments separating No. 2 and No. 4 seams. Whether these seams unite south of this locality has not been determined.

McGillivray Creek Coal and Coke Company[1]

The holdings of this company cover the outcrop and westerly slope of the Kootenay measures from the south boundary of Sec. 17, Tp. 8, Range 4, W. 5th Mer., northward for a distance of 5⅛ miles to the southern part of Sec. 8, Tp. 9, Range 4, W. 5th Mer. Two seams are being mined, No. 2 seam, which has an average thickness of 9½ feet, and No. 4 seam, which ranges in thickness from 4 to 7 feet. The seams strike approximately true north and have an average dip of 30 degrees west. A mile north of the southern boundary of the company's property the westerly dipping monocline is modified by a flattening of the coal seams in depth, followed by an abrupt steepening. Traced northward this gives place to a syncline and anticline that plunge gently northwards and, as surface features indicate, rapidly die out. Three miles north of the southern boundary of the company's property the monoclinal structure is again modified by a pronounced northerly-plunging anticline and syncline and by a thrust fault of small displacement.

The company's mining operations are largely confined to the southern 3 miles of their property (*See* Figure 7). The main mine entry is at the southern end of the property, and from it a main level has been driven in No. 2 seam northward for a distance of over 2 miles. From this haulageway crosscuts have been driven at intervals into No. 4 seam. A slope has also been carried on No. 2 seam northward from near the mine entry and from it levels 2, 3, 4, and 5 are being driven, the lowest level lying approximately 1,000 feet below No. 1 level (*See* Plate I). It was on levels 3, 4, and 5 that the company has encountered its greatest difficulty in mining the seams, due to the great variation in dip of the seams and the presence of numerous thrust faults of small displacement and pinches, all of which, especially in a thin seam like No. 4, present serious obstacles. As a result the deeper workings have been temporarily halted. The fold, however, is believed to be of limited extent, as all surface indications point to the measures resuming their regular westerly dip about a mile north of the present working face.

A few years ago a mine, known as the Upper Prospect, was opened at a point 2 miles north of the main entry. It is located near the northern border of Sec. 20, Tp. 8, Range 4, at an elevation 5,130 feet above sea-level, and on the north side of a small valley entering Nez-Percé Valley from the east. A main level is being carried northward and a slope is being sunk from which two lower levels are being run. The coal obtained is carried by mine cars southward along the hill-slope for a distance of 3,500 feet, where it is dumped down a chute in No. 2 seam of the main mine and removed by the main entry.

The Upper Prospect workings, if projected northward, will be in the western side of the anticline whose crest corresponds over much of its length with the valley of Nez-Percé Creek. Hence, with the exception of a small tonnage lying in the area immediately north of the mine entry, all the available coal lies below tunnel level. To mine the coal seams lying in the intervening trough will necessitate opening a new entry in the valley

[1]Mine entries of this company are indicated on Figure 7 by McG. C.C. and C. Co.

of Nez-Percé Creek near the southern boundary of Section 5, or 2 miles north of the Upper Prospect. The relation of these folds to the mine workings of the McGillivray Creek Coal and Coke Company is shown on the structure section model, Plate I.

International Coal and Coke Company[1]

The property of this company extends from the northern boundary of Sec. 8, Tp. 8, Range 4, W. 5th Mer., southward for a distance of 7 miles and covers the outcrop of the coal measures and the seams as far down their dip as it is practicable to mine. The measures strike a little east of south and have a westerly dip of from 30 to 34 degrees. Only two of the five seams combine sufficient purity and thickness to be mined. These are No. 2 seam which has an average thickness of 14½ feet, and No. 4 seam which has an average thickness of 7 feet. There are two mines, North mine located on the north side of Crowsnest River, and South mine located on the south side. At both mines the two seams are being developed, each seam being opened up by a separate entry that unites near the tipple, with the entry on the other seam.

In North mine each of the two seams has been developed by means of a main haulageway, a slope, and three levels for a distance of 2,000 feet to the north boundary of the company's property. A large tonnage is blocked out in No. 2 seam.

At the South mine, the tunnel in No. 2 seam has been driven over 2½ miles, or over a half mile south of York Creek, and the tunnel in No. 4 seam is 9,000 feet long. Most of the recoverable coal between tunnel level and the outcrop of these seams in the area north of York Creek has been extracted and development work on both seams is now being carried on in the lower levels B, C, and D.

A second entry has been driven in No. 2 seam south from the south side of York Creek for a distance of over a half mile and most of the coal between this tunnel and the outcrop has been developed by rooms driven up the pitch. These workings are connected with the main entry and lower workings of the main South mine through which all the mined coal is removed. Throughout the length of the property the seam has a uniform westerly dip and is cut by only one fault, and that of only a few feet displacement. Throughout the area prospected the seams maintain minable thicknesses and parts of the No. 2 seam yield an exceptionally pure grade of coal, so that the extent to which the seams will be developed will be determined by the depth to which mining can be profitably carried on. The maximum depth reached in the mine to date is 1,400 feet below the surface.

Central or Blairmore Area

The principal Kootenay outcrop of the central area is that on which the Greenhill mine is located and may be designated as the Greenhill outcrop. It extends (*See* Figure 4) along the western flank of the Blairmore Range from Blairmore southward for a distance of 11 miles to Carbondale

[1]Mine entries of this company are indicated on Figure 7 by I.C. and C. Co.

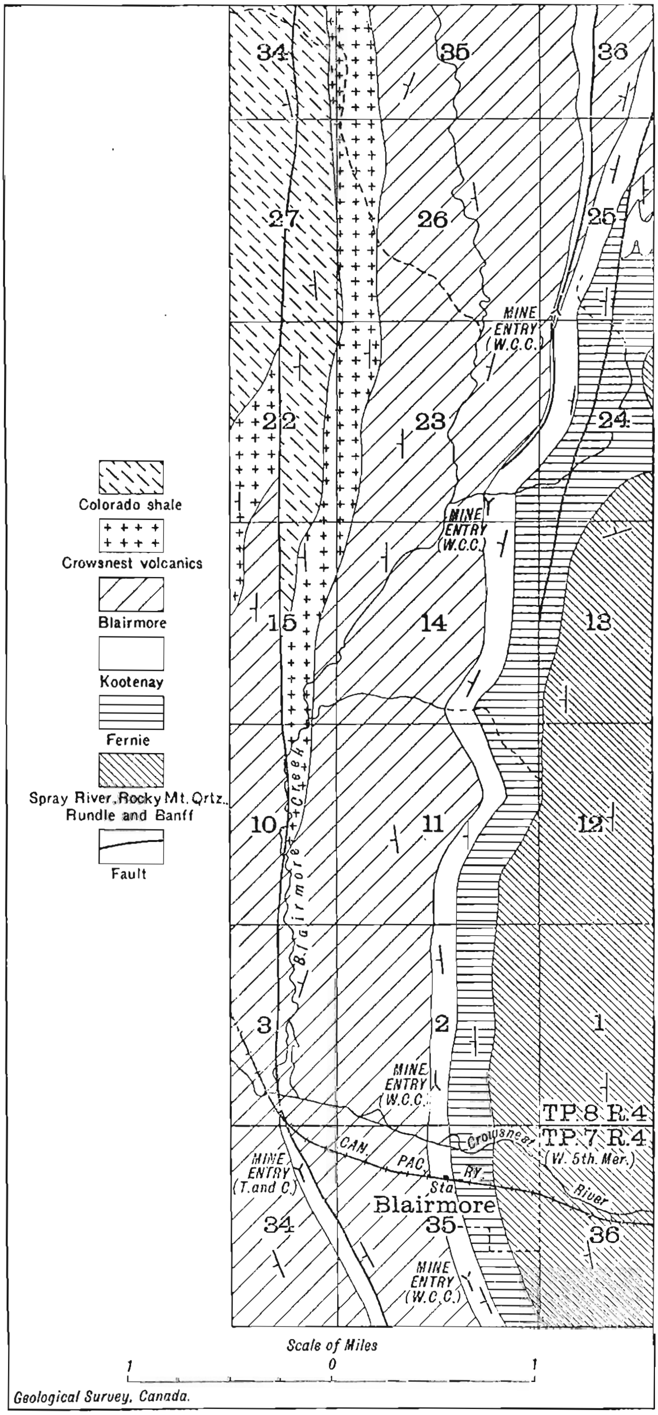


Figure 8. West Canadian Collieries, Limited, coal area.

River and northward for a maximum distance of 7 miles on Grassy Mountain where it occurs as three bands, two of which are terminated by thrust faults and the third by a narrow, northward-plunging, anticlinal fold that carries the Kootenay measures beneath the immediately succeeding Blairmore formation. Except at the northerly and southerly-plunging extremities of the Blairmore anticlinal range, the Greenhill-Kootenay outcrop has an average width of 650 feet and a westerly dip of about 45 degrees (*See* Plate II and Figure 8).

A second outcrop of Kootenay rocks, known locally as the Mutz outcrop, occurs three-fourths mile west of Blairmore. It extends from the south side of Crowsnest River southward to Carbondale River, converging slightly toward the main Blairmore outcrop. This outcrop is bounded on the east by a westerly-dipping thrust fault, so that only a partial section of the formation is obtainable. The beds dip from 45 to 60 degrees west, and represent an up-faulted segment of the Kootenay beds that outcrop to the east.

The Kootenay has a maximum thickness of 470 feet, but over much of the area the thickness is slightly less than this owing to the uppermost beds of the formation having been removed by erosion prior to the deposition of the basal conglomerate of the immediately overlying Blairmore formation. The most complete section available is that which occurs south of Crowsnest River at Blairmore. The section as measured by B. Rose[1] is as follows: No. 1 coal seam is missing but is present under the Blairmore conglomerate 1½ miles to the north where it has a thickness of 10 to 18 feet.

Section at Blairmore

	Feet
Massive, coarse-grained, crossbedded, grey sandstone with fossil stems and coal fragments	39
Coal seam No. 2	15
Dark shale	55
Dark grey, crossbedded sandstone	14
Shale, black, fissile, with a few sandy layers	25
Coal seam No. 3	2
Black shale, with sandy and carbonaceous layers and thin layers of coal	81
Coal seam No. 4	4
Black shale	3
Coal	2
Black shale	3
Coarse, crossbedded sandstone	37
Shale and small coal seams	70
Massive, grey sandstone, approximate thickness	100
	450

Both the Greenhill and Mutz outcrops have been prospected along their entire lengths and a maximum of five seams have been uncovered, but only three are of sufficient thickness to warrant consideration. These are seams Nos. 1, 2, and 4. They correspond, respectively, with seams 2, 4, and 5 of the series at Coleman. Of these it has been rather definitely proved that No. 1 seam is the only seam of sufficient purity to warrant development under existing conditions and that its commercial area is limited to less than 3 miles along the Greenhill outcrop. The outcrops, stratigraphic position, and structure of these coal seams is represented in the structure section model of Blairmore area (Plate II). The details pertaining to the seams are as follows.

[1]Geol. Surv., Canada, Sum. Rept. 1916, p. 110.

No. 1 Coal Seam. No. 1 seam lies at the top of the Kootenay formation and is generally capped by the conglomerate or coarse quartzitic sandstone that forms the basal bed of the Blairmore formation. In a few places the complete thickness of the seam appears to be present, and in places there occurs a thin lens of shale between the coal seam and the conglomerate. In other places the shale capping is missing, and the seam shows a considerable variation in thickness, or over long stretches is either absent or occurs only as small, isolated patches. These several conditions are well illustrated along the Greenhill outcrop. Thus, south of Crowsnest River, No. 1 seam is absent, or where present occurs only as thin, isolated patches. It begins as a thin, but persistent, coal seam near the entrance to Greenhill mine, ½ mile north of the railway; it gradually increases in thickness northward, until a mile to the north it attains its maximum thickness of 17 feet. North of there, seam No. 1 gradually thins, and at Cougar Creek 2½ miles north of Blairmore it is only 9 feet thick, and at Boisjoli Creek, a mile farther north, it is less than 5 feet thick. Another mile farther north, at the south boundary of Section 25, on the west slope of Grassy Mountain, mining operations, carried on between 1901 and 1907, proved the seam to be less than 3 feet thick. To the north of these operations, for a distance of 2½ miles, No. 1 seam is present at only a few places. Whether the conditions observed at the outcrop hold in depth can be determined only by diamond drilling or deep mining operations.

The correlation of No. 1 seam in Blairmore area with its proper seam in Coleman area, has a distinct application in postulating the coal resources of No. 1 seam in the Blairmore segment. For example, if No. 1 seam of Blairmore area corresponds with No. 1 seam of Coleman area, which is of limited extent and so thin and impure as to be of no commercial value, the probability is that No. 1 seam on the Greenhill limb will be less extensive in depth than its outcrop seems to indicate. If, however, as is believed to be the case, No. 1 seam of Blairmore area corresponds with No. 2 seam of Coleman area which is known to extend for many miles, there is a distinct probability of No. 1 seam in the Greenhill segment being more extensive in depth than is indicated by the outcrop. In either case No. 1 seam, though not present on the Mutz outcrop south of the river, is probably present in depth in the northern extension of this horizon opposite the locality in which it is first encountered on the Greenhill limb, although at this location the extent of rock overburden, the thinness of the seam, and its high dip may prevent it from proving a commercial deposit. Until much more systematic prospecting is done in the area it is impossible to estimate the amount of coal represented by this seam.

No. 2 Seam. No. 2 seam has an average thickness of 10 feet, and lies from 50 to 90 feet below No. 1 seam. It has been prospected along the Greenhill and Mutz outcrops over most of the area, and is known to underlie a much greater area than No. 1 seam. Considerable development work has been done on it in the Blairmore South mine, the Greenhill mine, and Cartwright and Thomason Sunburst mine, but nowhere in Blairmore area has it been found to be of sufficient purity to yield a marketable product without a heavy expenditure on preparation. Consequently, no development work is at present being done on it. This seam is believed to be the equivalent of No. 4 seam of Coleman area which, in that locality, is of commercial quality. Since, however, it could not be mined profitably on the Mutz segment, it is hardly possible that any improvement in quality will be found to take place in depth on the Greenhill segment.

No. 4 Seam. No. 4 seam ranges from 4 to 6 feet in thickness, but over most of the area the ash content is so high that the seam approaches a carbonaceous shale. It has been prospected at several localities, in the Blairmore South, the Cartwright and Thomason, and the Greenhill mines, and an attempt was made to mine it on Grassy Mountain, but nowhere was it found to yield a marketable product.

The West Canadian Collieries, Limited[1]

The West Canadian Collieries was incorporated in 1902 and is the largest of the pioneer operators in Blairmore district. It possesses by far the largest acreage of coal mining lands in the district and has developed four large mines, one located at Lille, one at Bellevue, and two at Blairmore, only two of which, Bellevue and Greenhill, are now in operation. The company's holdings in Blairmore area cover all the outcrop and slope of the Greenhill-Grassy Mountain limb and the Mutz segment from the southern boundary of Tp. 7, Range 4, W. 5th Mer., north to the north boundary of Tp. 8, Range 4, W. 5th Mer., with the exception of a half mile of the Mutz outcrop immediately south of Crowsnest River and which is held by Cartwright and Thomason. The West Canadian Collieries began operations at Blairmore in 1909 with the opening of the Blairmore South mine on No. 2 seam, which has a thickness of 12 feet, strikes 20 degrees east of south, and dips 45 degrees west. The entry to this mine is a half mile south of Crowsnest River at an elevation of 4,267 feet (*See* Figure 4). The main haulageway was driven in the seam southward for a distance of 6,600 feet. A half mile south of the northern entry, at the southern boundary of Sec. 35, Tp. 7, Range 4, a second level was started in the same seam at an elevation of 4,643 feet, and carried for a distance of 4,000 feet south. Most of the coal between the two tunnels, and between the upper tunnel and the outcrop, which has a maximum lift of 500 feet, has been developed by rooms driven up the pitch. Owing to the dirty character of the coal the mine was closed and abandoned shortly after the Greenhill mine on the north side of Crowsnest Valley was opened in the autumn of 1914.

The Greenhill mine entry is located 1,800 feet north of Crowsnest River or $\frac{1}{4}$ mile north of the southern boundary of Sec. 2, Tp. 8, Range 4, W. 5th Mer., at an elevation of 4,350 feet. The main mine workings are in No. 1 coal seam, but sufficient development work has been done in No. 2 seam to satisfy the management that no coal of commercial value was being overlooked. The seams strike true north and dip 35 degrees west. The main haulage or No. 5 level is driven from the seam outcrop at the mine entry northward for a distance of $2\frac{1}{2}$ miles to Boisjoli Valley where it emerges (*See* Figure 8 and Plate II). The coal between this level and the seam outcrop which ranges in slope distance from 0 to 2,100 feet, has been developed by three higher levels. The coal below the main haulage level,

[1]Mine entries of this company are indicated on Figure 8 by W.C.C.

for a distance of 650 feet down the dip, has been developed by a slope and No. 6 level. The present mining operations are largely confined to the lower workings. The seam is cut by a few thrust faults, with displacements of only a few feet, too small to be indicated on the structure section model. Attempts were made to mine the seams on the northern extension of the Greenhill outcrop on Grassy Mountain by the West Canadian Collieries between 1904 and 1907, but, due to the fact that No. 1 seam was less than 3 feet in thickness, and faulted, and Nos. 2 and 4 seams were too dirty to yield a marketable product, the venture proved unsuccessful.

Cartwright and Thomason Sunburst Mine[1]

The Cartwright and Thomason property covers that part of the Mutz segment that outcrops on the eastern part of Sec. 34, Tp. 7, Range 4, W. 5th Mer. No. 1 seam is missing and the mine workings are on No. 2 seam which strikes north 20 degrees west and dips 45 to 60 degrees west, the lower dip being at the most northerly outcrop. A small prospect slope was put down on the seam at a point a few hundred feet south of the Canadian Pacific Railway. The mine entry is located 670 feet southeast of the prospect slope, or 1,378 feet northwest of the centre post of Section 34. It is a cross-measure tunnel driven southwesterly for 200 feet to No. 2 seam. From this point the main haulageway was driven in the seam southward for a distance of 1,200 feet. A slope was driven southward from the same point for a distance of 750 feet down the seam, and from it two levels run southward for distances of 470 and 420 feet. The mine was in operation from early in 1927 to July, 1929, when, owing to the poor quality of the coal, work was terminated and the mine abandoned. The plant has been dismantled and it is not expected that any further work will be done on this property until the easily available resources of No. 1 coal seam on the adjacent properties are exhausted.

Eastern Area

The eastern area embraces the Kootenay measures lying east of the Blairmore range. It may be conveniently divided into the following sub-areas: (1) the Blairmore-Livingstone structural trough; (2) the Hillcrest-Byron Creek basin; and (3) the Passburg-Burmis coal area.

(1) *Blairmore-Livingstone Structural Trough*

Lying between Blairmore and Livingstone Ranges is a north-south trending structural trough underlain by Kootenay measures. This trough has its greatest width of about 2 miles at its southern extremity in the latitude of Hillcrest Station. It narrows gradually northward until at Lille, 4 miles north of the railway, it is only a mile wide. It maintains this width to beyond the northern end of Blairmore Range, 10 miles north of the railway, beyond which it opens out to the west losing its trough-like character, and its eastern flank becomes modified by the presence of two minor synclinal folds. The trough is asymmetrical in section with,

[1]Mine entries of this company are indicated on Figure 8 by T. and C.

over most of the distance, the western flank either vertical or overturned and the eastern flank dipping 40 to 65 degrees west. At the southern end the trough consists of two asymmetrical basins, a broad basin on the west, and a narrow basin on the east. These basins are separated by a southeasterly trending, asymmetrical anticline which crosses Crowsnest River at Hillcrest Station. At this latitude two thrust faults occur, one of large displacement that cuts the western limb of the coal basin at Frank, and one of small displacement that coincides with the axis of the eastern trough at Hillcrest Station. The maximum depth of the Kootenay measures is believed to be in the western basin at the southern extremity, where No. 1 coal seam is estimated to lie 2,100 feet below the level of the river. From there the two basins rise gradually northward, but the heavy deposit of alluvium that floors Gold Creek Valley prevents the amount of rise or the configuration of the two segments of the trough being accurately determined. Data pertaining to this are being supplied by the deep workings of the Bellevue mine.

The Kootenay formation has an approximate thickness of 420 feet and carries the three main seams that occur in the Blairmore and Hillcrest areas, i.e., Seams Nos. 1, 2, and 4, the thickness and stratigraphic position of which are shown in the table on page 37. Only the uppermost or No. 1 seam is of commercial quality and over much of the area even it is too thin to mine profitably.

West Canadian Collieries.[1] All the coal-bearing territory of the Livingstone-Blairmore structural trough is held by the West Canadian Collieries. This company opened their first mine at Lille, 4 miles north of Frank, in 1901, and their Bellevue mine, 2 miles southeast of Frank, in 1903, and during the same period carried out extensive tunnelling and surface prospecting on the east side of Grassy Mountain. Following the termination of mining operations at Frank in 1919 by the Franco-Canadian Collieries, the West Canadian Collieries acquired the equipment and holdings of this company. The only mining now being carried on is at Bellevue. The details of the several mines mentioned are as follows:

Lille Mine. The Lille mine is located on the east side of Gold Creek Valley, 4 miles north of Frank, and was connected with the Canadian Pacific Railway at Frank by a privately owned standard gauge railway, which with sidings and its extension to Grassy Mountain measured 6·95 miles in length. Mining operations were carried on in this mine from 1901 to 1912 and a large tonnage was extracted, much of which was used in the local manufacture of metallurgical coke. A battery of fifty ovens were kept in operation during much of the time. Only seam No. 1 was mined. It ranges from 4 feet to 6 feet in thickness, strikes approximately true north, and dips 30 degrees to 50 degrees west. Two mines were opened up, mine No. 1 being located near the northern boundary of Sec. 8, Tp. 8, Range 3, W. 5th Mer., and No. 2 mine, the main mine entry, being located a mile farther north at the northeast corner of Section 18. Mining operations were discontinued on account of the thinning of the seam and faulted ground.

[1]Mine entries of this company are indicated on Figure 9 by W.C.C.

Bellevue Mine. This mine is also located on the eastern limb of the Livingston-Blairmore structural trough and is on the southern extension of the seam mined at Lille. The mine entry is located on the Canadian Pacific Railway in the northeast quarter Sec. 20, Tp. 7, Range 3, W. 5th Mer., at an elevation of 4,016 feet above sea-level. It consists of a cross-measure tunnel 500 feet in length driven eastward through the Blairmore conglomerate. The tunnel tapped No. 1 seam at a distance of 140 feet, No. 2 seam at 250 feet, and No. 4 seam at 500 feet, all dipping west at an angle of 40 degrees. From this crosscut, a prospect tunnel was carried in No. 1 seam for a distance of 130 feet to the north and 400 feet to the south, but nowhere was the seam found to be over 4 feet in thickness. A gangway was then driven northward in No. 2 seam for a distance of 3,800 feet. At a point 3,200 feet from the cross tunnel a prospect crosscut was driven westward which cut No. 1 seam with a thickness of 12 feet. The workings were then carried in No. 1 seam south 1,700 feet to the southern boundary of Section 29, where, on account of the thinning of the seam, the gangway was terminated and an outlet was made by driving a tunnel at an angle to the back to No. 2 seam. The gangway (No. 6 level) in No. 1 seam has been carried almost 2½ miles north to near the centre of Sec. 5, Tp. 8, Range 3, W. 5th Mer. At points 900 and 400 feet, respectively, from the southern boundary of Section 29, two slopes were driven down in No. 1 seam; the first or No. 7 main slope 1,800 feet in length forms the main haulage slope to No. 7 level at an elevation of 3,670 feet and the other, 1,900 feet in length, forms the main slope to No. 8 level, lying at an elevation of 3,380 feet. The main haulage ways at these levels have been carried southward to the south boundary of Sec. 29, Tp. 7, Range 3, W. 5th mer., and northward 2 miles to the north border of Section 32 of the same township. Most of the coal between the 8th level and the outcrop over this distance has been developed. A structural basin occurs in the measures in the northern part of Section 29 and in Section 32 which prevents the upper part of the coal seam in this area being reached from the main mine workings. The coal of No. 1 seam in this basin was first developed by means of an entry, known as No. 4 level entry, driven in it at the southern end of the basin, 1,125 feet southeast of the northeast corner of Sec. 29, Tp. 7, Range 3, W. 5th mer., at an elevation of 4,440 feet above sea-level. A gangway has been carried along the eastern flank of the basin for a distance of 4,500 feet to the northern end of the basin, and from it rooms have been driven up the dip to the outcrop at an elevation of 5,000 feet. The coal below this haulage way is won by a 600-foot cross-measure slope driven eastward from the main haulage (No. 6 level) at an elevation of 4,057 feet, which taps the basin near its southern end at an elevation of 4,092 feet. All the coal being won from this basin is now removed by this slope and the main entry.

From the main entry crosscut a prospect gangway was carried south in No. 2 seam for a distance of 300 feet and from it was driven a slope on the seam to a depth of 185 feet. From the bottom of this slope, a level gangway and counter were carried north for a distance of 1,800 feet, where work ceased because of the lack of any improvement in the quality of the coal. No. 4 seam was tapped by the tunnel 125 feet stratigraphically below No. 2 seam. It has an average thickness of 7 feet, but is very impure.

A prospect gangway and counter were carried north on the seam for a distance of 1,200 feet, but nowhere was the seam found to be of commercial grade, and no further work has been done.

Franco-Canadian Collieries, Limited. This colliery was situated on the western limb of the structural trough at Frank on the Canadian Pacific Railway. The mine was opened shortly after the construction of the railway through Crowsnest Pass, and continued until 1919 when, due to cave-ins and gas explosions, the colliery was closed. When in operation there were two mines, locally known as the Old mine and the Shaft mine. Both these mines were working in No. 1 seam which has an average thickness of 12 feet, strikes north 35 degrees west and dips from vertical to 30 degrees east. The seam is cut by several faults, and rolls are frequent in the workings. The Old mine consisted of an entry on the south side of Crowsnest River, from which a gangway was driven approximately 2 miles south along the eastern flank of Turtle Mountain. A slope, driven southward from this gangway, tapped the deep coal. The Shaft mine is located on the north side of Crowsnest River. The shaft was 330 feet deep, and at depths of 120 and 220 feet from the surface levels were run northward to the vicinity of Bluff Mountain. The vertical attitude of the seam made its systematic development difficult, and finally forced its abandonment through gassy conditions.

(2) *Hillcrest-Byron Creeks Basin*

The Hillcrest-Byron Creeks basin forms the southern extension of the Livingstone-Blairmore structural trough. The complicated structure of this basin is portrayed in the structure section model (Plate III). The basin is modified by several pronounced thrust faults and secondary folds, so that it consists of two major basins, the Hillcrest basin on the west and the Byron Creek basin on the east. The Hillcrest basin is a comparatively shallow, U-shaped, southward-plunging trough which is bounded by two westerly-dipping faults that unite a mile west of Hillcrest Station, and along which the basin has been thrust northward and upward thousands of feet so that its coal measures override those of Frank area on the north and those of the western part of Byron Creek basin on the east. The Hillcrest basin gradually widens southward from its apex at the intersection of the two major faults, and where crossed by Byron Creek it has a width of 6,500 feet.

The coal seams in the western limb of Hillcrest basin are steeply dipping to vertical; those on the eastern flank have an average dip of 30 degrees west. The fault forming the western boundary trends slightly west of south, and that forming the eastern boundary trends southeast and crosses Byron Creek 1½ miles above its mouth. Another thrust fault of considerable displacement branches from the eastern fault on the north side of Falls Creek, and is believed to angle across the basin in a southerly direction to join the western major fault which skirts the base of Hillcrest Mountain. Lack of rock exposures due to the heavy blanket of boulder clay prevents the course of this fault being accurately determined; its trace is inferred from the direction of the fault observed at the most easterly workings in the Hillcrest mine, from the crushed condition of the strata in the rock upraise located on the north side of Falls Creek,

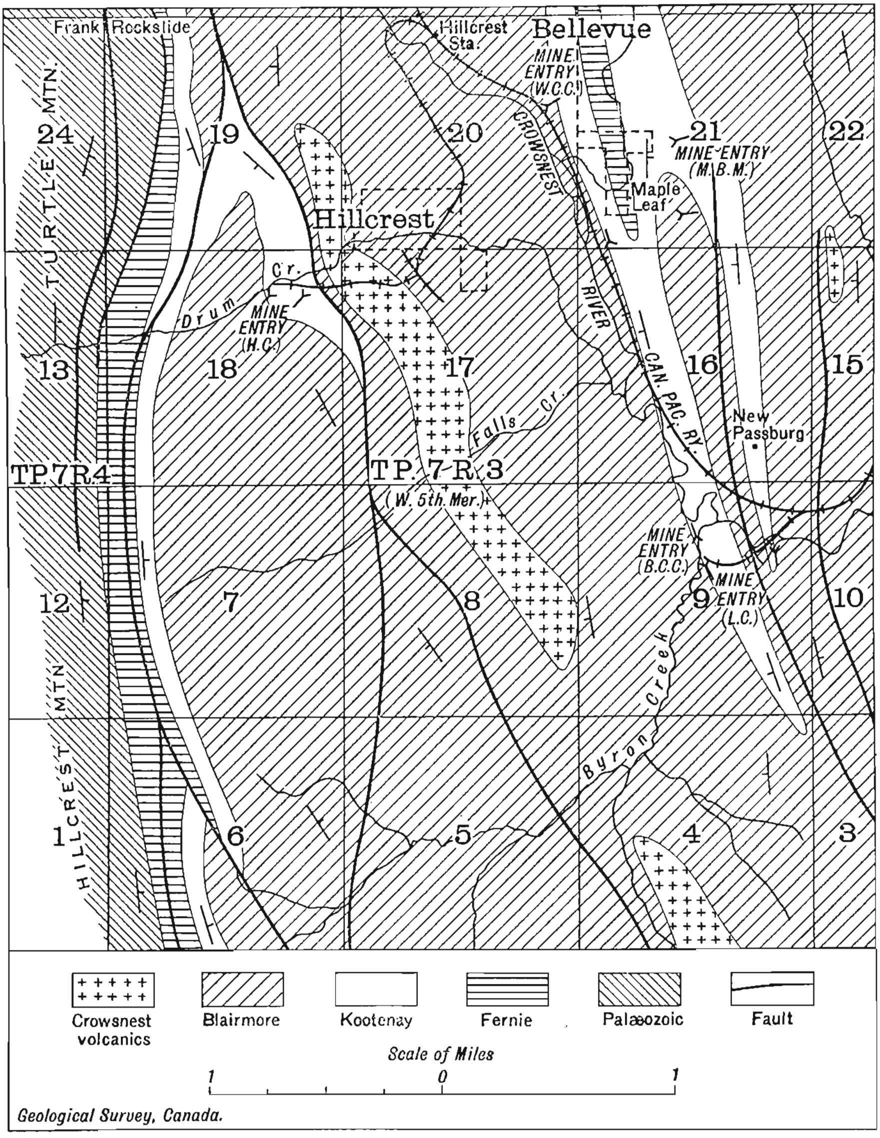


Figure 9. Hillcrest area.

and from the discordance in strike of adjacent rock outcrops observed near the summit of the 5,600-foot hill in the southwest quarter Sec. 8, Tp. 7, Range 3, W. 5th Mer. The eastern part of Hillcrest-Byron Creek basin, which is here referred to as Byron Creek basin, has an average width of a little more than a mile and, as may be observed on Plate III, is divided into two minor troughs by a low, asymmetrical anticline which crosses Crowsnest River at Hillcrest Station and Byron Creek a mile above its mouth. The broader and deeper of these two troughs lies on the western side of this anticline, its centre, in the vicinity of Hillcrest townsite, being occupied by approximately 600 feet of Crowsnest volcanics. A strike fault of small displacement is believed to coincide with the axis of the eastern trough. It is apparent on Crowsnest River immediately east of Hillcrest Station, but it is believed to die out before reaching Byron Creek.

Hillcrest Collieries, Limited.[1] Most of Hillcrest-Byron Creeks basin is held by the Hillcrest Collieries. The company began operations in 1905 and, with the exception of strike periods, has been in almost continuous operation up to the present. The mine entrances are on Drum Creek a half mile west of the town of Hillcrest. The main slope is approached through a tunnel about 600 feet long, this slope leads southward into the basin and is 3,800 feet in length. About 600 feet northwest of this slope and parallel to it, is another that extends into the mine for a distance of about 3,000 feet; it is known as the No. 2 slope. Levels driven from the west side of the No. 2 entry tap the coal lying on the west flank of Hillcrest basin. The coal on the east side of the basin is developed from the 3,800-foot slope. The "pillar and stall" system of underground development is used by the company.

Up to the present time Hillcrest Collieries have been extracting all their coal from the uppermost coal seam, known locally as the No. 1 coal seam. This seam varies in thickness from 4 to 17 feet and has an average thickness of 10 feet. At the eastern border of the basin the thickness increases to a maximum of 40 feet, due to drag-folding in the vicinity of the boundary fault. Operations are now being conducted in the west-central part of the basin, following closely along the branch fault that occurs in that region. Most of the available coal in No. 1 seam in the northern part of the basin has been removed. Development work southwestward has not been carried on to any great extent, due to the occurrence of thin and dirty coal in the western part of the trough. Prospect pits located on Byron Creek, about 3 miles from its mouth, do not reveal the presence of No. 1 seam, and other surface pits to the north of this locality show it to be very much reduced in thickness and dirtier than that part of the seam now being mined. In the light of these facts it is probable that No. 1 seam thins out toward the south, and the company will continue their development work along the east side of the basin, or else turn their attention to the development of one of the lower seams which analyses of prospect channel samples have shown to be of commercial quality.

[1]Mine entries of this company are indicated on Figure 9 by H.C.

Byron Creek Collieries, Limited.[1] Byron Creek Collieries was formed in 1927 to develop the coal deposits occurring in the company's property in the southeastern part of Hillcrest-Byron Creeks basin. Mining operations were started in September at the abandoned workings of the Leitch Collieries on the east side of Byron Creek 1,100 feet south of its junction with Crowsnest River, at an elevation of 4,075 feet above sea-level. The Coal Measures at the mine mouth strike north 20 degrees west and dip 65 degrees west, but the angle of dip at a depth of 800 feet has decreased to 45 degrees. The measure here contains only two thick seams. The Upper or No. 1 seam of Hillcrest and Bellevue areas is missing. The seam under development varies from 3 to 9 feet in thickness and is comparatively high in ash, and is believed to be No. 2 seam of those areas. From a point in the old main level 700 feet from its entry, a haulage slope was driven down the seam at an angle of 27 degrees in a direction north 30 degrees west for a distance of 1,700 feet. Two levels were driven northward from this slope, the upper at an elevation of 3,745 feet was carried a distance of 900 feet, and the lower at an elevation of 3,275 was carried from the base of the slope for a distance of 2,000 feet. Most of the coal lying between the two levels was developed, but the fact that Crowsnest River covered the seam outcrop over much of the distance prevented most of the coal above the upper level being extracted. Owing to difficulties encountered in marketing, the coal operations in this colliery were suspended early in 1931, the damageable machinery was removed, and the deep workings allowed to flood. The mine is still idle awaiting the return of the industry to normal conditions.

Once normal market conditions are restored and mining operations resumed, Byron Creek Collieries would be well advised to prospect the 50 odd feet of measures lying between the seam being worked, No. 2 seam, and the Blairmore conglomerate, either by a bore-hole or a tunnel driven from the northern end of the lowest level, in order to ascertain whether No. 1 seam is present in minable thickness. The northernmost deep workings of Byron Creek mine are located $1\frac{1}{4}$ miles due east of the southern workings of the Hillcrest mine where No. 1 seam has a thickness of 14 feet, but on the other hand they are 1,200 feet due west of the Canadian Pacific Railway cutting where No. 1 seam occurs as a mere coaly stringer in the westerly dipping beds on the Bellevue anticline. Prospecting and development work to the north of this last-mentioned locality has shown that for a distance of 2 miles to the northern boundary of Sec. 20, Tp. 7, Range 3, W. 5th Mer., No. 1 seam is present as small, isolated patches, and that beyond it occurs as a continuous seam of commercial thickness. Although the above facts do not favour the existence of No. 1 seam in workable thickness as far south as the present deep workings of the Byron Creek mine, the possibility of tapping large reserves of coal in No. 1 seam in the eastern part of Hillcrest-Byron Creeks basin warrants No. 1 seam horizon being prospected from this most critical position located near the southern border of the deposit at a distance of a quarter mile west of its nearest outcrop. Once the southern limit of this coal deposit

[1] Mine entries of this company are indicated on Figure 9 by B.C.C.

is determined the coal seam will, in all probability, be found to form a continuous deposit northward to the area being developed by the Bellevue mine.

Passburg-Burmis Coal Area

The Passburg-Burmis coal area, as here defined, embraces all the coal deposits lying between Hillcrest coal area and the major, westerly-dipping thrust fault that crosses Crowsnest River at Burmis, and along which the Kootenay coal measures have been thrust eastward upon the Allison formation. This area comprises four southward-plunging synclines separated from one another by narrow, anticlinal folds. For convenience in description they may be designated from west to east as the Maple Leaf trough, the Passburg basin, the Police Flats trough, and the Burmis basin. These synclines are apparent from the configuration of the Kootenay outcrop as indicated on Figure 4. The Maple Leaf trough lies between the two narrow, southward-plunging, anticlinal folds that form the southern extension of Livingstone Range. Its surface outline, as defined by the Kootenay beds, is shown on Figures 4 and 9, and its section on Plate III. This trough begins at the northern boundary of Sec. 21, Tp. 7, Range 3, W. 5th Mer., and has been traced southeasterly to the southern boundary of the township. It is open and symmetrical at the northern end, but becomes compressed and asymmetrical in section in the vicinity of Crowsnest River with its axial plane dipping about 60 degrees west. At its northern end the Kootenay measures carry three coal seams numbered from the top, Seams 1, 2, and 4. The thicknesses and intervals between these seams, as obtained in the Maple Leaf workings at the head of this basin and on the opposite flanks of the adjacent anticline, are indicated on the accompanying table (page 37). Where the trough crosses Crowsnest River the uppermost seam, No. 1, is missing, and the mining operations carried on there by the Leitch Collieries in the overturned western limb of the trough were in No. 2 seam.

Passburg basin lies immediately east of the southern extension of Livingstone Range. Its northern border as defined by the Kootenay outcrop lies within a few hundred feet of the northern boundary of Sec. 33, Tp. 7, Range 3, W. 5th mer. Here the basin is narrow and symmetrical in section. Traced southward it gradually widens and at the latitude of Bellevue attains its maximum width of a mile with its southerly trending axis lying a mile east of that town. It is the eastern basin portrayed on Plate III. The coal deposits in its western limb were prospected in 1910 by the Maple Leaf Collieries and are now being developed by the Mohawk Bituminous Mines. Farther southward the basin becomes asymmetrical in section with its western limb vertical or overturned and a fault occurs along its axis. The displacement along this fault becomes progressively greater as traced southwards. The basin is bounded on the east by a narrow, southward-plunging anticline that brings the Kootenay outcrop as far south as the mine at Police Flats formerly operated by Leitch Collieries and situated on the northeast quarter of Sec. 15, Tp. 7, Range 3, W. 5th Mer., 3,000 feet north of the Canadian Pacific Railway.

The Police Flats trough is the long, narrow trough that lies immediately east of the Police Flats anticline mentioned above (*See* Figure 4). It is less than ½ mile in width as defined by the Kootenay beds which outcrop on its opposite limbs, and it is delimited on the east by a southerly-trending, westerly-dipping thrust fault which has been traced from the southeast corner of Section 34 south and southeasterly to beyond the eastern border of Blairmore map-area. The beds on the west side of this fault have moved upwards and eastward with respect to those on the east side, and the displacement increases progressively southward. No development has been undertaken in this trough.

The Burmis basin lies between the aforementioned fault and the major thrust fault that crosses Crowsnest River at Burmis. The northern extremity of this basin lies at the southwest corner of Sec. 35, Tp. 7, Range 3, W. 5th Mer.; where it is traversed by Crowsnest River it has a width of a mile.

The Kootenay measures at Burmis trend north 15 degrees west. They dip 50 degrees west at the outcrop, flatten rapidly to near the centre of the basin where they again steepen to form a narrow trough. They contain five seams locally designated as 1, 2, 3, 4, and 5, three of which seams, Nos. 1, 2, and 5, have been mined to a small extent. The thicknesses and stratigraphic position of these seams are shown on the accompanying table (page 37).

Several attempts have been made to mine the deposits at Burmis, but all have proved unsuccessful.

Leitch Collieries, Limited.[1] Leitch Collieries commenced operations in 1907 on two mines. No. 1 South mine is located in the northeast quarter Sec. 9, Tp. 7, Range 3, W. 5th Mer., on the east side of Byron Creek, 1,100 feet south of its confluence with Crowsnest River. No. 2 North mine is situated in the northeast quarter Section 15 of the same township on a spur line of the Canadian Pacific Railway, a half mile north of the main highway.

At No. 1 mine a tunnel 3,000 feet in length was driven south 13 degrees east, in coal, from the seam outcrop. The seam has an average thickness of 6 feet, dips 63 degrees west, and lies on the western limb of the narrow anticline that extends southward from Bellevue. No. 1 seam of Hillcrest and Bellevue area is missing here, and the seam mined is believed to be the same as No. 2 seam of those areas. The analysis of the coal is given as sample No. 2048, page 39. Work in this tunnel was terminated on account of the coal becoming too dirty to mine and the mine was abandoned in 1922. At a point 1,500 feet due east of the mine a short prospect tunnel was driven in the coal seam outcropping on the south of Crowsnest River. The seam lies in the west flank of the eastern anticline and dips 60 degrees west.

Operations were commenced in 1909 by the Leitch Collieries at No. 2 North mine in the northeast quarter Sec. 15, Tp. 7, Range 3, W. 5th Mer., at the southern end of the Kootenay outcrop, a half mile north of a small settlement known locally as Police Flats. The measures prospected strike north 10 degrees west and dip 60 degrees west, and form the eastern limb of Passburg basin. They carry three seams, No. 1 seam 4 feet thick, No. 2 seam 6 feet thick, and No. 5 seam 6 feet thick, separated by 40 and 100 feet of sediments, respectively. A gangway was driven in No. 1 seam for a

[1]Mine entries of this company are indicated on Figure 9 by L.C.

distance of 2,700 feet north, and in No. 2 seam for a distance of 3,800 feet. Operations were continued until March, 1915, when, owing to the thinness of No. 1 seam and the impure quality of No. 2 and No. 5 seams, work was terminated. The mine was abandoned in October, 1915. The analyses of No. 1 seam is given as sample 305 on page 39.

Maple Leaf Collieries. This company began mining in July, 1907, and continued spasmodically until 1915 when they discontinued development work. Their mining operations were confined to the exploitation of the coal deposits in Sec. 21, Tp. 7, Range 3, W. 5th Mer. The structure of the coal measures in this area (*See* Plate III) consists of two narrow, southward-plunging anticlines that form the southern continuation of Livingstone Range and are separated by a narrow, shallow trough designated the Maple Leaf trough. Both anticlines are flanked by Kootenay measures that in places contain a maximum of three seams of sufficient value to have induced considerable development work, and in other places carry only two seams. The thicknesses and stratigraphic intervals between these seams are given on the accompanying table (page 37).

The company's operations began on July 5, 1907, with the driving of a cross-measure tunnel from a point on the Canadian Pacific Railway near the southeast corner of Section 21, northeasterly for a distance of 1,000 feet across the westerly anticline to permit access to the three seams that surface prospecting had proved to exist on both its flanks. No. 1 seam where crosscut had a thickness of 4½ feet, No. 2 seam 14 feet, and No. 3 seam 8½ feet. The seams where intersected on the western flank of the anticline had a dip of 60 degrees west and on the eastern were slightly overturned. Owing to the thinness of No. 1 seam, and the high ash content of No. 2 and No. 4 seams, only a small amount of development work was done. Another cross-measure tunnel was then driven from the eastern side of the Maple Leaf trough eastward for another 1,000 feet to cut the same series of seams outcropping on the two flanks of the eastern anticline. Where this tunnel intersected No. 1 seam, a gangway was carried to the northwest and southeast along the western limb of the anticline and the coal lying between tunnel level and the outcrop was extracted. The overturned and crushed conditions of the coal seams on the eastern flank of the anticline permitted only a small amount of development work being done, and in June, 1910, these mining operations were discontinued.

Attention was then turned to developing the coal from No. 1 seam in the deeper part of the Maple Leaf trough lying between the two anticlines. From a point on the main south haulage, 600 feet southeast of where it left the cross-measure tunnel, a slope, a thousand feet in length, was driven at an inclination of 28 degrees due south in No. 1 seam down the eastern flank of the Maple Leaf trough. From it two levels, known as the 250-foot level, and the 450-foot level, were carried 1,400 feet northwesterly around the head of the basin, and southward along its western limb for a distance of several hundred feet to where the seam was intersected by the first cross-measure tunnel run from the tipple site on the Canadian Pacific Railway. Most of the coal lying between the lowest level and the outcrop was extracted. Three short levels, known as the 700-foot level, the 800-foot level, and the 900-foot level were driven and the coal between these levels for several hundred feet on each side of the slope was developed. Operations terminated in June, 1920, and the property was taken over by the Bellevue Collieries, who in 1921 disposed of the property to the present owners, the Mohawk Bituminous Mines.

Mohawk Bituminous Mines, Limited.[1] Mohawk Bituminous Mines took over from the Bellevue Collieries, Limited, in 1921, the property in Secs. 16 and 21, Tp. 7, Range 3, W. 5th Mer., formerly held by the Maple Leaf Coal Company. They re-opened the No. 1 mine at the railway where they attempted the development of No. 1 seam which there had an original thickness of 4½ feet and a dip of 60 degrees west. This mine was abandoned in 1922 through the pinching out of the coal seam. The company then turned their attention to the prospecting and development of No. 2 coal seam that outcrops on the hill-slope a half mile to the northeast and that lies on the western limb of Passburg basin. Here they opened their main mine described below. In this area No. 1 seam is missing or occurs only as thin, isolated patches. During the past summer Bituminous Mines sank, at the head of the Maple Leaf trough, a prospect slope in No. 4 seam at a point 500 feet southwest from the mouth of the mine tunnel. The seam here strikes northwest and dips 35 degrees southwest. Where exposed in the slope the seam has a thickness of 10 feet, the increase over that observed elsewhere being due to a repetition of coaly layers through a series of small, southerly dipping thrust faults. The quality of the coal was such as to induce the company to consider its development. The thicknesses of the seams and the stratigraphic intervals between them, as obtained in the main workings, are given in the accompanying table (page 37).

The main mine is entered by a 400-foot rock tunnel driven in 1921 from the end of a mine spur located near the centre of Section 21. From this rock tunnel the main level has been driven in No. 2 seam for a distance of approximately 7,500 feet northward along the western rim of Passburg basin. The seam varies from 6 to 12 feet in thickness. Where tapped by the crosscut it is slightly overturned, dipping 80 degrees to the west. A thousand feet farther north it stands vertical, and beyond this it gradually assumes an easterly dip that northward becomes progressively less until 800 feet north of the centre of Sec. 28, Tp. 7, Range 3, W. 5th mer., the seam dips only 18 degrees to the southeast. Most of the coal in the western flank of the basin between the main haulage and the outcrop has been developed. At the present working face in the main haulageway at the northern end of the basin 800 feet northeast of the centre of Section 28, the outcrop of the seam lies approximately 2,000 feet vertically above and a mile to the north, permitting of an enormous recoverable tonnage of coal (*See* Figure 4). Unfortunately, the high ash content of the coal necessitates careful and costly preparation to ensure a satisfactory commercial product. This is the most easterly bituminous coal mining operation now being carried on in Crowsnest Pass, all operations attempted in the deposits farther east having proved unsuccessful owing to the dirty coal.

Burmis Mining Company. The history of mining development at Burmis is one of successive disappointments and heavy financial losses, and gives little hope for any future coal mining attempted in the area. The

[1]Mine entries of this company are indicated on Figure 9 by M.B.M.

Kootenay measures outcrop on the eastern limb of Burmis basin. They strike north 20 degrees west, dip 40 degrees west, and carry five coal seams, numbered in consecutive order from the top of the formation. Of these, the three most attractive, No. 5, No. 2, and No. 1, seams, were tested. The thicknesses of these seams and their stratigraphic intervals are given on page 37. In October, 1907, a mine was opened up on the lowermost or No. 5 seam by the East Crowsnest Coal Company at a point on the east boundary of Sec. 14, Tp. 7, Range 3, W. 5th Mer., and a little south of the centre of the section. Operations ceased on January 1, 1908. The mine was reopened the latter part of 1909 by the Davenport Coal Company which continued development work until 1915 when the mine was taken over by the Burmis Coal Company and closed down in October, 1916. No. 5 seam, which was being mined, has a thickness of 5 feet 6 inches and was reached by a tunnel 290 feet long driven in gravel. A gangway was carried in the seam northward for a distance of 1,400 feet, but the coal proving too high in ash to market, development work on this seam was discontinued. Coal seams Nos. 3 and 2 were then prospected by means of a crosscut driven west from No. 5 seam gangway from a point 400 feet north of the mine mouth. No. 3 seam was too thin to mine, but No. 2 seam had a thickness of 4 feet 6½ inches. A gangway was driven in it for 2,200 feet north, and the greater part of the coal lying between the gangway and the seam outcrop was developed.

In 1924 mining operations were commenced by the Pass Bituminous Mines. A prospect gangway 550 feet in length was driven in No. 1 seam which had a thickness of 3 feet 9 inches. The seam, however, continued too thin to mine profitably, and a crosscut was run northeast from a point in the gangway 365 feet from the mine entry and cut No. 2 seam, 4 feet 3 inches thick, at 75 feet, and No. 5 seam at 105 feet. Only a few pillars in No. 2 seam were withdrawn and operations terminated. In March, 1925, the company was reorganized under the name of the Pass Bituminous Collieries, Limited, and the mine was closed on April 2, 1925. On December 7, 1926, mining operations were recommenced by the Burmis Mining Company who operated until May 5, 1927. The mine was finally abandoned on May 10, 1928, the reason given by the company being the poor quality of the coal in all seams.

ALLISON (BELLY RIVER) COAL

Canadian American Coal Company

The only locality at which coal deposits of the Allison (Belly River) formation are being mined within the area described is at the Canadian American Coal Company mine in the northern half of Sec. 34, Tp. 7, Range 5, W. 5th Mer., approximately 2 miles due south of Sentinel Station or 6 miles due west of Blairmore, and at an elevation of 5,300 feet.

The Allison formation here has a thickness of approximately 4,000 feet and consists of soft sandstones and shales with several coal seams. The company officials claim to have uncovered six coal seams which from their relative position and attitude appear to be distributed through a stratigraphic interval of approximately 1,000 feet. The seam being mined in the present slope is approximately 3,800 feet above the base of the formation and is believed to be the highest of the series. The area is heavily wooded with second growth timber, and bedrock over most of the area is concealed by a blanket of boulder clay and talus so that it would necessitate an expensive program of systematic prospecting to prove the resources of the measures. The presence of at least two seams has been definitely established.

Operations began on the property by the driving of a tunnel in northwest quarter Sec. 3, Tp. 8, Range 5, but only a small amount of development was done and the prospect abandoned. The present operations are located on the centre line of Section 34, 1,347 feet north of quarter line, Sec. 34, Tp. 7, and were begun in October, 1928. Here, a slope 400 feet in length has been driven down the coal seam which is 5 feet 2 inches thick and has a dip of 27 degrees in a direction south 15 degrees west. Rooms are being driven in both directions from the bottom of the slope, but development has been retarded by the presence of cross folds, some of which have dips as high as 55 degrees.

The section of the coal seam being mined is as follows:

	Feet	Inches
Roof: hard, carbonaceous shale—		
Clean, hard coal	1	5
Hard coal		4
Canneloid coal		5
Hard, white, sandy clay		3
Carbonaceous shale		1
Hard coal	2	8
Floor: hard, carbonaceous shale		

Up to the present only a small amount of development work has been done and the shipments, which are made intermittently, are largely sold for local requirements. The analyses of the coal seam is given in the table (page 41).

The coal seam being mined lies within one-half mile of the Rocky Mountain fault scarp which, from the alinement of the Palæozoic rocks to the south and Crowsnest Mountain, formerly stood 3 miles farther east than at present, overriding this seam for a distance of at least 2½ miles. A number of observations made along the fault contact on the main range and Crowsnest Mountain determine the fault plane to have an average dip of 6 degrees west. Accordingly, it would lie only a few hundred feet above the present outcrop of the seam being worked. The proximity of the seam to this fault plane and the intensity of the westerly thrust have raised these Upper Cretaceous coals, which at Lundbreck and elsewhere are of much lower rank, to almost the same rank as that of the Lower Cretaceous Kootenay coals which are many millions of years older. On the other hand, the intense folding, faulting, and crushing to which the measures have been subjected have proved an obstacle to the profitable mining of these deposits.

ROCKY MOUNTAINS COAL FIELDS

Tent Mountain Coal Area

Tent Mountain is a Cretaceous remnant on the east rim of Fernie basin. Its summit forms the Alberta-British Columbia boundary at a point 5½ miles south of Crowsnest Station, or 3½ miles north-northwest of Corbin.

The mountain is capped by the Blairmore formation which is surrounded by a belt of Kootenay rocks varying from $\frac{1}{4}$ to over $1\frac{1}{2}$ miles in width and at least 5 miles in length. On the west side of this mountain two seams have been prospected, but have not been further developed. On the eastern or Alberta slope six seams are said to have been uncovered within 550 feet of measures and having thicknesses of 6, 15, 5, 7, 40, and 15 feet, respectively. The measures there have an average strike of north 20 degrees west and a dip of 45 degrees west.

In 1922, Mine No. 1065 was opened on these deposits by the Spokane and Alberta Coal and Coke Company. This mine is located on Crowsnest Creek at an elevation of 4,900 feet above sea-level, $3\frac{1}{2}$ miles south and 1 mile west of Crowsnest Station with which it is connected by the Tent Pass trail. The development work to date consists of two tunnels. The one on the west side of the creek runs in one of the coal seams for a distance of 570 feet from its outcrop; the other on the east side of the creek is a cross-measure tunnel run southeasterly to tap some of the other seams. It was terminated at a distance of 670 feet from the entrance as a result of encountering faulted measures. Only a small tonnage of coal has been mined and no work is at present being done.

Michel Head Coal Area

Michel Head Mountain, another Kootenay outlier, lies on the west side of Michel Creek between Fernie basin and Corbin coal field. A partial section of Kootenay sediments measured from the base of the formation upward on the eastern side of Michel Head Mountain gave a thickness of 1,800 feet. Two seams of good bituminous coal, 43 and 10 feet in thickness, outcrop high up on this slope directly west of Corbin, but owing to their inaccessibility no attempt has been made to develop them.

Corbin Coal Area

The Corbin coal area is one of the smallest and at the same time one of the most important coal fields in the district. It forms an oval-shaped erosion remnant, $2\frac{1}{2}$ miles in length and 4,700 feet in maximum width, with its longer axis oriented in a north-south direction. It is situated on the east side of Fernie basin and contains the lowermost 1,200 feet of the Kootenay coal measures. These contain two seams, the lower of which is 180 feet in maximum thickness and lies 350 feet above the base of the Kootenay formation, and the upper seam is 15 feet in maximum thickness and lies 800 feet above the base. Assuming an average total thickness of 60 feet of workable coal the basin contains an estimated tonnage of 81,000,000 tons, all of which lies above valley level. The deposits are concentrated in three tightly compressed and faulted synclinal troughs, resulting in places in a greatly increased thickness of the coal. Operations begun in 1908 have been almost continuous to the present. During the year 1930 the colliery reached its maximum production of a little over 266,000 tons of coal. The Corbin colliery is at present one of the largest producers in southeastern British Columbia. A detailed report on these deposits appears in the Geological Survey, Summary Report 1930, part B.

BIRCH RIDGE STRUCTURE, ALBERTA[1]

By G. S. Hume

CONTENTS

Illustrations

INTRODUCTION

The Birch Ridge structure lies south of Elbow River between Sec. 2, Tp. 23, Range 5, W. 5th Mer., and Sec. 31, Tp. 21, Range 4. It was discovered in 1931 as the result of mapping on a scale of 2 inches to 1 mile and a preliminary report was published in Summary Report 1931, part B. In 1932 detailed mapping was carried out on a scale of 10 inches to the mile and as a result some modification of the former map was found to be necessary, particularly in the north part of the structure (*See* Figure 10) where the well of Elbow Oils, Limited, is being drilled. As a result of this new mapping some modification of the conclusions set forth in Summary Report 1931, part B, in regard to Elbow Oils, Limited, well are now necessary.

STRATIGRAPHY

The stratigraphic section is shown in the following table.

Formations	Thickness in feet
Upper Alberta shale	1,600
Cardium sandstone and shale member	350
Lower Alberta shale	850
Blairmore	1,600 (?)
Kootenay Fernie	550 (?)
Palæozoic limestone	

Only the higher formations down to the upper part of the Blairmore are exposed in the Birch Ridge structure. The thicknesses of the lower formations are, therefore, not exactly known. West on Elbow River, how-

[1]Geological maps with cross-sections on the scale of 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.

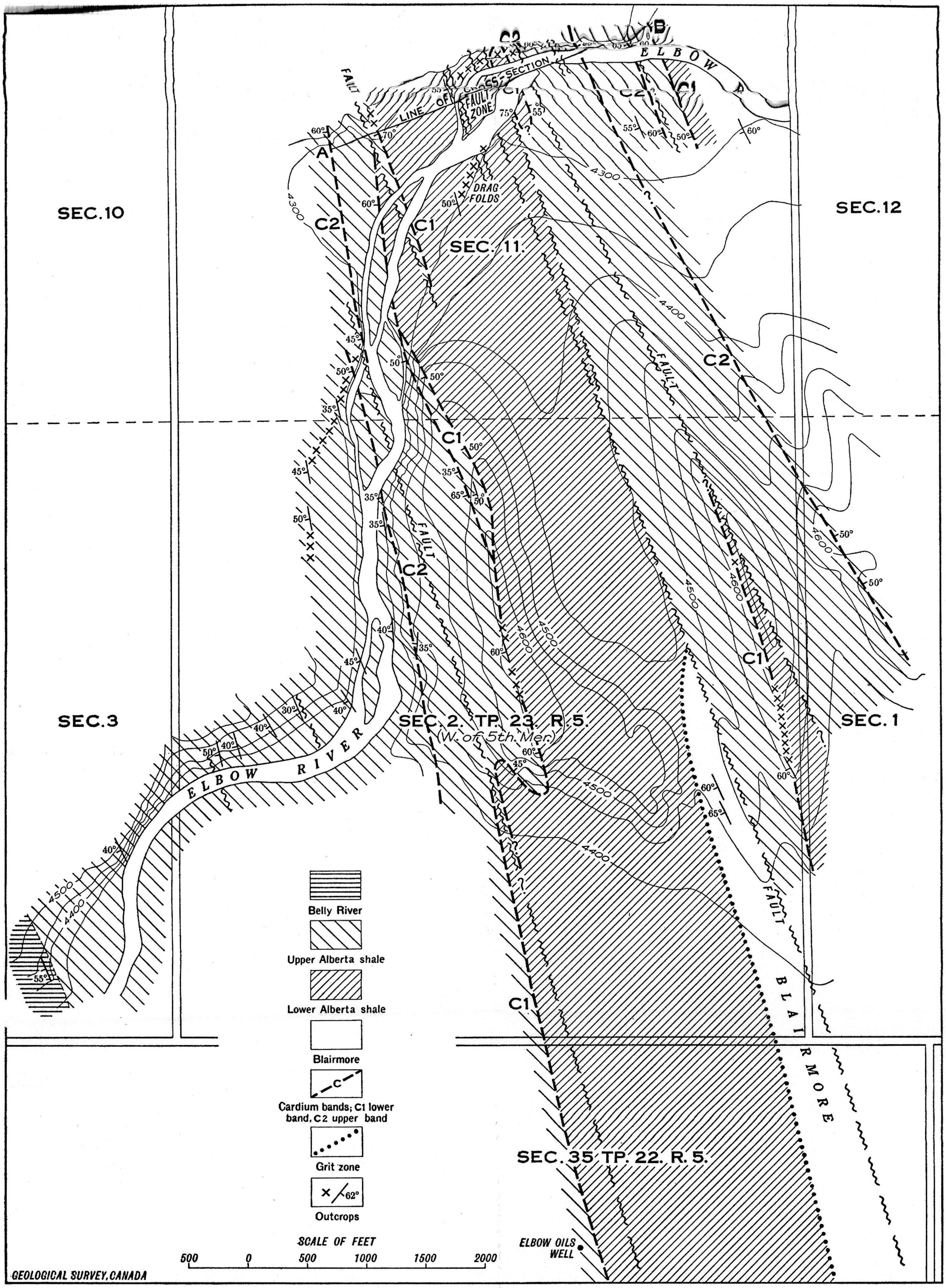


Figure 10. North end of Birch Ridge structure (for cross-section, *See* Figure 11).

ever, on the east flank of Moose Mountain, the Blairmore consists of 1,630 feet of strata with shales and sandstones predominating in the upper part, underlain by several hundred feet of sandy and brown, limy beds interbedded with dark shales and resting on the basal Blairmore conglomerate. As the Blairmore thins eastward a tentative thickness of 1,600 feet is here ascribed to it in the Birch Ridge area. This is probably a maximum rather than a minimum thickness.

Below the Blairmore at Moose Mountain are 350 feet of Kootenay, and about 200 feet of Fernie, beds. Undoubtedly the thickness of the Kootenay also decreases eastward, but the combined thickness of the Kootenay and Fernie is not likely to be less than 550 feet. The Kootenay consists of dark shales and sandstones with coal underlain by more massive, brown sandstones, whereas the Fernie is for the most part composed of dark to black shales with lime bands, but very thinly bedded (ribboned), brown sandstones immediately overlie the Kootenay. Throughout this general area, of which the Birch Ridge area is a part, there are, so far as known, no Triassic beds and the Fernie rests on an eroded surface of Palæozoic limestones. These limestones, known to be 1,400 feet thick in Moose Mountain, belong to the Rundle formation which is mostly Mississippian in age although the upper part may be Pennsylvanian.

STRUCTURE

In Birch Ridge area Blairmore strata outcrop in a long, narrow strip not more than a quarter of a mile wide but extending 7 miles from Sec. 31, Tp. 21, Range 4, to Sec. 2, Tp. 23, Range 5. The strip is bounded on the east by a fault along which the Blairmore has been thrust over Alberta shales varying somewhat in stratigraphic horizon throughout the length of the structure, but being for the most part either just above or below the Cardium zone. Along the west side of the strip the Blairmore strata dip westerly beneath Alberta strata, and at each end the Blairmore apparently plunges under Lower Alberta shales, and for this reason Lower Alberta shales appear on the strike of the structure on Elbow River in Sec. 2, Tp. 23, Range 5, where a good section is exposed. Here it can be seen that the fault bounding the structure on the east side is not a single break but is composed of a number of faults constituting a fault zone (*See* Figure 11). West of the fault zone, between it and the lower Cardium band exposed farther west, there are approximately 650 feet of strata and, therefore, since the Lower Alberta shale is about 850 feet thick, it is believed the lowest exposed horizon is not more than 200 feet above the base of the Alberta shale. The main fault of this fault zone appears to be almost vertical and along it the lower part of the Lower Alberta shales is brought against a higher part which to the east is thrust onto the lowest Cardium band. Most of the faults can be readily detected by a band of gouge usually grey to black and mostly not more than 2 inches thick. The fault zone on the surface is confined to a width of 400 feet. East of it, on Elbow River, there is an anticline with the lower Cardium band present on both limbs, but it is quite apparent that the westward dipping band of the Cardium is cut by a fault. At the top of a high shale bank on the north side of the river the full thickness of the Cardium sandstone

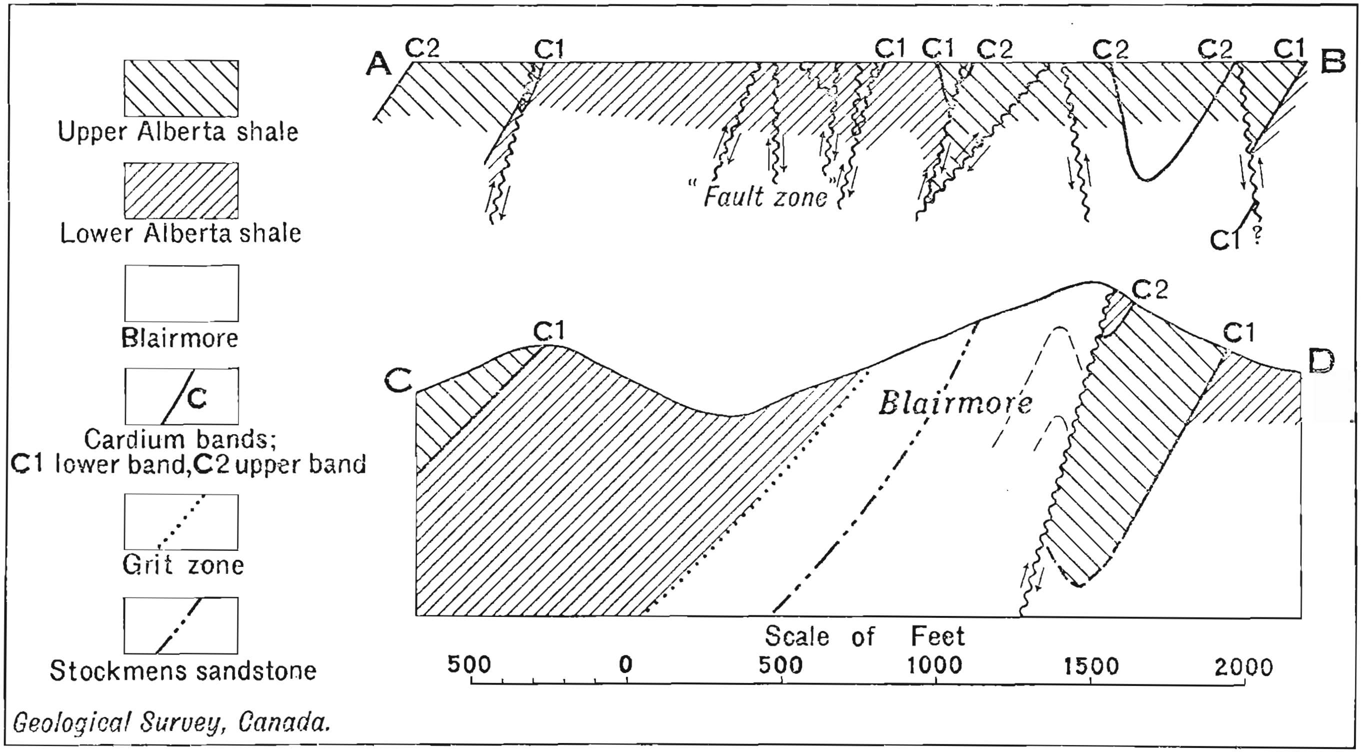


Figure 11. Cross-sections of Birch Ridge structure, *See* Figures 10 and 12.

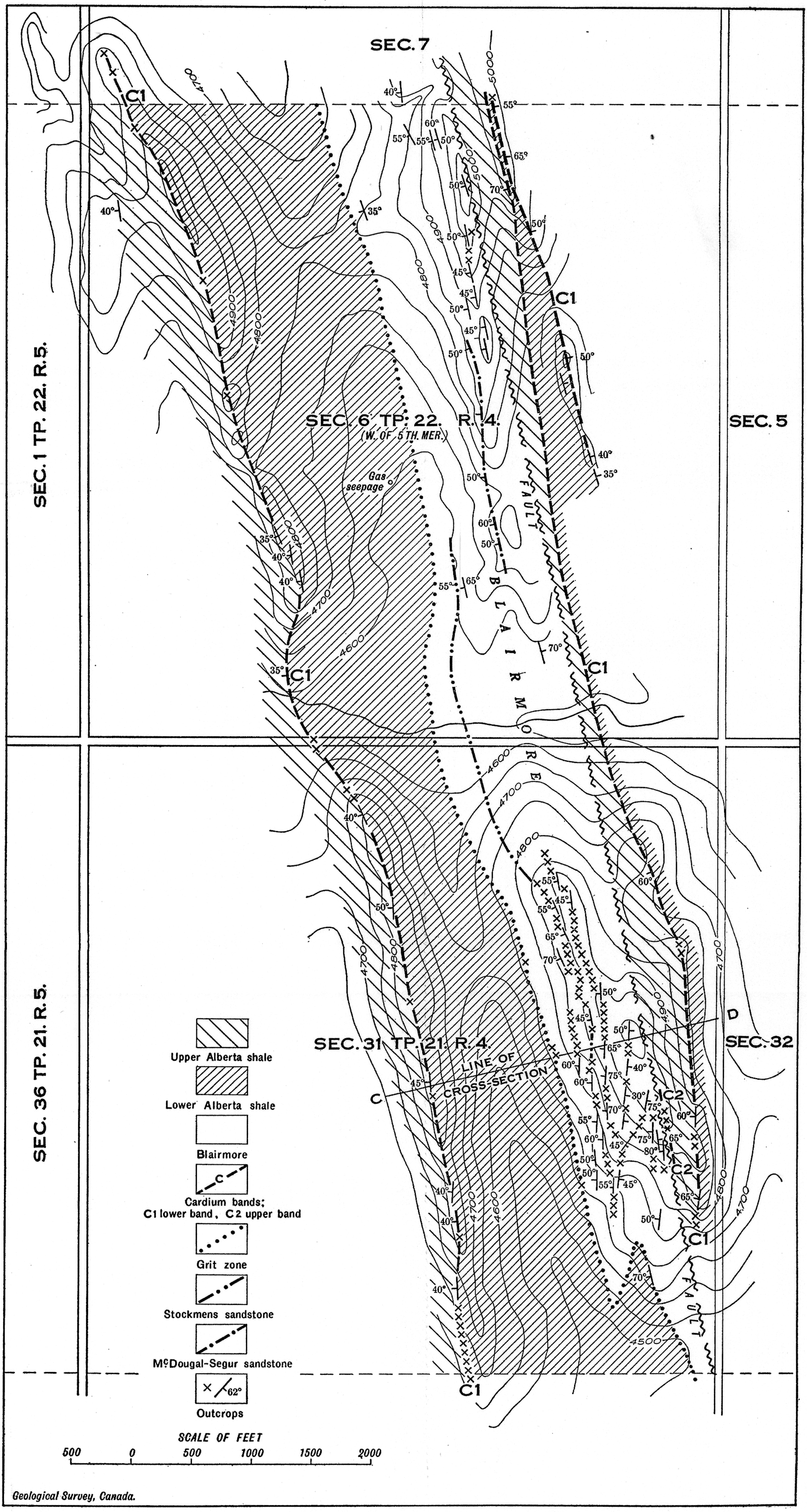


Figure 12. South end of Birch Ridge structure (for cross-section, *See* Figure 11).

with its capping of conglomerate is exposed, but at river-level the fault cuts out the conglomerate because the plane of the fault is steeper than the dip of the strata. As a result of this fault, shales that by their content of nodules over a foot in diameter are known to immediately underlie the Cardium band, are thrust over it. The fault is thus of only small displacement and is one of many that occur within the fault zone. To the east of the anticline, the structure is complicated by numerous small faults as shown in Figure 11.

South of Sec. 2, Tp. 23, Range 5, there is a broad flat without exposures and covered by heavy gravel deposits. Within this area on Sec. 35, Tp. 22, Range 5, the well of Elbow Oils, Limited, is being drilled. The flat is apparently a former river valley of Elbow River, although there does not appear to be any obvious reason why the river subsequently changed its channel to a slightly more northerly course.

At the south end of the Birch Ridge structure (*See* Figure 12) in Sec. 31, Tp. 21, Range 4, and Sec. 6, Tp. 22, Range 4, the structure west of the main fault appears to be less broken by faults than on Elbow River. This is a matter of inference rather than direct observation, because across a considerable breadth there are no exposures, but it is inferred that the structure is underlain by Lower Alberta shales. This assumption is borne out by the following facts. On section 31 there are a number of places where poorly exposed beds of the "grit" occur dipping to the west. East of these there is a normal succession of Blairmore strata down to the Stockmen's sandstone band. At some distance west of the "grit" bed, beyond the area where there are no exposures, the lowest band of the Cardium outcrops in a low series of hills. When the available information is plotted in the form of a cross-section (*See* Figure 11), it is apparent that the required thickness of 850 feet of Lower Alberta shales can just be accommodated between the "grit" and the Cardium band and thus it is inferred that from the Stockmen's sandstone westerly, the dip is uniform without repetition by thrust faulting and that the full thickness of the Lower Alberta shale is present. This regularity of structure continues northward into Sec. 6, Tp. 22, Range 4, but toward the north side of Section 6 where the McDougal-Segur sandstone beds outcrop and north of it in Township 23, the Blairmore is repeated in a series of slices probably somewhat similar to those on Elbow River in the Lower Alberta shales. The character of the fault or fault zone on the east side of the structure is not definitely known south of the exposures on Elbow River, but at the south end on Sec. 31, Tp. 21, Range 4, outcrops of Blairmore beds appear within a few feet of a Cardium band and in this case there seems to be but a single fault rather than a fault zone.

OIL AND GAS PROSPECTS

Outside of Turner Valley much disappointment has followed drilling on favourable surface structures within the foothills, due to the fact that in many areas that have been drilled low-angle faults have been encountered above the Palæozoic limestone. These faults caused repetitions of the strata and made further drilling futile. Such cases as New Black Diamond, Fisher Creek, Jumpingpound, and Wildcat Hills may be cited and it is not without significance that a low-angle fault occurs under Turner Valley, although in this case the fault over a large area is below the top of the Palæozoic limestone. Low-angle faults at depth, therefore, seem to be the rule rather than the exception for this part of the foothills. Where these low-angle faults have not been encountered, as in the wells in Highwood area, it may be that a sufficient depth has not been reached, although here again such faults if they do occur must be below the top of the Palæozoic limestone since this horizon was reached in several wells. The character of the fault or fault zone on the east side of the Birch Ridge structure is, therefore, highly important because if the fault or series of faults continue to depth with the steepness they exhibit on the surface the Birch Ridge structure undoubtedly contains Palæozoic limestone. If, however, the fault or fault zone should turn into a low-angle fault at depth the limestone might not be present above it. It has not been possible to arrive at a definite conclusion regarding the presence or absence of a low-angle fault under the Birch Ridge structure. At one locality, namely, on Sec. 24, Tp. 22, Range 4, the McDougal-Segur sandstone appears to be thrust from east to west onto the Stockmen's sandstone, although the interpretation is somewhat difficult due to some doubt about the interpretation of horizons. As already explained[1] such a fault might originate at a point of change from a high-angled fault to one of less steepness. Faults of this type on the Fisher Creek and Two Pine structures are regarded as evidence of low-angled faults at depth and in the case of Fisher Creek such a fault was encountered in drilling at 2,680 feet. On the Birch Ridge structure, however, the best exposed cross-section occurs on Elbow River and at this locality all the faults are steep and no evidence was seen that would point to any change in the steepness at depth. The fault or fault zone on the east side of the structure also appears to follow a straight line on the surface regardless of topography, thus confirming the observations of high dips for the fault planes. If the steep dip persists to depth, wells located west of the fault or fault zone on the west flank of the Birch Ridge structure, as for example the well of Elbow Oils, Limited, can reach the Palæozoic limestone at a reasonable depth and thus make a test of this possibly productive horizon. In such a structure any concentration of oil and gas in the westward dipping strata would be sealed against the fault or fault zone on the east side in any horizons that are sufficiently porous to act as oil or gas reservoirs.

Only one gas seepage was observed on the Birch Ridge structure, namely on Sec. 6, Tp. 22, Range 4. At this locality gas issues with a water spring from drift materials lying above Lower Alberta shales. This seepage, however, may have no particular significance because it is highly probable certain dark shale zones in the Lower Alberta formation are capable of producing small amounts of both oil and gas. Water is likely to occur in the porous horizons in the upper part of the Blairmore because these outcrop. The Fernie and underlying beds are, however, deeply buried and any oil or gas in them is under sufficient cover to be retained.

[1]Hume, G.S.: Geol. Surv., Canada, Sum. Rept. 1931, pt. B, p. 53.

DEPTH OF DRILLING

The stratigraphic thickness in this area from the Cardium zone to the top of the Palæozoic limestone is not absolutely known because the thicknesses of Blairmore and Kootenay vary from locality to locality. A reasonable estimate, however, would be as follows: Lower Alberta shale 850 feet, Blairmore 1,600 feet, Kootenay and Fernie 550 feet, or a total thickness of 3,000 feet. Elbow Oils, Limited, well penetrated the base of the Lower Cardium band at 390 feet and reached the top of the Blairmore at 2,220 feet, nearly 500 feet lower than would be expected if the dip of the stratigraphic thickness of 850 feet of Lower Alberta shale is 50 degrees as is indicated by the surface dips on the Cardium band southeast of Elbow Oils location. It may be, therefore, that a part of the shales are repeated by a small fault such as occurs on Elbow River (*See* Figure 11). It is possible the angle of dip may decrease somewhat in depth, but it is hardly probable that the angle will become much less than 45 degrees. On a dip of 50 degrees the drilling depth from the top of the Blairmore to the Palæozoic limestone would be about 3,450 feet, making the total depth of the Elbow well to the Palæozoic limestone 5,670 feet. On a 45-degree dip the drilling thickness for the same stratigraphic thickness would be approximately 3,030 feet, making a total drilling depth of 5,250 feet. This does not take into consideration any minor faults that may occur. In the section of the Blairmore east of Moose Mountain, coal and coaly shales[1] occur about 800 feet below the top of the Blairmore. Black and coaly shales occur in the Elbow well at 3,356 feet, or 1,136 feet below the top of the Blairmore. Assuming an angle of dip of 45 degrees, the drilling thickness of 800 feet of strata amounts to about 1,130 feet, a thickness equal to that encountered in the well. Although the black and coaly shales in the well cannot be definitely correlated with those in the Moose Mountain section, it is not improbable that they do occur at the same horizon and, if so, the strata being drilled at this depth in the Elbow well are dipping at an angle of approximately 45 degrees. Such a dip is quite in harmony with the dips observed on the Cardium band (Figures 10 and 12) on the west flank of the Birch Ridge structure and these dips are probably more nearly indicative of dips likely to be encountered at depth than the dips observed in the narrow strip of Blairmore, for these are steeper due to proximity to a fault. Thus it follows if the dip in the Elbow well is approximately 45 degrees the Palæozoic limestone should be reached at a depth of about 5,250 feet if no faults intervene.

In the southern part of the Birch Ridge structure on Sec. 31, Tp. 21, Range 4, and on Sec. 6, Tp. 22, Range 4, it has been shown that there is no reason for supposing faults within the Lower Alberta shales. A well starting at the outcrop of the Cardium band and encountering dips of 45 degrees should, therefore, reach the Palæozoic limestone at a depth of between 4,000 and 4,500 feet. An excellent location for such a well is on section 6 on the edge of Whisky Creek on a broad flat that occurs in this area. At the present time, however, no road leads to this area. It could be reached from the end of the road to the Cottonbelt well at Fisher Creek by constructing a road 2 miles long, or it could be reached from a poor trail that runs west

[1]*See* Geol. Surv., Canada, Sum. Rept. 1931, pt. B, p. 47.

from the Priddis road at the north side of Sec. 35, Tp. 21, Range 3, to Sec. 4, Tp. 22, Range 4, on Whisky Creek 2 miles east of the suggested location. Perhaps, however, a more satisfactory route would be to follow the road from Bragg Creek south to Fish Creek and to the southern boundary of Sec. 18, Tp. 22, Range 4. From the end of this road it is 2 miles directly south to the proposed location on Whisky Creek over a rather low and in part swampy flat bounded by hills on each side.

CONCLUSIONS

In spite of unfavourable drilling results in the foothills outside of Turner Valley, it is believed that the Birch Ridge structure merits serious attention. The completion of Elbow Oils, Limited, well on Sec. 35, Tp. 22, Range 5, would give definite indications of what might be expected. It is believed the top of the Palæozoic limestone can be reached in this well at a depth of slightly more than 5,000 feet, if no low angle fault intervenes. It is also thought that the same deep horizon can be reached at a somewhat less depth at the southern end of the structure at locations sufficiently far west of the fault on the east side of the structure to avoid penetrating this fault. The Birch Ridge structure is a westward dipping fault block in which, if accumulations of oil and gas occur, they will be found in porous horizons in the higher structural part against the fault on the east side of the structure and extending down the dip westward for an unknown distance toward the major synclinal basin which lies to the west.

THE ARTESIAN WATER AREAS OF THE WEST HALF OF RUSH LAKE, AND THE EAST HALF OF ELBOW, QUADRANGLES, SOUTHERN SASKATCHEWAN

By D. C. Maddox

CONTENTS

Illustrations

INTRODUCTION

In southern Saskatchewan the small annual rainfall and the very high evaporation loss of surface moisture during the summer months, largely due to the hot, dry winds, render the question of water supply one of great importance. The supply of water from the deep, soft water wells here described is not affected by climatic conditions. In very dry seasons these wells are a dependable source of water. The maps and well lists accompanying this report provide information to the prospective well driller as to the depth at which water may be expected to occur and the approximate height to which it will rise. The approximate limits of the flowing well areas are also outlined. The water analyses given show the general nature of the water and the limits of its use. From the geological standpoint the data on the wells give information regarding structural conditions in an area in which outcrops are largely confined to the valleys of the rivers.

The work in 1932 was a continuation of that commenced in 1931. E. W. Shaw again acted most capably as field assistant. The co-operation of many well owners is gratefully acknowledged. The late Mr. Robert Cruickshank, pioneer rancher, south of Beechy, extended his hospitality to the field party for a few days. Messrs. G. Anderson of Beaver Flat and Brunyee of Saskatchewan Landing also assisted in providing facilities for field work. The following well drillers co-operated in providing information: Messrs. C. Olmen of Riverhurst, H. N. Williamson of Eston, R. Midgley of Elbow, G. Kipp of Kenaston, H. W. Hanscam of Hawarden, Len Adams of Craik, A. Rankin of Hanley, M. J. Ward of Govan, Duncan Campbell, Jean Sullivan, and A. J. Kargleder of Davidson, and E. Olsen of Kyle. Mr. R. H. Murray of the Division of Sanitation, Regina, again co-operated by providing analyses of water from many wells.

A few deep tests for oil and gas have been made in the area. The Imperial Rush Lake well (Table I, No. 161) was abandoned at 2,335 feet and the Hanley Development Company's well (Table II, No. 47) was drilled to 2,063 feet. Both of these wells are discharging water and a little gas. The Eden Valley Oil Company have put down a deep test south of Outlook and the Canadian Western Natural Gas, Light, Heat, and Power Company put down a diamond drill hole to 2,134 feet in L.S. 9, Sec. 28, Tp. 30, Range 5, W. 3rd Mer.

In interpreting the data on wells given in this report the probable accuracy of the figures must be considered. Information on wells was collected chiefly from well owners, but a good deal was also contributed by the drillers. The Dominion Drilling Company was the only organization that has kept written records of the well data, information otherwise acquired was given from memory. The depth figure was impressed on the owner's memory by the fact that he generally had to pay for the well by the foot. When the figures given by driller and owner coincided it was considered to be probably accurate, but in some cases the ownership had changed since the well was drilled and information was not very reliable. Another possible source of error is that the total depth of the well and the depth to the top of the water sand do not always coincide. In the wells drilled by the Dominion Drilling Company data as to length of the screen or of the slotted pipe gave information as to the distance drilled into the aquifer[1], but in most other cases no information of this nature was obtainable. Consequently, it was assumed that the total depth and depth to top of aquifer coincided.

WEST PART OF RUSH LAKE QUADRANGLE

TOPOGRAPHY

The west half of Rush Lake quadrangle includes Townships 17 to 24 and Ranges 8 to 15, west of the third meridian. Much of the northwest part of the area is part of the upland known as Missouri Coteau and is hilly, the highest hills having elevations of about 2,850 feet above the sea or 600 to 700 feet above the general level below which South Saskatchewan River is entrenched. Numerous undrained hollows, many occupied by shallow lakes or alkali flats, lie between the hills. South of South Saskatchewan River and east of Swiftcurrent Creek much of the country also is hilly, the general elevation being somewhat above 2,350 feet. West of Swiftcurrent Creek the surface has about the same general elevation, but the local relief is much less than in the areas to the east. Two large river valleys and many small ones occur. The South Saskatchewan occupies a valley that in some parts is 500 to 600 feet below prairie level. The valley sides vary greatly in steepness, there is occasionaly a steep descent with bad land topography, but in general the slopes are only moderate. The elevation of South Saskatchewan River is 1,695 feet at the crossing of the southern boundary of Township 22 and is 1,788 feet at the crossing of the western boundary of Range 15. Coulées, many steep sided and generally with a thick growth of bush or small trees, are very numerous and in some cases

[1]An aquifer is a formation, group of formations, or part of a formation that is water bearing.

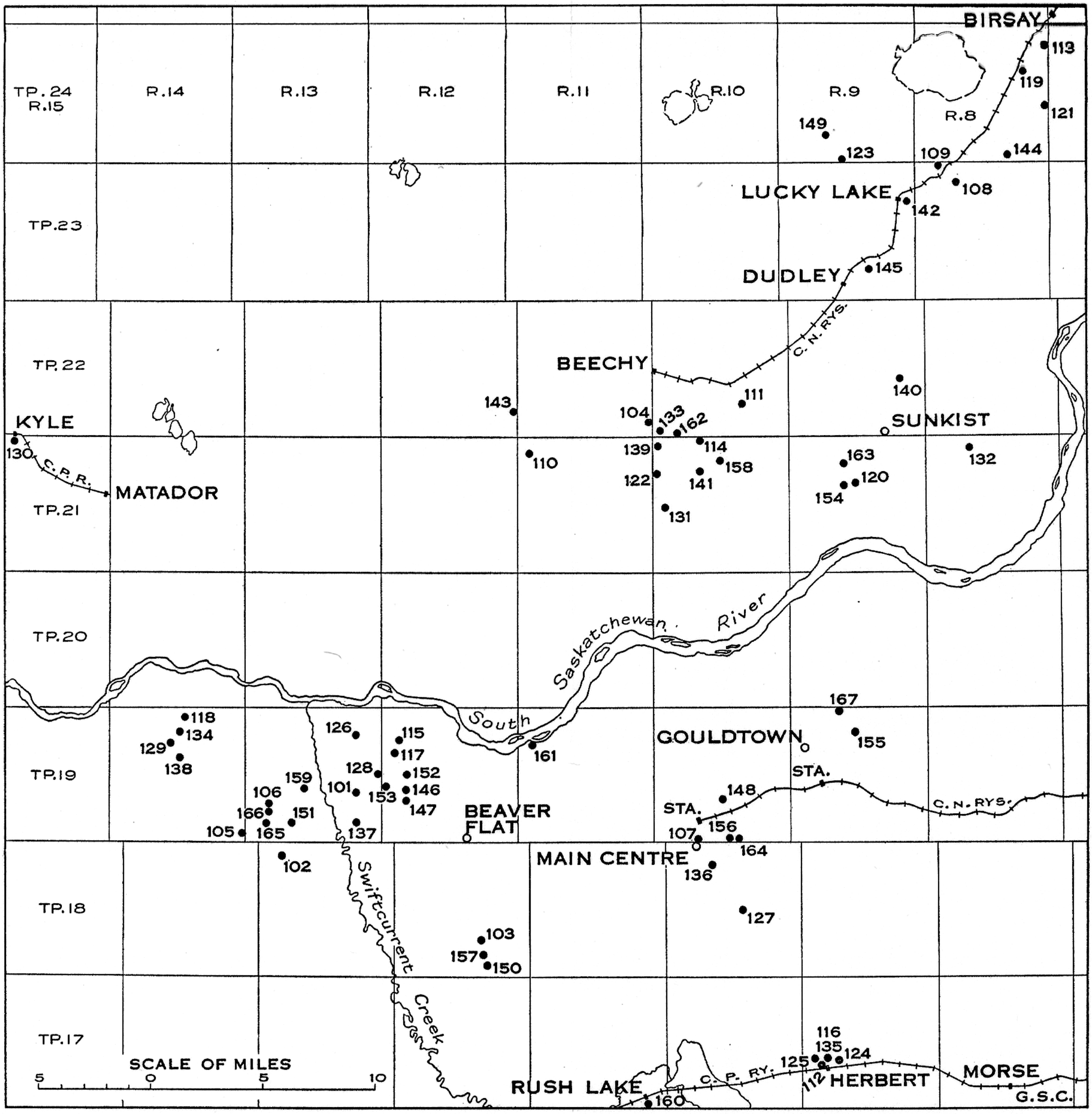


Figure 13. Index map showing positions of wells, western half of Rush Lake quadrangle, Saskatchewan.

extend back several miles from the river valley. They are occupied by watercourses that are generally dry except at times of heavy rainfall or in the spring.

The lower part of the valley of Swiftcurrent Creek is much more steep sided than is the valley of South Saskatchewan River. Within the limits of Rush Lake quadrangle the creek descends from an elevation of nearly 2,350 feet to one of about 1,750 feet. North of Township 18 the fall is about 50 feet to the mile, measured in a straight line in the general direction of flow. In Township 18 and a little south from it the fall is high, but less so than in Township 19. In the southern two-thirds of Township 17 the fall greatly decreases and meanders are numerous. There are no falls, but in the lower part rapids are very numerous and most of the bed of the creek is occupied by boulders or gravel. The flow of the creek varies greatly. The mean monthly discharge as determined by the Dominion Water Power and Hydrometric Survey for the period 1909-1931 showed a maximum of 1,351 cubic feet a second, a minimum of 0, and an average of 80·3 or 43,362,000 gallons a day. The rate of flow during the months of the year shows great variation. For the period stated the average flow a month in cubic feet a second, for March and April, was 306, the average for the remaining ten months being 35·2, December showing the lowest figure, 11. Within the limits of the area a few springs feed the creek, but in the summer they are generally small, some being mere seepages. The largest one found yielded about 0·11 cubic feet a second.

The area is entirely agricultural, Swift Current, a few miles south of the limit of the quadrangle, being the nearest town. In Coteau district north of South Saskatchewan River are located the Matador ranch and several other ranches, the soil and topography favouring ranching rather than farming.

GENERAL GEOLOGY

Most of the area is deeply drift covered and exposures of the bedrock are confined almost entirely to the banks of the river and coulées. The Bearpaw formation of Upper Cretaceous (Montana) age as determined by P. S. Warren[1] underlies a great part of the area. Younger formations, including the Whitemud beds, form the bedrock in the higher parts of Coteau region. The Whitemud beds outcrop on Snake Bite Butte south of Beechy, other non-marine beds may lie between the top of the Bearpaw and the base of the Whitemud beds, but their presence has not been proved. The Belly River formation, or its marine equivalent in the east, is believed to underlie the Bearpaw, but no exposure of it occurs in the area.

Very thick sections of drift are exposed in places in the banks of South Saskatchewan River and Swiftcurrent Creek. Sections at places on Swiftcurrent Creek show at least 150 feet of drift. Good sections of the Bearpaw formation occur along South Saskatchewan River above the ferry south of Beechy and along Swiftcurrent Creek.

At an elevation of about 1,950 feet on the southwest quarter, Sec. 30, Tp. 20, Range 10, a spring occurs from which soft water and gas are emitted. The spring occurs on a small bench covered with gravel and

[1]Geol. Surv., Canada, Sum. Rept. 1926, pt. B, p. 41.

boulders and generally free from vegetation, about 5 feet above the base of the nearby stream bed. Analysis of the water showed 93·2 grains a gallon of total solids, chloride, and carbonate of sodium, and there seems no doubt that the gas and water are coming from the bedrock and not from the drift.

DESCRIPTIONS OF WELLS

(Data on the wells in the western part of Rush Lake area are given in Table I. Locations of the wells are shown on Figure 13.)

Swiftcurrent Creek Group. Many deep wells occur east and west of the lower part of Swiftcurrent Creek. At least two aquifers are present. The water is moderately soft, analyses showing types 2 and 3[1] with total solids about 100 grains a gallon.

Beaver Flat Group. Wells 103, 150, and 157, south of Beaver Flat, are in an aquifer considerably higher than in the case of the previous group; the water is soft and aquifer and piezometric surface[2] rise to the south.

Main Centre Group. Water in well 127 is brown. Water moderately soft; one analysis shows total solids 63 grains a gallon of water of type 2.

Gouldtown Group. Wells 155 and 167.

Rush Lake and Herbert Wells. The Rush Lake town well and the Herbert town well (125) conform fairly well as regards elevation of aquifer and piezometric surface. A little gas is recorded in both wells and the water of the Herbert town well contains no sulphates. In some of the Herbert town wells a hard water aquifer also occurs, the elevation of aquifer and piezometric surface being much lower than those of the soft water wells and the water being brown. It is difficult to connect the soft water aquifer with any aquifer of the groups previously described. If it be that which supplies wells 120 and 154 (Sunkist group) a rise to the south of 10½ feet a mile is shown from well 120 to well 125.

Area in Rush Lake Sheet North of South Saskatchewan River. Most of the deep, soft water wells in this area are located within a few miles of the Canadian National Railway between Birsay and Beechy. The wells can be arranged in fairly well-defined groups.

Soft Water Wells South of Beechy. A few of these wells located in the lower parts are flowing. The records show that the aquifer rises to the north, the rise from well 131 to well 122 being 13½ feet a mile. The piezometric surface also shows a rise to the north. Well 111 may be on the same aquifer as 163. The sand in well 110 is described as being as fine as flour and a well on the northwest quarter, Sec. 34, Tp. 21, Range 11, obtained no water. These facts suggest that the westerly limits of the aquifer are not far from well 110.

Hard Water, Flowing Well Area South of Beechy. Five flowing wells were located on this aquifer which is a little over 200 feet above the soft water aquifer and probably consists of glacial gravels overlain by boulder

---

1 See page 81 for definitions of types.

2 The piezometric surface of an aquifer is the surface to which the water of the aquifer will rise under its full head.

clay. Levels were run on the most westerly, No. 143, and the two most easterly, 104 and 133. The figures show a drop in the aquifer of about 10 feet a mile towards the east. It seems probable that well 132 is on the same aquifer, the fall to the east being about 9 feet a mile from well 104.

Sunkist Group. Wells 120 and 154 do not conform to the group south of Beechy, either as regards the elevation of the aquifer or the piezometric surface. Well 163 is probably on the same aquifer as No. 111.

Lucky Lake-Birsay Group. Elevations of aquifer and piezometric surface indicate the presence of two aquifers. Of these, the higher shows a general dip towards the north, the amount from well No. 108 to well 103, Table II, being about 7 feet a mile in a direction 20 degrees east of north. Figures on the piezometric surface are rather conflicting, but there appears to be a rise to the north amounting in the two wells mentioned to about 4½ feet a mile. Gas is recorded in well 103, Table II, and the water analysis, 179 grains a gallon of total solids, shows an increase of 28·4 grains a gallon from a well 6½ miles south and the composition of the solids—chlorides dominant and no sulphates—suggests marginal conditions. Wells 142 and 123 show a piezometric surface much higher, and the aquifer lower, than the previous group. The small number of wells, however, makes conclusions difficult. Well No. 145 shows a very high piezometric surface, although the elevation of the aquifer conforms fairly well with that of the Lucky Lake-Birsay group.

EAST PART OF ELBOW QUADRANGLE

INTRODUCTION

The area includes the part of the Elbow quadrangle east of South Saskatchewan River. Much of the area is nearly level and has a general elevation of 1,750 to 2,000 feet above the sea. Allan Hills in the northeast are the highest part and have a maximum elevation of about 2,300 feet. Another hilly area lies between Hawarden and South Saskatchewan River. Except in the southwestern part of the area the east bank of Saskatchewan River is not very steep and is 100 to 200 feet high. In the southwest the bank is fairly steep and is 200 to 300 feet high. The valley of Brightwater Creek, in which flowing wells occur, is one of the lowest parts. Dundurn Forest Reserve is a sandy, low-lying area in the northwest. The elevation of water-level in Saskatchewan River is 1,664 feet at the crossing of the north boundary of Township 24 and 1,587 feet at the crossing of the north boundary of Township 32.

The area is largely agricultural and there are many villages and small towns, Outlook and Davidson being the largest of these. Dundurn Forest Reserve, the area adjacent to it, and the valley of Brightwater Creek are well wooded and patches of bush occur both north and south of Outlook and on the banks of South Saskatchewan River; other parts are prairie. The area is 42 miles from east to west and 48 miles from north to south and lies immediately north of the Darmody-Riverhurst artesian area. The map, Figure 14, accompanying this report, adjoins that published in Summary Report 1931, part B. Outcrops are few, but the Bearpaw formation of Upper Cretaceous (Montana) age is believed to underlie the drift over most of the area. Belly River beds probably underlie the northern part.

ARTESIAN WATER AREAS

There is a small, hard water, flowing well area in Rosemae district. The aquifer probably is in the glacial drift. A deep, soft water area extends from the southern limits of the map-area north to Hawarden and probably beyond it. Analyses show the water to be of type 1 (*See* notes on water analyses). There is a deep, moderately soft water area north of Hawarden and extending north as far as well 59. The water is of type 2. A hard water area north of this includes wells 72 and 133 and probably extends to the northern limits of the map-area. A small, flowing well area south-east of Hanley yields hard and alkaline water, probably from outwash sand or gravel in the drift.

The valley of Brightwater Creek is a flowing well area the approximate limits of which are shown on Figure 14. In the southern part, well 114 has a flow of about 35 gallons a minute; well 102 has a large flow; most of the other wells have comparatively small flows. In the north, well 59 flows about 10 gallons a minute, well 133 is reported as having come in with a very heavy flow, but is now partly choked up. It is difficult to define the limits of the soft water, artesian area. Many aquifers appear to be present. In the north, well 59 is the most northerly soft water well, well 134 obtained water containing 377·6 grains a gallon of total solids, chiefly sodium chloride, from an aquifer at 1,464 feet elevation. In the west a well close to well No. 14 was drilled to an elevation of 975 feet and obtained no water from horizons comparable in elevation to those at Strongfield or Hawarden. The water in well 81 is of type 6, higher in sodium chloride than the normal water; this may indicate submarginal conditions. To the south of the quadrangle, in Rush Lake quadrangle, the northern part of the Darmody-Riverhurst artesian area lies about 12 miles south of the boundary between the two quadrangles. No deep wells have been drilled in the area between Darmody-Riverhurst and Elbow quadrangle artesian areas and the relations between them are not known. The water sand in well 135, the most southerly of the Elbow quadrangle, was reported as 15 feet of clay and sand with only 3 to 4 feet of pure sand.

In the east part of the artesian area, water with 406·8 grains of total solids a gallon was found in well 76 at an elevation of 1,303 feet. No records of deep, soft water wells east of the Canadian National Railway from Davidson to Hanley were obtained. The westerly limit of the aquifer that supplies wells 16, 26, 71, 141, and 142 apparently lies between these wells and 21, 128, and 55, as the three latter wells obtained water at a depth of several hundred feet below that of the wells of the previously mentioned group. The water sand in well 102 is reported as "normal", but in wells 2, 82, 67, and 68 as shaly. This may indicate that the eastern limit of that particular aquifer is not far distant from these wells.

Information on the water-level in wells is generally less reliable than that as to total depth. In the case of flowing wells information as to the elevation of the piezometric surface is not usually available unless that surface is close to the ground surface. Owners of flowing wells Nos. 23, 55, 82, 114, and 140 report a decrease in flow, but this may be due to sanding up of the wells. Well 59 filled a 50-gallon drum in 308 seconds on July 18. On September 19 the same drum was filled in 320 seconds,

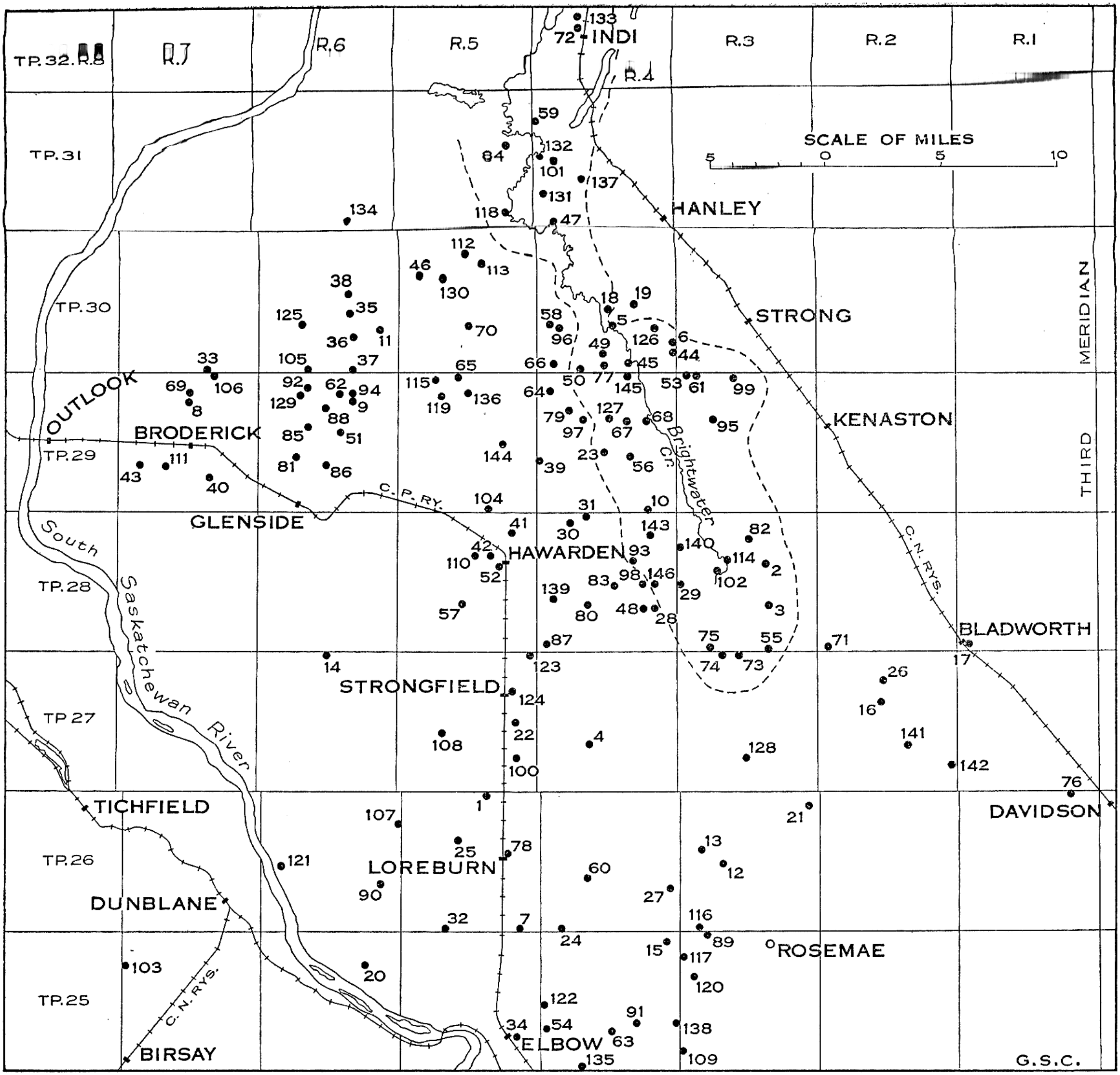


Figure 14. Index map showing positions of wells, eastern half of Elbow quadrangle, Saskatchewan. The approximate limit of the area of flowing wells is shown by a line of pecks.

showing a falling off of about a third of a gallon a minute in three months. Of the non-flowing wells in No. 18 the water-level is reported to have fallen 10 feet since 1910, in No. 105, 5 feet since 1925, in No. 128, 9 feet since 1929, in No. 121, 15 feet since 1916, in No. 97, drilled before 1914, about 14 feet. In well No. 78 no change of level is recorded since 1926. The owners of wells report changes in the character of the water as follows. In well No. 76 water was soft until a cavity was reached during drilling. In No. 16 water is harder than originally; in a well drilled northeast of Hawarden in the drift, the water changed from soft to hard. The aquifer for deep, hard water wells in this area being considered as probably in the glacial drift, the fact that the Woodman well 401 feet deep, 2½ miles southwest of well No. 76, a well opposite well 76, 300 feet deep, and one 5½ miles east of Kenaston, 220 feet deep, all obtained hard water, may possibly show a great thickness of drift in this area.

Character of the Water

Analyses of water made by the Division of Sanitation, Regina, give the total solids in grains a gallon and the relative abundance of the salts. For convenience in tabulating results numbers as under are assigned to the principal constituents: 1, sodium sulphate; 2, sodium carbonate; 3, sodium chloride; 4, calcium sulphate; 5, magnesium sulphate; 6, calcium chloride; 7, magnesium chloride; 8, calcium carbonate; 9, magnesium carbonate. The waters found have been grouped into various types according to the principal constituents and their relative abundance. These types are listed below, the individual numerals in the columns headed salts indicate the constituents present and their order of relative abundance, the first (left hand) figure indicating the most abundant constituent. Increasing hardness, increasing chloride content or decreasing sulphate content, are the chief factors on which the classification is based.

Type No.	Salts	Type No.	Salts	Type No.	Salts
1	123	21	213	31	32
2	12345	22	231	232	32617
3	12453	23	23	33	3672
4	13245	....	....	....	....
5	14253	....	....	....	....
6	14523	....	....	....	....

All wells in Rush Lake quadrangle are numbered consecutively, Nos. 1 to 100 being found in Summary Report 1931, part B, pages 69-71. Wells in Elbow quadrangle are in Table II, this report, and are indicated thus, 103-2.

Type 1 is the normal type in Darmody-Riverhurst area, and also, apparently, in the case of the soft water wells south of Beechy and the wells of the south half, at least, of Elbow quadrangle. The relative proportions of the three salts are known in well 62 to be about 5: 3: 1 and in well 85 to be 5: 2: 1. In wells 8 and 97 the proportions are about equal, no information regarding proportions in the waters represented by the remaining analyses is available. Water of this type, as of types 21, 22, 23, and 31, is absolutely soft.

Type 2 is slightly harder than No. 1, but the owners of wells yielding such water generally consider the water to be soft. It appears to be the normal type in the west half of Rush Lake quadrangle south of South Saskatchewan River and in the north half of the east half of Elbow quadrangle.

Type 6 is characteristic of the deep, hard water wells, the hard water flowing well area south of Beechy being of this type.

Water of type 21 occurs in Riverhurst district both in the town well No. 84 and in the Mammoth No. 1 well, *See* below. It seems to be a sub-marginal type. Water of the 23 type, with gas, is found in wells 125 and 142, in gas spring south of Beechy, and in well 120. It seems to be a marginal type.

Type 31 seems to be marginal in well 91 (mid-western limit of Darmody-Riverhurst area) and in wells 46 and 103-2 (northern limit of the Lucky Lake-Birsay group). The only well in type 32 is 76-2, which is 731 feet deep. Type 33 is practically entirely sodium chloride with only traces of other chlorides; it seems in wells 61 and 68 to mark the northeastern limits of Darmody Riverhurst area and in 135-2 to mark the mid-northern limit of the Elbow sheet artesian area.

The relation between the absence of sulphates and the presence of gas seems general over all the areas mapped and is in accord with the general idea of the reduction of sulphates by organic matter. Analyses of the water in the Mammoth No. 1 well near Riverhurst, made by the Chemical Department of the University of Saskatchewan, are of interest and are as follows.

Depth in feet	Elevation	Water	
		Total solids grains a gallon	Type
121	1,647	115·29	21
215	1,553	107·24	31
300	1,468	160·72	31
423–432	1,336–1,345	95·2	22
554–568	1,200–1,214	327·67	31

The sulphate at 423 to 432 feet is reported as only a trace. Of these waters the upper one is the only one that corresponds with that found in the Riverhurst town well. Gas was found in this well in small amounts at 118 feet and 225 to 245 feet, and a fair flow was found at 554 to 568 feet.

The deep, soft water of Rush Lake and Elbow quadrangles is suitable for drinking and is quite palatable if drunk at the temperature at which it issues from the well, usually 45 degrees to 48 degrees. It may have a slightly laxative effect when first used or when drunk in large amounts, but the well owners prefer it to the hard water after they have become accustomed to it. Cattle like it and it seems to suit them better than the hard water, the sodium chloride content rendering salt licks unnecessary. The water is too high in salts to be used for irrigation.

Comparison of Water Composition with That of Other Areas

Six analyses of water from the southern Alberta artesian area, arranged in order of increasing distance from the intake area, showed the first to be of type 21, the next three of type 23, and the last two of type 32. Total solids vary from 73·9 to 380·8 grains a gallon, the carbonate content remaining practically stationary and the chloride content increasing as distance from the intake area increases. In the well-known Dakota artesian basin the aquifer is the Dakota sandstone and possibly Lower Cretaceous sandstone. In parts of this basin two waters of different composition are found; of these the upper is comparatively soft, approximating type 2; the lower is hard and is probably harder than any water in the deep wells in Rush Lake and Elbow quadrangles. The average of many analyses shows the total solids in the soft and in the hard waters of the Dakota basin to be 152·28 and 141·33 grains a gallon respectively. The first is about 50 per cent higher than the average in Darmody-Riverhurst area, but in Elbow quadrangle artesian area the average total solid content of the deep, soft water wells, 160·2 grains a gallon, is slightly higher than that of the soft water of the Dakota basin.

TABLE I

List of Wells, Western Half of Rush Lake Sheet

Serial No.	Name of owner	Location: West 3rd meridian				Depth	Surface to water in feet	Elevation of		Analysis total solids, grains a gallon	Nature of water and remarks
		¼ Sec.	Sec.	Tp.	Range	Of well in feet		Surface in feet	Top of water sand in feet		
101	Austring, J. J.	SE.	14	19	13	315	200	2,346	2,031	....	Soft
102	Beckett, J.	SW.	32	18	13	325	100±	2,427	2,102	....	Soft
103	Beisel, F.	NE.	10	18	12	116	100	2,438	2,322	....	Soft
104	Bryce, W.	NE.	1	22	11	184	Flowing	2,104	1,920·5	....	Hard
105	Caffyn, H.	SE.	1	19	14	244	84	2,377	2,149	99·6	Soft. Type 2
106	Campbell, J. B.	NW.	8	19	13	232	130	2,374	2,142	....	
107	Cornelson, F. A.	SE.	5	19	10	169	100	2,489	2,320	63	Soft. Type 2
108	Couch, B. F.	SE.	32	23	8	540	350±	2,059	1,549	....	Soft
109	Couch, W. H.	NW.	32	23	8	508	290±	2,015	1,537	....	Soft
110	Covey, C.	SE.	31	21	11	480	90	2,264	1,784	....	Soft. Not in use
111	D'Armond, J.	SE.	10	22	10	525	60±	2,186	1,661	....	Soft
112	Douk's Livery	NE.	7	17	9	400	200	2,319	1,919	....	Soft, brown
113	Fisher, F.	NE	25	24	8	480	250	1,965	1,497	....	Soft
114	Fitzmorris, H.	NW.	33	21	10	400	5	2,080	1,680	....	Soft
115	Funk, H. F.	NE.	30	19	12	280	210	2,313	2,033	....	Slightly hard
116	Funk, J.	SE.	18	17	9	400	....	2,319	1,949	....	Soft
117	Funk, J. H.	SE.	30	19	12	216	....	2,272	2,056	....	Hard
118	Garies, F. J.	NW.	34	19	14	230	....	2,252	2,082	102·4	Soft. Type 2
119	Gemmill, F.	SE.	26	24	8	493	200±	1,930	1,457	....	Soft
120	Gimby, C. W.	NE.	21	21	9	422	320±	2,148	1,733	108·4	Soft. Type 23
121	Graham, Mrs.	SE.	13	24	8	434	200±	1,946	1,532	....	Soft
122	Hall, Mrs.	SW.	30	21	10	425	30	2,123	1,698	127·2	Soft. Type 1
123	Hargrave, G.	SE.	4	24	9	632	200±	2,048	1,436	....	Soft
124	Herbert Milling Co.	SW.	17	17	9	464	0	2,319±	1,855±	....	Soft, brown
125	Herbert town	SE.	18	17	9	320	160	2,319	1,999	90·2	Soft. Type 23, gas
126	Hermanson, Ed	NE.	26	19	13	240	....	2,291	2,051	....	Soft
127	Hoffman, Mrs.	SW.	22	18	10	216	196	2,527	2,311	....	Soft, brown
128	Hovdestad, D. E.	SE.	24	19	13	265	....	2,374	2,109	....	Fairly soft
129	Husey	SE.	28	19	14	233	140	2,296	2,063	....	Slightly hard
130	Jentzen	NE.	32	21	15	286	246	2,127	1,851	....	Soft
131	Johnson, E.	NE.	18	21	10	714	300	2,384	1,670	....	Soft. Not in use
132	Johnson, H.	SE.	32	21	8	640	Flowing	2,097	1,797	262·4	Hard. Type 6
133	Jones, A. B.	SW.	6	22	10	175	Flowing	2,095	1,920	150·6	Hard. Type 6
134	Kohler	NW.	27	19	14	160	140	2,287	2,127	....	Hard

135	Klassen, I.	SE.	18	17	9	425±	3	2,319	1,894±	....	Soft
136	Kolb, A. C.	SW.	33	18	10	189	79	2,481	2,292	....	Soft
137	Laidlaw, J.	NE.	2	19	13	198	35	2,329	2,131	....	Soft
138	Laidley Bros.	NW.	22	19	14	195±	180±	2,345	2,150±	....	Fairly soft
139	Livingstone, Mrs. E.	NW.	31	21	10	400	Flowing	2,107	1,707	....	Soft
140	Loitz, John	NE.	14	22	9	454	164	2,256	1,814	....	Hard
141	Lowe, W.	SW.	28	21	10	500	200	2,157	1,664	....	Soft
142	Lucky Lake town	SW.	25	23	9	642	150±	2,101	1,499	127·2	Soft. Type 23
143	McElhone, C. J.	SE.	12	22	12	172	Flowing	2,151	1,979	170	Hard. Type 6
144	McLean, A.	SW.	2	24	8	407	225±	1,927	1,535	....	Soft
145	Miner, Mrs. A.	SE.	10	23	9	640	12	2,178	1,538	....	Soft
146	Moen, J. O.	SW.	17	19	12	335	200±	2,406	2,071	....	Rather hard
147	Moen, P.	NW.	8	19	12	330	200±	2,412	2,082	....	Fairly hard
148	Neufeld, W. W.	NW.	10	19	10	165	100	2,476	2,311	....	Soft
149	Nicholson, Sam	SW.	9	24	9	675	152	2,043	1,337	....	Soft. Gas
150	Nickel	NW.	2	18	12	270	180	2,522	2,251	....	Soft
151	Nicodemus, A.	NW.	4	19	13	251	123	2,342	2,191	....	Soft
152	Olsen, G.	SW.	20	19	12	360	160±	2,358	1,998	....	Rather hard
153	Olsen, L. K.	NW.	18	19	12	315	200±	2,392	2,077	....	Rather hard
154	Peders, Gus.	NW.	21	21	9	426	320±	2,142	1,728	....	Soft
155	Pennar, J. C.	NE.	28	19	9	150	130	2,522	2,372	53·2	Soft. Type 2
156	Redekop, Mrs.	SW.	3	19	10	240	170	2,515	2,275	....	Soft
157	Renfennig	SE.	10	18	12	145	....	2,473	2,328	....	Soft
158	Rice	NE.	28	21	10	375	60	2,072	1,697	....	Soft
159	Rogers, R.	SE.	16	19	13	280	180	2,266	1,986	....	Soft
160	Rush Lake town	SW.	1	17	11	350	100±	2,335	1,985	....	Soft. Gas
161	Rush Lake Imperial	SE.	30	19	11	281	Flowing	1,762	1,481	....	Soft. Gas
162	Santy, D.	SW.	5	22	10	375	Flowing	2,082	1,707	....	Soft
163	Scott, J.	NW.	28	21	9	500	450	2,148	1,648	....	Soft. Gas
164	Seibert, A.	SE.	3	19	10	225	....	2,517	2,292	....	Soft
165	Stewart, F.	NE.	6	19	13	215±	....	2,388	2,173±	....	
166	Stewart, J. T.	SW.	8	19	13	250	150±	2,379	2,129	....	Rather hard
167	Weens	NW.	33	19	9	77	70	2,431	2,354	....	Soft

TABLE II

List of Wells, Eastern Half of Elbow Sheet

Serial No.	Name of owner	Location, West 3rd meridian: ¼ Sec.	Sec.	Tp.	Range	Depth of well in feet	Surface to water in feet	Elevation of: Surface in feet	Top of water sand in feet	Analysis total solids, grains a gallon	Nature of water and remarks
1	Aadland, L. G.	NE.	34	26	5	606	195±	2,034	1,448	....	Soft
2	Adams, A. J.	NE.	22	28	3	569	Flowing	1,905	1,356	....	Soft
3	Adams, A. J.	SE.	15	28	3	369	Flowing	1,909	1,540	....	Soft
4	Akre, Mrs.	SW.	16	27	4	604	89	1,999	1,410	....	Soft
5	Allen, G.	NW.	10	30	4	387	Flowing	1,811	1,424	....	Soft
6	Anderson, G.	SE.	12	30	4	329	Flowing	1,852	1,523	....	Soft
7	Anderson, J. H.	SW.	1	26	5	560	240	1,996	1,456	196·0	Soft
8	Anderson, T. J.	NW.	27	29	7	207	125	1,773	1,566	....	Hard
9	Anholt, C.	NW	26	29	6	352	200	1,836	1,484	....	Soft
10	Asay, C. R.	SE.	2	29	4	368	Flowing	1,863	1,495	....	Soft
11	Barron, G.	NW.	12	30	6	230	30	1,801	1,571	....	Soft
12	Bender, Mrs.	NE.	17	26	3	536	24	1,923	1,387	....	Soft
13	Bender, R.	NE.	19	26	3	540	32	1,930	1,390	....	Soft. Not in use
14	Beremik, J.	NW.	34	27	6	280	....	1,950	1,670	....	Fairly soft
15	Berndt, W.	NW.	36	25	4	275	100	1,922	1,647	....	Soft
16	Bishop, J.	NE.	21	27	2	318	98±	2,093	1,775	....	Soft
17	Bladworth town	NW.	6	28	1	400	....	2,077	1,677	99·4	Hard. Type 6
18	Bohrson, B.	NW.	15	30	4	265	20	1,820	1,555	....	Soft
19	Bohrson, E.	NW.	14	30	4	280	8	1,832	1,567	....	Soft
20	Boos, G. T.	NW.	26	25	6	343	210	1,873	1,530	....	Soft
21	Bristol, W.	SE.	36	26	3	667	3	1,935	1,288	....	Soft
22	Bristow, G.	NW.	13	27	5	566	140	2,012	1,458	....	Soft
23	Burnett, C.	NE.	16	29	4	314	Flowing	1,867	1,565	....	Soft
24	Bush, C.	SE.	6	26	4	653	250±	2,000	1,359	....	Soft
25	Buskirk, H. H.	NW.	21	26	5	700	190	2,025	1,345	....	Soft
26	Butler, N.	NE.	28	27	2	205	30	2,056	1,851	....	Soft
27	Carlson, O.	NE.	12	26	4	500	70	1,932	1,440	....	Soft
28	Cowan, F.	NW.	12	28	4	394	5	1,921	1,539	....	Soft
29	Croon, H. A.	NW.	18	28	3	360	Flowing	1,891	1,531	....	Soft
30	Devitt, A. H. and Sons	NW.	32	28	4	437	40	1,939	1,514	149·8	Soft
31	Devitt, J. S.	NW.	33	28	4	427	33	1,926	1,519	....	Soft
32	Dodds, J. R.	SE.	5	26	5	612	260±	1,987	1,387	....	Soft
33	Duncan Bros.	SE.	3	30	7	220	60	1,745	1,525	....	Soft
34	Elbow town	NE.	11	25	5	350	180	1,932	1,582	....	Soft. Not in use

35	Eliason, E. J.	NE.	15	30	6	500	....	1,829	1,329	....	Soft, gas
36	Eliason, E. J.	NW.	11	30	6	100	30±	1,807	1,707	....	Soft
37	Eliason, E. J.	SW.	2	30	6	240±	100±	1,816	1,576±	....	Slightly salty
38	Eliason, E. J.	SE.	22	30	6	430	150±	1,773	1,343	....	Salty
39	Feltis, A.	SW.	18	29	4	392	50	1,920	1,540	....	Soft
40	Findlater, G.	SE.	10	29	7	376	65	1,861	1,485	....	Soft
41	Fullmer, F. W.	SE.	35	28	5	646	140	1,986	1,352	....	Soft
42	Fullmer, F. W.	SE.	27	28	5	480	230±	2,008	1,540	....	Soft
43	Gordon Bros.	NE.	7	29	7	212	40	1,790	1,578	....	Fairly soft
44	Haight, C. E.	NE.	1	30	4	297	Flowing	1,844	1,547	....	Soft
45	Hamm, H. J.	SE.	3	30	4	296	Flowing	1,825	1,529	....	
46	Hamre, T. O.	SE.	30	30	5	960	65	1,770	810	....	Very salty
47	Hanley Development Co.	SE.	6	31	4	480	Flowing	1,765	1,285	....	Salty
	Hanley Development Co.	SE.	6	31	4	80	Flowing	1,765	1,685	....	Gas
48	Hanscam, H. W.	NE.	11	28	4	407	....	1,926	1,531	....	Soft
49	Haroldson, O. H.	NE.	4	30	4	298±	Flowing	1,831	1,533±	....	Soft
50	Haroldson, O. H.	SE.	5	30	4	450	Flowing	1,855	1,405	....	Soft. Not in use
51	Harrington, W.	SE.	22	29	6	310	90	1,827	1,517	....	Soft
52	Hawarden village	NW.	23	28	5	529	132	2,001	1,472	151·4	Soft. Type 1
53	Heath, F. B.	NW.	31	29	3	340	Flowing	1,883	1,543	....	Soft
54	Heese, P.	NW.	7	25	4	593	230	1,937	1,364	160·6	Soft. Type 1
55	Hodgins, E. C.	SE.	3	28	3	470	Flowing	1,920	1,450	....	Soft
56	Holm, H.	SW.	14	29	4	328	Flowing	1,853	1,540	....	Soft
57	Hudson, G.	SE.	16	28	5	540	160	2,020	1,492	149·6	Soft. Type 1
58	Hunter, W.	SE.	18	30	4	200	36	1,853	1,653	....	Soft
59	Jacobi, E. P.	NW.	30	31	4	204	Flowing	1,732	1,528	166·61	Soft. Type 2
60	Jacobson, O.	SW.	16	26	4	463	150	2,000	1,549	....	Soft
61	Jarvis, C.	NE.	31	29	3	402	Flowing	1,879	1,497	133·6	Soft. Type 2
62	Jentzen	SE.	34	29	6	318	40	1,816	1,498	....	Soft
63	Joel, J.	NW.	10	25	4	455	100	1,937	1,482	171·2	Soft. Type 1
64	Johnson, I.	SE.	31	29	4	350	9	1,863	1,525	....	Soft
65	Johnson, J. M.	NE.	33	29	5	900	30	1,865	965	....	Soft
66	Johnson, J. O.	SE.	6	30	4	398	16	1,861	1,463	....	Soft
67	Karst, S.	NE.	22	29	4	281	Flowing	1,850	1,589	....	Soft
68	Karst, S.	NE.	23	29	4	296	Flowing	1,839	1,563	....	Soft
69	Kelly, E. L.	SW.	34	29	7	222	50	1,765	1,543	....	Soft
70	Kidd, W. E.	SW.	15	30	5	48	29	1,828	1,780	115·8	Hard. Type 5
71	Kisaw, E.	SW.	6	28	2	300	50	2,043	1,743	....	
72	Koch, Mrs. L.	SW.	16	32	4	235	Flowing	1,781	1,546	146·2	Hard. Type 6
73	Lee, O. G.	NE.	33	27	3	496	Flowing	1,982	1,406	....	Soft
74	Lee, O. G.	NE.	32	27	3	403	Flowing	1,887	1,493	....	Soft
75	Lee, O. G.	SW.	5	28	3	486	Flowing	1,888	1,423	....	Soft
76	Lick, W. J.	NE.	35	26	1	731	100	2,034	1,303	406·8	Salty. Type 32
77	Loe, H. B.	SE.	4	30	4	320	Flowing	1,835	1,515	....	Soft
78	Loreburn Village	SW.	23	26	5	604	185	2,018	1,434	190·2	Soft. Type 1
79	Love	SW.	29	29	4	....	....	1,860	....	....	Soft

TABLE II—*Concluded*

List of Wells, Eastern Half of Elbow Sheet—Concluded

Serial No.	Name of owner	Location: West 3rd meridian, ¼ Sec.	Sec.	Tp.	Range	Depth of well in feet	Surface to water in feet	Elevation of surface in feet	Elevation of top of water sand in feet	Analysis total solids, grains a gallon	Nature of water and remarks
80	McEwen	SW.	16	28	4	454	70	1,963	1,521	....	Soft
81	McFee, J. R.	SE.	17	29	6	425	50	1,839	1,439	183·6	Soft. Type 4
82	McIntyre, A.	NW.	27	28	3	350	Flowing	1,892	1,562	....	Soft
83	McKay, H.	NW.	15	28	4	415	47±	1,936	1,533	....	Soft
84	McNeil, J. W.	NE.	23	31	5	204	Flowing	1,736	1,532	....	Soft
85	McPherson, A.	NW.	21	29	6	275	12	1,794	1,519	....	Soft
86	McPherson, D.	SE.	16	29	6	575	75	1,895	1,320	....	Soft
87	MacSindon	SW.	6	28	4	570	120	2,000	1,442	....	Soft
88	Marten, J.	SE.	28	29	6	235	40	1,809	1,574	....	Soft
89	Martens	NW.	32	25	3	240	230	1,916	1,676	....	Soft
90	Martens, J.	SW.	13	26	6	593	200	1,982	1,393	....	Soft
91	Martin, R.	SW.	14	25	4	375	75	1,932	1,557	....	Soft
92	Matheson	SW.	33	29	6	230	9	1,774	1,544	....	Fairly soft
93	Meyer, C. S.	NW.	23	28	4	325	Flowing	1,917	1,592	....	Soft
94	Miller, H. J.	SW.	35	29	6	357	20	1,835	1,478	....	Soft
95	Mills, J. E.	SE.	29	29	3	407	Flowing	1,932	1,537	....	Soft
96	Mireau, D.	NE.	7	30	4	330±	40±	1,842	1,512±	....	Soft
97	Mooney	NW.	21	29	4	333	2±	1,868	1,534	....	Soft
98	Nixon, J. A.	NE.	14	28	4	411	35±	1,926	1,527	....	Soft
99	Odell, S. A.	NW.	33	29	3	445	Flowing	1,935	1,490	156·4	Soft. Type 2
100	Olsen, M.	SW.	12	27	5	553	120±	2,017	1,484	....	Soft
101	Paulson, J.	NE.	18	31	4	312	Flowing	1,770	1,458	....	Soft
102	Peacock, G. W.	SE.	20	28	3	352	Flowing	1,870	1,538	....	Soft
103	Pearson, H.	NW.	30	25	7	565	250±	2,012	1,467	179	Soft. Type 31, gas
104	Petman, C.	SE.	3	29	5	642	140±	1,985	1,355	....	Soft
105	Pratt, A.	SW.	4	30	6	202	Flowing	1,760	1,558	....	Soft
106	Ramsey, T.	NW.	35	29	7	230	50	1,743	1,513	....	Soft
107	Reed, S.	NE.	25	26	6	436	160	2,006	1,590	....	Soft
108	Reinbrecht, A. P.	NE.	17	27	5	696	160±	2,029	1,353	....	Soft
109	Reynolds, R.	NW.	6	25	3	297	20	1,895	1,598	....	Soft
110	Robertson, K.	SW.	27	28	5	481	60	2,025	1,544	....	Soft
111	Ross, W.	NW.	9	29	7	263	60	1,820	1,557	....	Soft
112	Schwanbeck, A. R.	NE.	28	30	5	366	30	1,774	1,408	....	Salty. Gas
113	Schwanbeck, O.	NE.	27	30	5	121	....	....	....	....	Gas

114	Scubery, J. W.	NW.	21	28	3	320±	Flowing	1,865	1,545±	135·8	Soft
115	Seaverson, E.	NE.	32	29	5	240	20	1,849	1,609	....	Soft
116	Sheldon Farms	SE.	6	26	3	270±	260±	1,922	1,656±	....	Soft
117	Sheldon Farms	NW.	30	25	3	210±	200±	1,915	1,709±	....	Soft
118	Sheldon Farms	NE.	2	31	5	401	Flowing	1,750	1,349	....	Soft, gas
119	Sheldon Farms	NE.	29	29	5	626±	....	1,966	1,340±	....	Soft
120	Smith, W. A.	SE.	30	25	3	137	25	1,899	1,762	....	Soft
121	Sokolowsky, A. K.	NE.	18	26	6	347	47	1,785	1,438	....	
122	Southam, M. H.	NW.	18	25	4	535	225±	1,967	1,452	....	Soft
123	Strand, J.	NE.	36	27	5	620	140±	2,009	1,409	....	Soft
124	Strongfield Village	SE.	26	27	5	570	135±	2,015	1,465	183·4	Soft
125	Swainson, O.	SE.	17	30	6	400±	....	1,753	1,353±	....	Soft, salty
126	Syra, T.	NW.	12	30	4	359	Flowing	1,835	1,480	....	Soft
127	Tangeman	SW.	27	29	4	303	Flowing	1,861	1,558	....	Soft
128	Theobald, R. C.	SE.	9	27	3	560	3	1,923	1,383	....	Soft
129	Tomacet, F.	SE.	32	29	6	200	6	1,728	1,528	....	Soft
130	Treleaven, W. R.	NE.	20	30	5	186	4	1,772	1,590	....	Soft, gas
131	Turgeson Bros.	....	7	31	4	390	Flowing	1,762	1,372	....	Salty
132	Turgeson Bros.	SW.	19	31	4	227	Flowing	1,731	1,504	....	Soft
133	Turgeson, T.	NE.	17	32	4	263	Flowing	1,781	1,518	156·8	Hard
134	Tutton, G.	SW.	2	31	6	285	40	1,749	1,464	377·6	Salty. Type 33
135	United Grain Growers	SE.	5	25	4	463	60	1,882	1,429	163·8	Soft
136	Utigaard, T.	SW.	34	29	5	262	35	1,874	1,612	....	Soft
137	Waunsch, Mrs. E.	SW.	16	31	4	386	Flowing	1,802	1,416	....	Soft
138	Weens	SE.	13	25	4	240	40	1,901	1,661	161·8	Soft. Type 3
139	Wheeler, G.	SE.	18	28	4	565	100	1,979	1,426	....	Soft
140	White, C. F.	NW.	30	28	3	350	Flowing	1,871	1,533	....	Soft
141	Willner, H.	SE.	15	27	2	226	75±	2,055	1,829	....	Soft
142	Willner, Senior	SE.	12	27	2	230	100	2,063	1,833	....	
143	Wills, J. A.	SE.	35	28	4	248	Flowing	1,874	1,626	....	Soft
144	Yates, E.	NE.	14	29	5	600±	100	1,923	1,323±	....	Soft
145	Young, C. M.	NE.	34	29	4	300	Flowing	1,826	1,526	....	Soft
146	Zeman, J.	NW.	13	28	4	414	1	1,915	1,521	....	Soft

DEEP BORINGS IN THE PRAIRIE PROVINCES

By W. A. Johnston

(Geologist-in-Charge, Division of Pleistocene Geology, Water Supply, and Borings)

Borings made in search of oil and gas in the Prairie Provinces in 1932 were confined largely to Alberta. Through an arrangement with the Department of Lands and Mines, of the Government of the Province of Alberta, samples and well logs were received from the Petroleum and Natural Gas Division of that department. Samples from fifty-five wells, including nineteen shallow test holes, were received. These samples and logs of the wells are of considerable value in the study of the geology of Alberta by officers of the Geological Survey. They form permanent records which are available for re-examination in the light of new information obtained from time to time and afford a means of supplying information to companies prospecting for oil and gas in new fields. The logs of the wells also give information regarding the occurrence and character of underground water, a question of importance in many places where usable supplies of underground water for domestic and other purposes are difficult to obtain.

In Saskatchewan " seismic " tests were carried out in Dirt Hills area, which are said to have indicated that some favourable structural conditions occur, but no drilling has been done. The Petroleum Engineering Company carried on some test drilling for gas or oil in the vicinity of Hudson Bay Junction, and the Blackfoot Oil and Gas Development Company is reported to have commenced drilling near Wilcox. No samples from these wells were received and only a few from water wells.

The results of ground water investigations in the eastern part of Rush Lake sheet area, and in the eastern part of Elbow sheet area in southern Saskatchewan, by D. C. Maddox, are given in another part of this report. Results of the study by R. T. D. Wickenden of samples from some deep wells in Saskatchewan are given in the Trans. Roy. Soc. Canada, vol. XXVI, sec. IV (1932).

Drilling of the Manitou No. 2 well of the Commonwealth Petroleum, Limited, in Pembina Valley, southern Manitoba, furnished a remarkably good section, for the well started in the Upper Cretaceous and extended through to the Precambrian. Little was previously known regarding the character and thickness of the formations below the Upper Cretaceous in this part of Manitoba; the beds are not exposed and no other good well sections extending below the Cretaceous are available. The well samples were received from the drillers, Messrs. George W. Lea and N. C. Shaver, through the courtesy of Hon. E. Michener, President of the company. Examination of the samples was made by R. T. D. Wickenden and

F. J. Fraser of this division. Notes on the geological interpretation of the samples are by R. T. D. Wickenden. The well is on the valley flat of Pembina River and has an elevation of approximately 1,260 feet above sea-level.

Log of Commonwealth Petroleum Manitou No. 2

Location: L.S. 8, Sec. 26, Tp. 2, Range 9, W. 1st Mer.

Formations	Depth Feet	Lithology and colour	Acid		Remarks
			Cold	Hot	
Glacial drift	0– 20	Pebbles, brown and grey	0	5	
	20– 30	Clay, dark grey	2	2	
	30– 60	Missing	......	......	
	60– 80	Clay, medium grey	1	5	
	90– 100	Pebbles, brown and grey	1	4	
Boyne and Morden (Upper Cretaceous)	100– 140	Missing	......	......	
	140– 180	Shale, dark grey	2	3	
	180– 200	Missing	......	......	
	200– 300	Shale, dark grey	2	2	Some samples vary a little in acid reaction
	300– 320	Missing	......	......	
	320– 440	Shale, dark grey	1	2	Some samples vary a little in acid reaction
Assiniboine and Keld (Upper Cretaceous)	440– 450	Shale, dark grey	3	4	
	450– 460	Limestone, dark grey	5	6	
	460– 500	Shale, dark grey	4	5	
	500– 600	Shale, dark grey	3	4	Some samples vary a little in acid reaction
Ashville (Upper Cretaceous)	600– 670	Shale, dark grey	1	2	
	670– 700	Missing	......	......	
	700– 705	Shale, medium grey	0	0	
Basal Beds (Upper Cretaceous)	705– 735	Sand, light grey to white	0	0	Coarse grained, sub-angular with occasional rounded grain
Lower Cretaceous?	738– 755	Shale, medium grey	0	0	Some pyrite
	755– 764	Shale, light grey	1	1	
	764– 780	Shale, light grey and reddish brown	1	1	
	780– 820	Shale, light grey	1	1	
	820– 855	Shale, medium grey	1	1	
	855– 860	Shale, reddish brown and grey	1	1	
	860– 870	Shale, medium grey	1	1	
	870– 880	Shale, reddish brown	1	1	
	880– 890	Shale, medium grey	1	1	
	890– 895	Shale, reddish brown and grey	1	1	
	895– 900	Sand, light grey to white	1	1	
	900– 970	Shale, medium grey	1	3	Samples vary a little in the acid reaction

Log of Commonwealth Petroleum Manitou No. 2—Continued

Location: L.S. 8, Sec. 26, Tp. 2, Range 9, W. 1st Mer.

Formations	Depth Feet	Lithology and colour	Acid Cold	Acid Hot	Remarks
Jurassic	970–1,090	Shale, varigated reddish brown, green, white, and yellow	3	4	Some samples vary a little from this in the acid reaction, some gypsum
	1,090–1,120	Shale, light grey and white	2	4	Some gypsum
Devonian	1,120–1,140	Dolomite, light grey	1	6	
	1,140–1,200	Shale, light grey	2	3	
	1,200–1,210	Missing	.....	.....	
	1,210–1,220	Shale, cream colour	1	3	
	1,220–1,270	Shale, reddish brown and white	1	3	Much gypsum
	1,270–1,280	Shale, grey and reddish brown	1	3	
	1,280–1,390	Shale, reddish brown	1	3	
	1,390–1,400	Sand, quartz, reddish stain	1	4	Medium to coarse grains, well rounded
	1,400–1,430	Shale, reddish brown	4	6	
Silurian	1,430–1,450	Limestone, dirty cream	6	6	
	1,450–1,470	Dolomite, reddish brown	3	6	
	1,470–1,490	Shale, brick red	2	6	
	1,490–1,500	Dolomite	3	6	
	1,500–1,510	Limestone, pinkish	5	6	
	1,510–1,530	Limestone, light grey	5	6	
	1,530–1,540	Dolomite, pink	2	7	
	1,540–1,550	Dolomite, cream	2	7	
	1,550–1,570	Dolomite, pink	2	7	
	1,570–1,580	Limestone, cream colour	5	7	
	1,590	Dolomite, pink	2	7	
	1,595	Limestone, pink	5	7	
	1,600	Dolomite, pink	2	7	
	1,600–1,620	Limestone, cream colour	5	7	
	1,630	Limestone, pink	5	7	
	1,635–1,705	Dolomite, pink	1	6	
	1,705–1,790	Dolomite, cream colour	1	6	
	1,790–1,800	Shale, brick red, and sand	.....	.....	Sand grains well rounded
	1,800–1,850	Dolomite, pink	1	6	
	1,850–1,870	Dolomite, brown and grey	1	6	
	1,870–1,890	Sandy dolomite, grey	3	6	
	1,890–1,900	Dolomitic sandstone	3	6	
Stony Mountain (Ordovician)	1,900–1,910	Sandy dolomite and calcareous shale	3	6	Sand grains well rounded
	1,925–1,933	Limestone, medium grey	4	6	Sandy with some fossils
	1,935	Sand, light grey	1	2	
	1,935–1,940	Missing	.....	.....	
	1,940–1,980	Dolomite, light grey	3	5	
	1,980–2,000	Dolomite, medium grey	1	6	
	2,000–2,017	Dolomite, buff and grey	1	6	

Log of Commonwealth Petroleum Manitou No. 2—Concluded

Location: L.S. 8, Sec. 26, Tp. 2, Range 9, W. 1st Mer.

Formations	Depth Feet	Lithology and colour	Acid Cold	Acid Hot	Remarks
Red River............ (Ordovician)	2,030	Dolomite, cream..........	1	6	
	2,040	Dolomite, medium grey..	1	6	
	2,045	Dolomite, buff and grey..	1	6	
	2,055	Dolomite, light buff......	1	6	
	2,060–2,080	Dolomite, cream..........	1	4	
	2,080–2,130	Limestone, cream.........	4	6	
	2,145–2,290	Limestone, cream.........	5	6	Some chert at 2,260-88 feet
	2,290–2,340	Dolomite, cream..........	2	7	
	2,350	Calcareous mud...........	6	7	
	2,360	Limestone, cream colour..	6	7	
	2,370	Calcareous mud...........	6	6	
	2,380	Dolomitic mud...........	3	7	
	2,390	Calcareous mud...........	5	7	
	2,400	Limestone, cream colour..	5	7	
	2,410–2,430	Dolomitic mud, light grey	3	4	
	2,440	Calcareous mud...........	5	6	
	2,450	Dolomitic mud...........	1	4	
	2,460–2,480	Calcareous mud...........	4	6	
Winnipeg............. (Ordovician)	2,490–2,600	Shale, dull green..........	0	0	The top 30 feet somewhat calcareous
	2,600–2,602	Sand, quartz.............	0	0	Medium to coarse grained. Sub-angular and rounded
	2,610–2,612	"Arkose," green-grey.....	0	0	
	2,612–2,613	Shale, dull green..........	......	......	
Precambrian..........	2,615–2,639	"Granite," brown stained.	......	......	Much decomposed and rusty. Much biotite

The stratigraphic position of the beds from 738 to 900 feet suggests that they are Lower Cretaceous in age, but no definite evidence of their age was found. The sand at 895 to 900 feet evidently forms the basal part of the series.

There is good evidence for placing in the Jurassic the horizons represented by the samples from 900 to 1,120 feet; fragments of marine shells and Jurassic foraminifera appear in the samples from the upper 80 feet of this group; freshwater fossils which belong to genera not known to occur in beds that are older than the Jurassic were found in the samples from the variegated shales between 980 and 1,120 feet.

The sample from 1,910 feet contained the following microfossils: *Scetropora facila* Ulrich, *Batostoma manitobense* (?) Ulrich, *Primitia parallela* Ulrich. These species, as described by Ulrich, are from the Stony Mountain formation. No occurrences of these species at any other horizon in the Palæozoic of Manitoba are known.

A notable feature of the well is the occurrence of four sands below the basal sandstone of the Upper Cretaceous and above the Winnipeg sandstone. Gas was reported from 491 feet from calcareous shale and at 705 feet from the basal sandstone of the Upper Cretaceous. Salt water under considerable pressure was struck in the lower sandy horizons. A sample of the water from a depth of 2,636 feet, according to an analysis by F. J. Fraser of this division, has a specific gravity of 1·04 and contains 6·8 per cent solids. Sodium, calcium, chlorides, and sulphates are present in the water, and the residue after evaporation effervesces with acid.

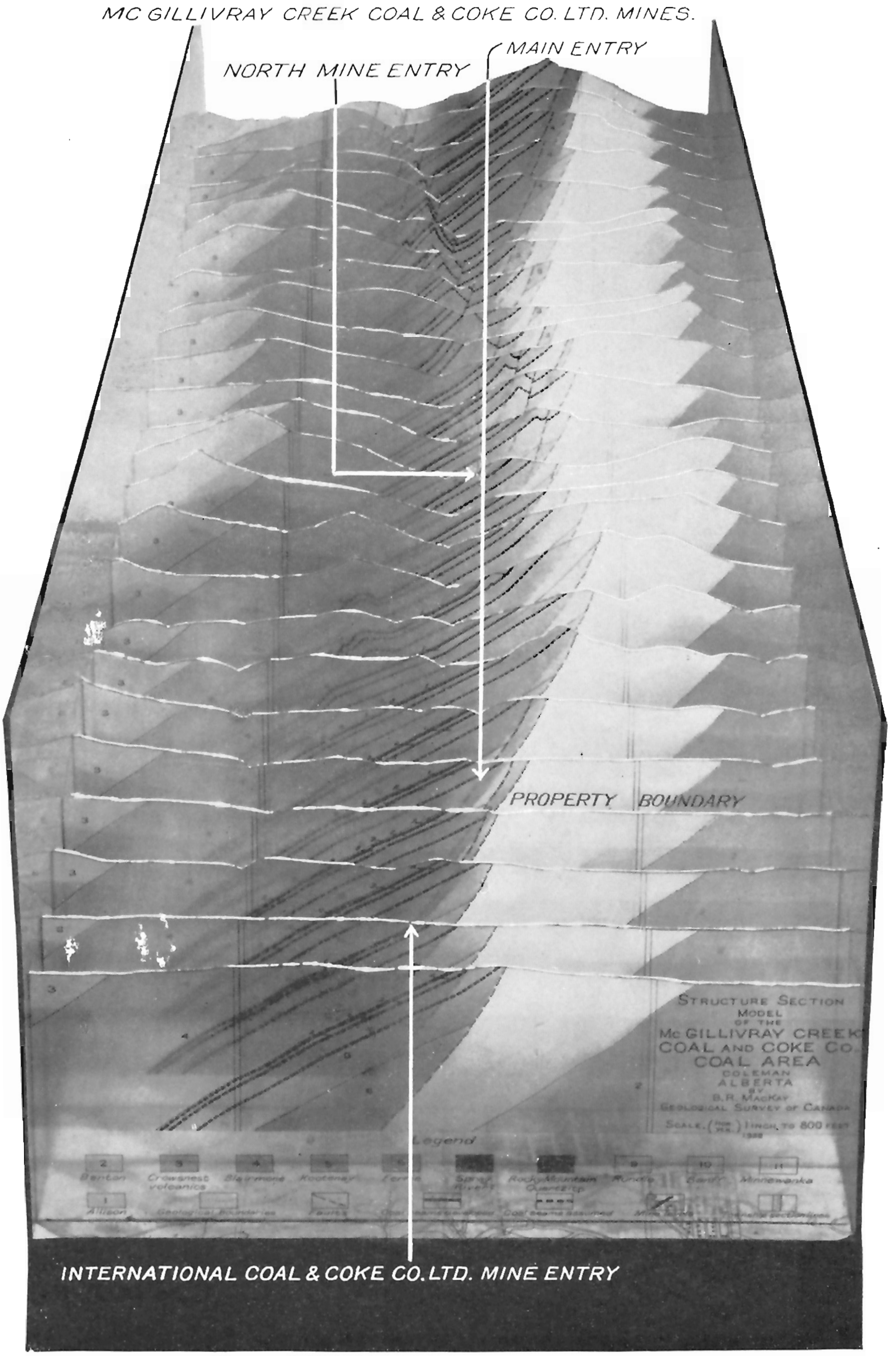
OTHER FIELD WORK

L. S. Russell. Mr. Russell commenced geological mapping and investigation of the Peace River 8-mile map-area.

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

60482—7

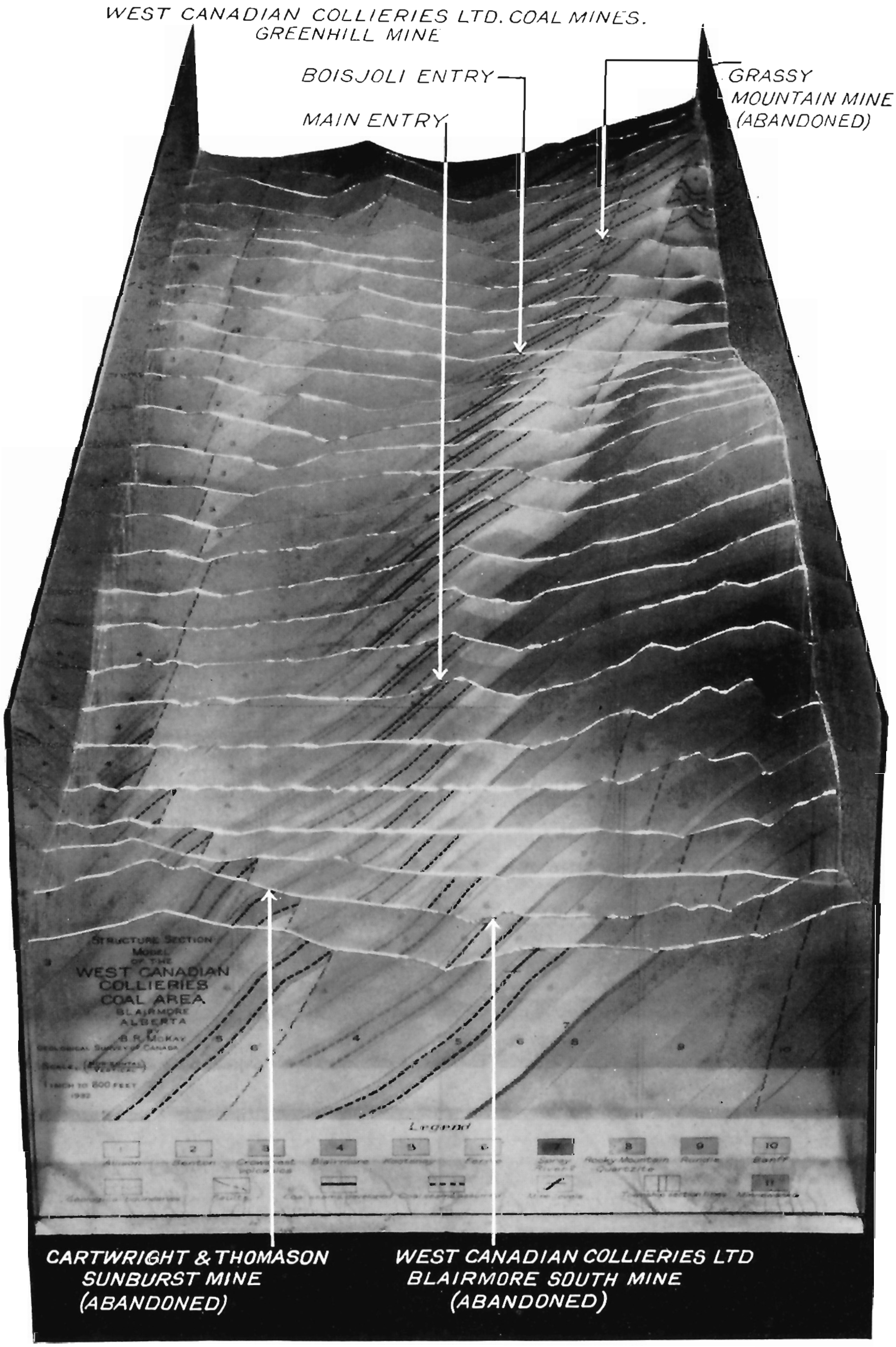
PLATE I



Model of north coal area, Coleman, Alberta. (Pages 26, 48, 49.)

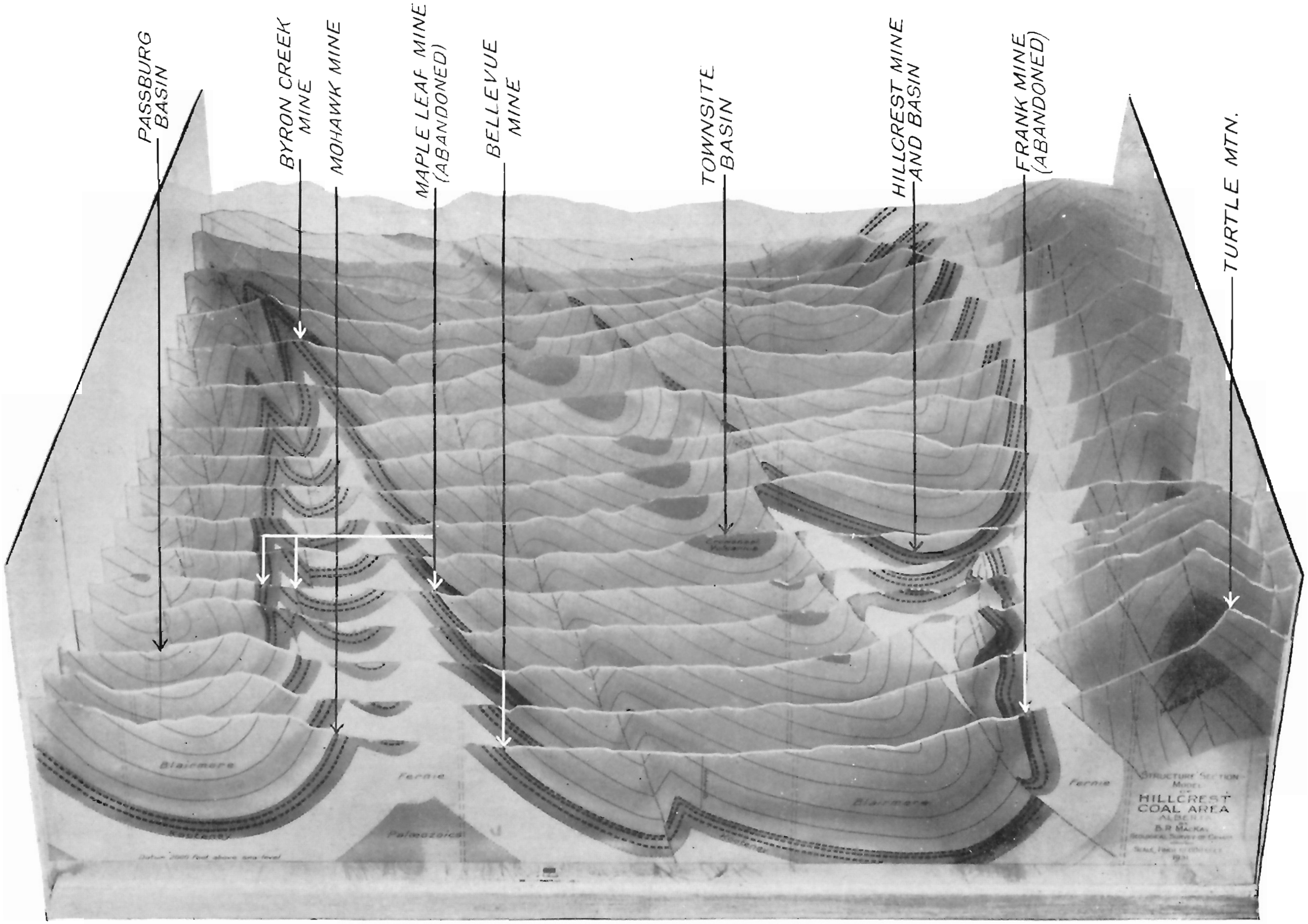
60482 -8

PLATE II



Model of Blairmore coal area, Alberta. (Pages 26, 51.)

PLATE III



Model of Hillcrest coal area, Alberta. (Pages 26, 34, 57, 61, 63.)

INDEX

The annual Summary Report of the Geological Survey is issued in parts, referring to particular subjects or districts. This year there are five parts, AI, AII, 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.