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W. H. COLLINS, DIRECTOR

Summary Report, 1923, Part B

CONTENTS

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SUMMARY REPORT, 1923, PART B

MACKENZIE RIVER AREA, DISTRICT OF MACKENZIE, NORTH-WEST TERRITORIES

By G. S. Hume

CONTENTS

Illustrations

GENERAL STATEMENT

The summer of 1923 was spent by the writer in continuing the investigation of the geology and oil resources of the Mackenzie basin begun in 1921. The route followed to Mackenzie river was by the Alberta and Great Waterways railway to Waterways and thence by canoe via Athabaska and Slave rivers to Great Slave lake. The ice on Great Slave lake did not permit crossing until June 22 and, for a few days subsequent to this, heavy ice floes filled Mackenzie river as far north as Mills lake. At Wrigley, W. A. Kelly took charge of a sub-party, composed of J. O. G. Sanderson as student assistant, W. N. McDonald, and J. L. Lafond, and investigated the Dahadinni-Redstone Rivers area on the west side of the Mackenzie. It had been the intention to ascend Gravel river, and to study the complete section from east to west, afforded by the mountains along this river; but Gravel river was in flood in July and cut banks on both sides made the tracking of canoes impossible. This expedition was, therefore, abandoned and instead the geology along Little Bear river, north of Norman, was studied and mapped. A base map was kindly supplied by the Imperial Oil Company, Limited, from a stadia survey by T. A. Link and W. N. McDonald. Later in the season the sub-party under Mr. Kelly joined the main party and a survey was made of the Brackett River-Whitefish Lake area. The writer kept in touch as far as possible with drilling operations in the Norman area, and a reconnaissance study was afterwards made of the area along the Mackenzie from Carcajou river to Good Hope.

DESCRIPTION OF AREAS

NORMAN OIL FIELDS

During 1923 two wells were completed in the Norman oil fields. The Imperial Oil Company's well on Bear island, Mackenzie river, about 2 miles from their Discovery or No. 1 well, was drilled to a depth of 2,304 feet, the hole from 1,948 feet to the bottom being in Middle Devonian limestone. At about 2,060 feet salt water was encountered, the flow increasing as the hole was deepened. The only showing of oil of any account was a small flow (possibly two barrels per day) at the contact between the Upper and Middle Devonian. The possibilities of this horizon were discussed[1] in the Summary Report for 1922 and the results from the drilling verify the predictions then made.

The Imperial Oil Company's " C " Camp well on the west side of the Mackenzie[2] was drilled to a depth of over 3,000 feet, the contact of the Upper and Middle Devonian being reached at approximately 2,950 feet. No oil was found.

Discovery well (No. 1), on the east side of the Mackenzie, was cleaned out and deepened slightly, with the result that an increased flow of oil was obtained, probably amounting to 100 barrels per day.

Since both Bear Island and " C " Camp wells are down the dip from Discovery well, the results of drilling in this direction are not encouraging unless wells are located on minor undulations of the flank of the anticline, or on folds in the syncline which extends from Norman range on the east to Carcajou range on the west. Such folds are believed to exist, but their location is somewhat difficult on account of the limited number of rock exposures outside the mountains. The best tests of these structures would be obtained where the Bosworth formation of Upper Devonian age is covered with Cretaceous shales.

A summary of conditions in the Norman oil fields was published in the Summary Report[3] for 1922.

DAHADINNI-REDSTONE RIVERS AREA

General Statement. This area, as previously mentioned, was examined by a sub-party under the direction of W. A. Kelly. It was found impossible to ascend either the Dahadinni or the Redstone by canoe; but, under the guidance of W. Haywood, who has spent several years trapping and prospecting in this country, an overland trip was made to the mountains to the west. A sketch map was made by Mr. Haywood and verified so far as possible by Mr. Kelly and party, a pace and compass traverse being carried from the Mackenzie to mount Haywood, one of the summits of the front range of mountains on Dahadinni river, 25 miles west of the Mackenzie. From points on this trail side trips were made to points where outcrops were seen, one trip being made as far north as Redstone river where Cretaceous rocks are exposed on cut banks of the river valley.

Topography. From the summit of mount Haywood, which is about 1,500 feet above Mackenzie river, the Dahadinni valley can be seen to its junction with the Mackenzie. The valley is broad and is bordered by

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1 Geol. Surv., Can., Sum. Rept., 1922, pt. B, p. 62.

2 For location *see* Map 1977, Geol. Surv., Can., Sum. Rept., 1922, pt. B.

3 Geol. Surv., Can., Sum. Rept., 1912, pt. B, p. 63.

gently sloping ridges, but there are no prominent topographic features, although a fairly large tributary from the south can be traced for many miles by the sharply cut banks bordering it.

North of mount Haywood, on the same ridge but with lower relief, eastward-facing limestone cliffs form a prominent bluff, and across Dahadinni river to the south, Dahadinni mountain is the most prominent topographic feature. Mount Haywood ridge stands well out in front of the much higher and more rugged main range of mountains lying about 20 miles to the west. The divide between the Redstone and Dahadinni lies a few miles west of Mount Haywood ridge and is in places flat and poorly defined, with numerous lakes and sloughs.

As observed from mount Haywood, Dahadinni river is divided for long stretches into a number of small, shallow channels flowing through a wide gravel flat. The same characteristic was found to be true in the case of Redstone river where it was crossed in a traverse about 25 miles from the Mackenzie. Keele noted a similar condition on Gravel river after it leaves the mountains.

Redstone river issues from the mountains through a large valley which in direction and position would much more logically belong to Dahadinni river. For many miles after leaving the mountains the Redstone flows almost directly northward, when it again turns northeast to the Mackenzie. Between the point where the Redstone makes the northward turn, and the farthest westward tributary of the Dahadinni, only a narrow ridge separates the two drainage systems. The northward-flowing branch of the Redstone has evidently been able to cut back until it has intercepted the drainage from the mountains and thus beheaded the Dahadinni. This would also explain the wide valley of the Dahadinni to which attention has already been called. At the northward turn the Redstone has cut a deep canyon with precipitous sides. The main source of drainage for Dahadinni river is the country to the south, the main fork draining an area northwest of Wrigley.

Geology. Except for mount Haywood and Dahadinni mountain the country between the Mackenzie and the high mountains to the west is covered by muskeg and forest with few rock exposures. Mount Haywood is a sharp, asymmetrical fold, the axial plane of which dips to the west and trends in a north-south direction. On this many minor folds are superimposed, resulting in jointing which in places almost obscures the bedding. Middle Devonian fossiliferous limestone occurs on the summit of the mountain and in the bluff to the north. Farther to the northeast at Cloverleaf lake and on Redstone river Cretaceous rocks occur. At Cloverleaf lake these rocks consist of conglomerate and sandstone, the former containing small pebbles of quartzites and chert in a matrix of sand.

It is known from other regional studies that the base of the Cretaceous consists of sandstones with thin layers of conglomerate, whereas the higher beds are shale. The outcrop on the east side of Cloverleaf lake is evidently near the base of the Cretaceous, and, because strata higher than the Simpson (Fort Creek) shale of Upper Devonian age occur in the vicinity of Wrigley and again north of Bear rock near Norman, it is inferred that strata of a similar age occur in the Dahadinni-Redstone area. Such strata are the equivalent of the Bosworth formation in the Norman-Carcajou area, but, as the Devonian is separated from the Cretaceous by an erosional unconformity, there is a possibility that the highest part of the Devonian has been eroded from the Dahadinni-Redstone area. It is believed by the writer that such a condition for this area is unlikely.

On the west bank of the Mackenzie, north of Dahadinni river, Cretaceous shales occur, the sequence being what would be expected from easterly dips. It is thought there are minor undulations in the Cretaceous between mount Haywood and the Mackenzie, but the data are very unsatisfactory, no folds having been actually located. The excessive amount of deformation that has taken place in mount Haywood, an isolated mountain well in front of the main range of mountains farther west, implies that other warpings of a smaller nature may occur east of mount Haywood, especially as the Mount Clark range to the east of the Mackenzie shows much deformation.

REDSTONE AND SALINE RIVERS AREA

General Statement. As will be noted from the accompanying map (No. 2022) Williams has Cambrian rocks not far from the Mackenzie on Saline river. Cretaceous occurs between the Dahadinni and the Redstone and again on the ridge which crosses the Redstone about 12 to 15 miles from its mouth. Nothing is known of the structure of the area between the Cretaceous rocks of this ridge and the Cambrian on Saline river. Elsewhere in Mackenzie district Cretaceous rests on Devonian with an erosional unconformity separating the two, but with the attitude of the rocks almost the same above and below the erosional unconformity. Although it might be inferred from the distribution of outcrops, as shown on Map 2022, that Cretaceous rocks rest on Cambrian, this is improbable because it would mean an unconformity of a much greater magnitude than observed elsewhere. Sufficient data have not yet been obtained to give a satisfactory interpretation of the relationship of these rocks.

LITTLE BEAR RIVER AREA

Topography. Little Bear river enters the Mackenzie from the west a short distance below Bear rock. It is a river that fluctuates much in volume, even a moderate rain in the mountains to the west causing it to flood. Mr. T. Link and Mr. W. N. McDonald, who surveyed part of this river for the Imperial Oil Company, report a rise of 6 feet in the water during one night.

At low water the river contains clear water which flows over gravel and boulder bars, and is, in many places, too shallow to float a canoe. After rain, the river rushes like a mountain torrent, completely filling the canyon located about 40 miles from the mouth, and carrying in suspension a great amount of sediment. At such times the small riffles become completely drowned out or the boulder bars may form rapids.

In the gorge-like part of the river are several well-developed meanders, now incised to a depth of 200 to 300 feet below the level of the plateau, and which must antedate the last uplift.

Geology. Except near the mouth, where the river cuts through high gravel and clay banks, the exposures along the river are of Cretaceous rocks. Nothing is known of the character of the rocks, however, beyond the large bend 50 miles above the mouth. The Cretaceous consists of a lower series of sandstones containing *Inoceramus* (Plate I A) and in places coal seams, overlain by a higher series of fine, black, fissile marine

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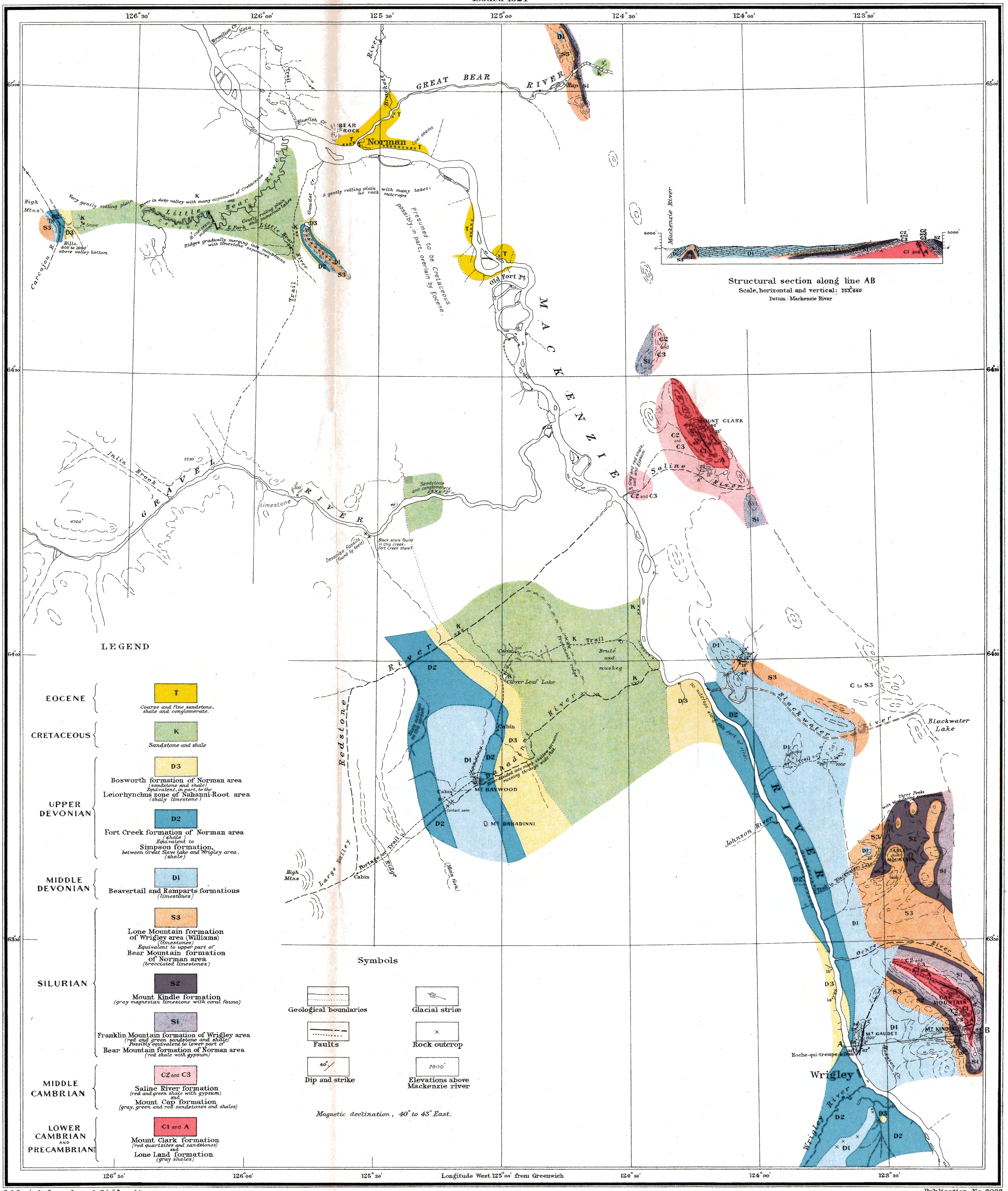

C-O. Senécal, Geographer and Chief Draughtsman.
J.O. Fortin, Draughtsman.

Publication No. 2022

MACKENZIE RIVER, BETWEEN WRIGLEY AND NORMAN, DISTRICT OF MACKENZIE.

Scale of Miles
10 5 0 10 20

SOURCES OF INFORMATION
Geology by M.Y. Williams, 1922, and G.S. Hume, 1923.
Base-map from surveys by M.Y. Williams, 1922, G.S. Hume, 1923, the Topographical Surveys Branch, Department of the Interior, 1921, 1922, and the Imperial Oil Company, 1921.
Map compilation by J.O. Fortin.

To accompany report by G.S. Hume, in Summary Report, Part B, 1923.

shales. The greatest thickness of coal observed was 18 feet, but for considerable distances along the river 6 to 10 feet of coal of possibly the same seam are exposed. Where the coal outcrops the dip of the rocks is very gentle, although downstream this increases slightly. On exposure to the atmosphere the coal disintegrates very slowly. In late summer large pieces of coal observed near the mouth of the river were still solid, although they had evidently been transported there by the last spring flood. No analysis of the coal has been made, but from its appearance it is apparently superior to that found in the Tertiary deposits along the Mackenzie south of Norman.

BRACKETT RIVER-WHITEFISH LAKE AREA

General Statement. Whitefish Lake area is easily reached by canoe from Norman. The lower half of Brackett river is marked by numerous small riffles and boulder rapids and through this distance it is necessary to track canoes. The upper half, however, as well as the whole length of Loche river, has a gentle current against which canoes can be paddled with ease. In fact the Indians take small boats to Whitefish lake for fishing purposes, although some difficulty must be encountered with these on the lower part of Brackett lake and just at the entrance to Whitefish lake. In a dry season Brackett river becomes quite shallow over the riffles, and weeds grow over extensive areas of Brackett lake, but in a rainy season both lake and river are much higher throughout the summer and no difficulty would be encountered with a small boat other than the labour of getting through the swift water in the lower part of Brackett river. However, this route has been used so much that there is a good tracking path for most of the distance where tracking is necessary. From Norman to Good Hope there is a winter trail via Whitefish lake and the chain of lakes to the north, but this trail is not used for summer travel.

Whitefish lake and surrounding territory are much used by the Indians as fishing and hunting grounds. The lake abounds in whitefish, inconnu, bluefish (grayling), lake trout, and other fish. The whitefish and bluefish average 5 to 6 pounds. Inconnu and trout of fifteen pounds are not rare, but the average is about 8 pounds. The marshes between Whitefish and Loche lakes, and also around Brackett lake, form a favourable breeding ground for ducks and in the autumn are frequented by large flocks of geese. Of the large game, moose and bear were seen by the writer, but the moose are not very plentiful.

Topography. Brackett river enters Great Bear river from the north about 8 miles above the Mackenzie, bringing down, especially in flood, a considerable volume of sediment-laden water which is in sharp contrast with the clear blue water of Great Bear river. The drainage basin which finds its outlet in Brackett river extends over many square miles between the Mount Charles range of mountains on the east and the Norman or Discovery range on the west, and from Great Bear river on the south to the watershed of Hare Indian river on the north, a distance of 60 miles. Most of this country between the mountains is at a low elevation, especially in the vicinity of Brackett lake. Brackett river, about 25 miles long, drains Brackett lake, which in turn is fed by Loche river and tributaries. The current of Loche river is slow, but the river is deep and the channel has steep sides. Its main supply of water is from Whitefish

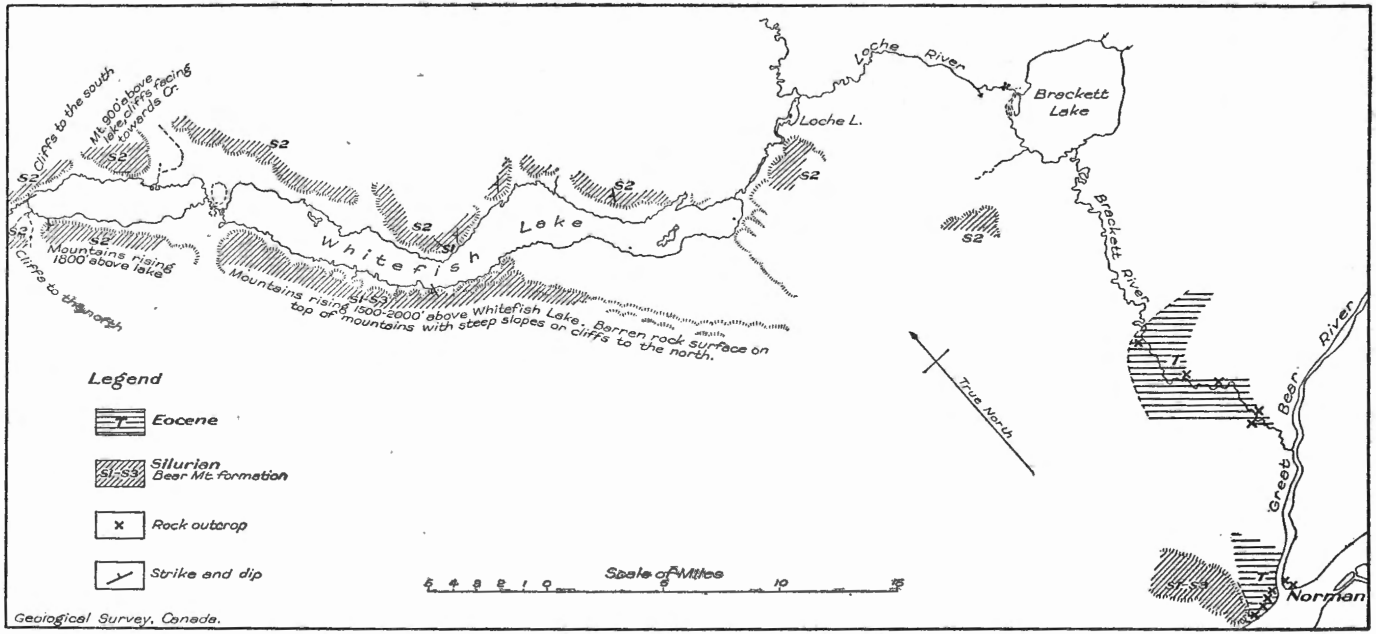

FIGURE. 1. Geology along Brackett river and Whitefish lake, district of Mackenzie.

lake, about 22 miles long and bounded on the east by wooded hills rising 1,000 feet above the lake, and on the west by a continuous chain of mountains with barren rock surfaces rising over 2,000 feet. At its northern end a small, sluggish stream connects it with a shallower lake about 8 miles long, also bounded on the east and west by mountains. The valley north of the lake is bounded by cliffs less than 2 miles apart, the whole suggesting an old river valley. The country between the cliffs is low and dotted with numerous lakes, a 10-mile divide separating the upper lake of the Whitefish-Brackett River system from the first lake that drains north to Hare Indian river.

Geology. At the mouth of Brackett river on the south side of Great Bear river are cut banks exposing Eocene deposits. These deposits can be traced for some distance up Brackett river, but beyond Brackett lake no rocks are exposed. Three and a half miles southwest of Brackett lake a hill 1,450 feet high exposes rock of Silurian age believed to be the middle member of the Bear Mountain formation. On the mountains bordering Whitefish lake and the lake to the north of it, only Silurian rocks were encountered, although in various parts of this area almost the whole section of the Bear Mountain formation is exposed. This consists at the top of massive brecciated beds forming the summits of some of the high mountains, as on Bear rock, and, below, hard, well-bedded limestone believed to correspond to limestones on mount Charles included by Williams in the Mount Kindle formation. At one place part of this series of limestones contained, as it does on mount Charles, considerable chert. Below this limestone series and well exposed about midway along the east side of Whitefish lake are thin-bedded limestones, some quite shaly and of a greenish colour. At several places on the west side of the lake, the red beds similar to those at the base of Bear rock are exposed, and in one instance the top of these red beds was 300 feet above the lake.

Oil Possibilities. The primary object of the trip to Brackett and Whitefish lakes was to discover whether the reports of oil seepages for this area indicated possibilities of commercial supplies. The reported oil seepages were not seen, but in several places iron stain which often gives an iridescence on the surface of water and superficially resembles a thin coating of oil was found on small springs. These have undoubtedly been mistaken for oil seepages and from the character of the rocks no oil can be expected.

CORRELATION OF FORMATIONS IN MACKENZIE RIVER BASIN

General Statement. Owing to the extent of the area examined in the Mackenzie district, measuring 600 miles north from Great Slave lake, considerable differences of sedimentation were found in different areas, and as a result mapping units or formations adopted by one investigator for one area do not exactly correspond to mapping units adopted by another investigator for another area. For this reason no final correlation can be made until a detailed faunal study has been completed, but in the absence of this it is thought a useful purpose will be served by bringing together the known facts into a tentative correlation, even though slight discrepancies may later be found.

Correlation Table

	[1] Great Slave Lake area	[2] Providence-Simpson area	[3] Nahanni-Root River area	[4] Franklin Mountain area	[5] Norman-Carcajou Mountain area	[6] Redstone-Dahadinni area	Remarks
Pleistocene			Sand, gravel, etc.	Boulder clay, sand, gravel 200 feet	Boulder clay, sand, gravel, etc., 250 feet	Boulder clay, sand, gravel, etc.	
Tertiary					Eocene		
Cretaceous	Shales	Mountain Shale	None present		Sandstone and shale, 500–1,000 feet	Sandstone and shale	
Upper Devonian	Hay River limestone 300 feet Hay River shale 400 feet	Hay River beds 700 feet	Shale zone 100 feet *Athyris angelica* zone 200 feet {Shale zone 1,000–1,200 feet *Leiorhynchus* zone 800–1,100 feet}		Bosworth sandstone and shale 1,600 feet	Bosworth (assumed to be present, none exposed)	
	Simpson shale 250 feet	Simpson shale 150 feet	Simpson shale 1,000 feet	Simpson shale 1,000 feet	Fort Creek shale 1,300 feet	Fort Creek shale	
Middle Devonian	Slave Point limestone 200 feet Presqu'île dolomite 375 feet Pine Point limestone 595 feet	Pine Point limestone 100 feet Horn River shale 100 feet	Limestone and dolomite .. } 2,500 feet	Limestones 2,000 feet	Beavertail limestone Ramparts limestone } 700 feet	Limestones	
Silurian	Fitzgerald dolomite 275 feet (Cephalopods have Guelph affinities. Not correlated with Silurian of Mackenzie)		Lone Mountain dolomite (Kindle) (Corals) } 2,500 feet	Lone Mountain dolomite 530–1,600 feet Mount Kindle formation (corals) 560 feet Franklin Mountain formation 500–1,000 feet	Brecciated limestone and dolomite 400-450 feet Limestones 1,000 feet Shales (no fossils) } [7] Bear Mountain formation	Brecciated limestone and dolomite	Mount Kindle formation according to Williams is Niagaran in age. Brecciated beds are without fossils

Ordovician	Red beds 595 feet (*Receptaculites*)				?	770 feet		
Upper				Saline River formation 500 feet	Shales (Upper or Middle Cambrian) gypsum bearing			
Middle Cambrian				Mount Cap formation 200 feet				
Lower				Mount Clark formation 600 feet				
Precambrian?				Precambrian?				

[1] Cameron, A. E., Geol. Surv., Can., Sum. Rept., 1921, pt. B, p. 13.
[2] Whittaker, E. J., Geol. Surv., Can., Sum. Rept., 1921, pt. B, p. 51.
[3] Hume, G. S., Geol. Surv., Can., Sum. Rept., 1921, pt. B, p. 69.
[4] Williams, M. Y., Geol. Surv., Can., Sum. Rept., 1921, pt. B, p. 59; 1922, pp. 72, 73.
[5] Hume, G. S., Geol. Surv., Can., Sum. Rept., 1922, pt. B, p. 52.
[6] Hume, G. S., Geol. Surv., Can., Sum. Rept., 1923, pt. B.
[7] Kindle, E. M., and Bosworth, T. O., Geol. Surv., Can., Sum. Rept., 1920, pt. B, p. 45.

Explanation of Correlation Table. The Lone Mountain dolomite was a name applied by Kindle to the bottom of the Mount Camsell and Lone Mountain sections where Silurian corals were found well down in a series of limestones, 2,500 feet thick. The top of this series contains a good Middle Devonian fauna, but since most of the section is unfossiliferous and the lithology changes only slightly throughout, no field division could be made to separate the Silurian from the Devonian; no disconformity being observed, although search was made for it. Williams has used the name Lone Mountain formation for a series of brecciated limestones and dolomites occurring under Middle Devonian strata in Franklin mountains. These brecciated beds overlie limestones carrying a coral fauna (Mount Kindle formation), so that it is possible Williams has used the name Lone Mountain formation in a much more restricted sense than Kindle. In the Norman-Carcajou River area the Bear Mountain formation as described by Kindle is readily divisible into two lithologic parts, an upper series of brecciated beds similar and probably equivalent to the Lone Mountain formation of Williams, and a lower part which it seems probable includes Mount Kindle formation and at least part of the Franklin Mountain formation.

The best horizon on which to correlate the Middle Devonian is the *Stringocephalus* horizon which occurs in the Presqu'île dolomite of Great Slave lake and the Ramparts formation of the Norman-Carcajou River area. The Simpson shales, which Kindle[1] has shown to carry a Portage fauna in the Simpson area, are believed to be the equivalent of the Fort Creek shale of the Norman area. The Hay River beds contain the *Spirifer disjunctus* fauna, which is represented, but not so well developed, in the Bosworth sandstone and shales. Since the Devonian is separated from the Cretaceous by an erosional unconformity it is to be expected that the Devonian will be much more deeply eroded in some places than in others, and from studies so far made the thickest section is in the Nahanni-Root River area. At the Ramparts near Good Hope all the Upper Devonian is gone and the Cretaceous rests directly on Middle Devonian limestones.

The correlation of the Cretaceous has not as yet been satisfactorily made. In the Norman-Carcajou River area the base of the Cretaceous has some thin layers of conglomerate and much sandstone containing coal seams, one of which has a maximum thickness of 18 feet. Thus, at least for this area, the basal part may differ widely from other parts of the Mackenzie district, but the upper shale member containing Ammonites is marine and is probably widespread over the whole area.

HISTORICAL GEOLOGY OF THE MACKENZIE VALLEY

GENERAL STRUCTURAL GEOLOGY

The actual contart between the Cretaceous and the Devonian has been seen by the writer only at two places, at the north end of the Wolverine anticline (Plate I B), and at the upper end of the Ramparts of the Mackenzie, but at other places rocks of these two ages are so close together that the relationships can be accurately deduced. The contact itself is an

[1] Kindle, E. M., Geol. Surv., Can., Mus. Bull. 29, 1919.

irregular line cutting across the Devonian strata with the beds above and below the contact easily separable on account of their lithological dissimilarity. The difference in the attitude of the beds above and below the line, however, is very slight. This seems to indicate a widespread regional uplift prior to Cretaceous sedimentation, in which time the Devonian suffered considerable erosion. Whether younger rocks above the Devonian occurred in this area prior to Cretaceous time is difficult to say, but at least Carboniferous rocks do occur to the west in Gravel River mountains, and Triassic rocks are found in Liard mountains. The absence of an angular unconformity separating the Devonian and Cretaceous, and the fact that the extension of the Cretaceous strata would pass over the mountains seem good evidence for post-Cretaceous mountain building. As was pointed out[1] Cretaceous rocks are found folded into the mountains of Liard River area and although none have been so far found in Mackenzie mountains in a sharply folded condition, the mountains in both areas are undoubtedly the same age.[2]

Following the major mountain disturbance[3] Eocene rocks of non-marine origin were deposited in basins along Mackenzie valley. In the vicinity of Norman these Eocene rocks are nearly horizontal and although there is a small covered interval separating the Eocene outcrops from Bear rock, the structure is such as to leave no doubt that the flat-lying Eocene beds abut against the sharply-tilted Silurian and Devonian strata of Bear rock. Thus, the Eocene beds are distinctly younger than the mountain building and can be used as an indicator of later differential movements.

Although the Eocene near Norman is almost horizontal, south on Mackenzie river the beds are tilted[4] to the south at about 50 to 60 feet to the mile. In Peel River area[5] Camsell has shown the Eocene to be gently folded into a series of anticlines and synclines near the mountains, whereas out on the low-lying plateau in front of the mountains the beds are almost undisturbed.

From this it would appear the Tertiary in the Mackenzie region has suffered a slight local disturbance, but the major movement seems to have been in the nature of a regional uplift indicated in the new cycle of erosion displayed on many tributary rivers entering the Mackenzie. For example, Little Bear river, which enters the Mackenzie from the west just north of Bear rock, shows extremely well-developed meanders now entrenched 200 to 300 feet below the plateau level of the surrounding country. Near the Mackenzie the same river cuts through about 200 feet of Pleistocene gravel, indicating that the uplift movement that caused renewed erosion on this river is post-Pleistocene in age. Obviously the meanders must have been developed in an erosion cycle previous to the uplift and subsequent to the retreat of the ice, and it is suggested the uplift itself may be an isostatic readjustment following the release of the ice load.

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[1] Geol. Surv., Can., Sum. Rept., 1922, pt. B, p. 48.
[2] Geol. Surv., Can., Sum. Rept., 1922, pt. B, p. 49.
[3] Geol. Surv., Can., Sum. Rept., 1921, pt. B, p. 76.
[4] Williams, M. Y., Geol. Surv., Can., Sum. Rept., 1922, pt. B, p. 82.
[5] Camsell, C., Geol. Surv., Can., Ann. Rept., vol. XVI, 1904, p. 41 C.

HISTORY OF THE MACKENZIE VALLEY

There is no doubt the Mackenzie valley is very old and may have existed as a drainage valley since early Tertiary, although, of course, many modifications have taken place through such a great lapse of time.

As has been shown the mountain-building movements which outlined the present ranges were late Cretaceous or (and) early Eocene. The Eocene deposits are now found in basins along the Mackenzie valley and extending up some of the tributaries, for example Great Bear river. Below Bear rock, in the vicinity of Bluefish creek, the Eocene rests on Upper Devonian, but at other places the proximity of the outcrops suggests Eocene resting on Cretaceous. Thus, prior to Eocene deposition erosion had in some places completely removed the Cretaceous, although on Little Bear river these sediments are from 500 to 1,000 feet thick. There they consist of a lower continental sandstone member and an upper marine shale member, the former containing coal beds and varying greatly in thickness over the area as a whole. Thus a thickness at least of 500 feet must have been removed from the vicinity of Bluefish creek prior to Eocene deposition. Nowhere in the Eocene were coarse conglomerates seen, so that no torrential streams are indicated reaching as far as the deposits now found along Mackenzie valley. Evidently in the Eocene swamp conditions prevailed, leaves being entombed in the sediments and showing an abundant growth of such trees as oak, maple, birch, walnut, hazelnut, etc.

It is the writer's belief that Cretaceous sediments originally extended over all the mountains in the Mackenzie area, although now no Cretaceous is found except low down on the flanks of the mountains and in the intervening valleys. However, Cretaceous rocks are folded into the mountains in the Liard River country and there is reason to believe these mountains are the same age as those of the Mackenzie area. Drainage established on these Cretaceous rocks prior to mountain building has in some instances, it is believed, been able to maintain itself along certain drainage channels to the present day. This is probably the explanation of some of the drainage courses of such rivers as the Peace and the Liard, and seems to be the origin of at least certain parts of the larger tributaries of the Mackenzie, for instance Root, Gravel, Blackwater, Carcajou, etc., in which gorges are now cut into the hard Devonian and Silurian strata and even into the Cambrian. Part of North Nahanni river is in a structural valley and cuts across the hard limestones of the front range of mountains near its mouth, though the present valley is quite wide and the river shows no effect of flowing over the harder rock. About 20 miles from the mouth there is a tributary from the south which obtains part of its water from a smaller stream draining a lake lying between the mountains and Mackenzie river. In the case of this small stream the normal drainage should have been direct to the Mackenzie, as the lake is on the Mackenzie lowland and there are no obstructions whatever between the lake and Mackenzie river. However, as indicated, the drainage is through the front range of mountains to the North Nahanni, the valley through the mountains being very narrow with precipitous sides in the lower part and a steep slope in the upper part to an elevation of 1,000 to 1,500 feet above the valley bottom. It is difficult to understand how such a drainage could have originated, except from an antecedent stream that on account of mountain building became superimposed on the hard limestones through which the gorge through the mountains has been cut.

Root river, about 50 miles from its mouth, cuts across hard limestones, forming a gorge-like valley about half a mile wide. Blackwater river drains from east of the Franklin range of mountains and Williams[1] has indicated his belief that this is an antecedent river. The Carcajou has a gorge in the mountains which extends for many miles and at least one tributary stream drains through hills 800 to 1,000 feet high to the Carcajou from the plateau separating Little Bear and Carcajou rivers, whereas there are only a few very minor ridges separating this tributary from Little Bear river (Map 2022). A striking example of a river draining across the mountains regardless of structure is found in the Gravel, one of the larger tributaries of the Mackenzie. This river, on account of its length and the diversity of the material that it traverses, is regarded as a good example of antecedent drainage.

If parts of these river valleys antedate the mountain-building, it is obvious there must have been a large river formed by the confluence of the ancestral rivers, just as the Mackenzie today is the result of the confluence of the present rivers. Since the Franklin range represents folds developed during pre-Eocene time there must have been a valley in Tertiary time occupying the position of the present Mackenzie lowland between the mountains, into which the Tertiary representatives of such rivers as the Gravel must have discharged. Enough data are now at hand to show how far this ancient Mackenzie river followed the present Mackenzie valley, because there are now many low gaps in the Franklin range through which rivers might possibly have escaped to the east.

The Eocene deposits occur in basins in the Mackenzie valley and exhibit the characters of freshwater deposits, and were so described by McConnell. They may have been formed in lakes at only a slight elevation above sea-level, but in later Tertiary time regional elevation took place because Mackenzie river had cut a well-defined valley prior to the deposition of the boulder clay of the Keewatin ice-sheet. Instances have been noted along the Mackenzie banks where old stream channels are filled in with glacial material. One such channel cut through by the Mackenzie occurs on the west bank of the river about 20 miles north of Good Hope. The basal part of this section in the old stream valley contains boulders of rocks presumably derived from the Precambrian shield to the east.

The glacial deposits left by the ice must have greatly disarranged the drainage, but in many instances parts at least of the old valleys were left well enough defined to become drainage channels once more. Along the Mackenzie at least 200 to 250 feet of glacial material occurs, and Keele records one section 500 feet thick on Gravel river 50 miles west of the Mackenzie. Following the glacial period, and possibly as a result of the removal of the ice load, an uplift occurred. This is well shown on Little

[1] Williams, M. Y., Geol. Surv., Can., Sum. Rept., 1922, pt. B, p. 71.

Bear river where meanders are deeply entrenched in Cretaceous sandstone, and the river near its mouth has cut through Pleistocene gravel banks 200 feet high.

Following the retreat of the ice there was developed on the Mackenzie above Good Hope a large waterfall, the retreat of which gave rise to the present Ramparts. At the Ramparts the river suddenly narrows from 2 to 3 miles to about 500 yards and flows for approximately 6 miles between vertical cliffs of hard, Middle Devonian limestones. The top of the limestone away from the gorge forms a flat surface which, as pointed out by Kindle,[1] has been swept clear of glacial materials. Overlying the Middle Devonian are Cretaceous rocks rising abruptly from the flat limestone surface to form the walls of the old river valley which was at least 2 miles wide. The gorge of the Ramparts is thus post-Pleistocene and represents a recession of a fall for about 6 miles through southward-dipping, resistant limestones underlain by softer shale, a condition which was most favourable for the formation of the gorge. At the level of the river a very short distance from the upper end of the gorge the contact of the relatively soft Cretaceous with the hard Devonian limestone is exposed. From the entrance of the gorge to this contact the river widens like a funnel and rock-cliffs occur facing upstream. As this part is subject to very severe erosion every spring due to the concentration of ice into the gorge and the occurrence of frequent jams the funnel-shaped mouth of the gorge is undoubtedly being constantly eroded back, not only increasing the height of the up-river facing cliffs owing to the southward dip of the rocks, but also widening the entrance.

GLACIATION OF MACKENZIE VALLEY

The thickness of the ice in the Mackenzie valley has been referred to by Keele[2] who found a large boulder of gneiss at the mouth of Nidhe creek, Gravel river, 1,800 feet above the Mackenzie. Camsell[3] records pebbles and boulders of gneiss on the summit of mount Goodenough, at an elevation of 3,000 feet above the Mackenzie delta. In speaking of glaciation in Franklin mountains Williams[4] says " glacial erratics (Precambrian) lie on the very top of Cap mountain and within 400 feet of the top of mount Clark," about 5,000 feet above the sea. Glacial erratics, therefore, occur up to 4,600 feet above sea-level, a height well above other records for this area. Coleman[5] states that in the south "many large blocks of Archæan rocks are found scattered over the foothills in southern Alberta almost to the foot of Rocky mountains at levels from 3,000 to 5,280 feet above sea-level." To explain these glacial erratics at such high elevations it seems necessary to assume that the ice-sheet was very thick, in fact, to get a glacial boulder within 400 feet of the top of mount Clark an ice-

[1] Kindle, E. M., and Bosworth, T. O., Geol. Surv., Can., Sum. Rept., 1920, pt. B, p. 42.
[2] Keele, J., Geol. Surv., Can., 1910, Pub. No. 1097, p. 46.
[3] Camsell, C., "Peel River and Tributaries," Geol. Surv., Can., 1906, p. 40.
[4] Williams, M. Y., Geol. Surv., Can., Sum. Rept., 1922, pt. B, p. 71.
[5] Coleman, A. P., Trans. Roy. Soc., Can., 1909, p. 3.

sheet would have to be at least 4,300 feet thick whether the boulder was carried there by the ice-sheet itself or on floating ice on water dammed by the ice-sheet.

The effect of glaciation in the Mackenzie region is well shown on Bear rock and on mount Charles, and glacial erratics are scattered over the Discovery range of mountains which rise 2,500 feet above Mackenzie river.

Keele came to the conclusion that the Keewatin glaciation preceded the Cordilleran glaciation, as the following quotation indicates: "The valley of Mackenzie river was occupied by an ice-sheet of considerable thickness which pushed up the valley of Gravel river, before the ice from the Cordilleran glacier began to pour down." If this is the case it is just the reverse of what happened in southern Alberta where Coleman has conclusively demonstrated that the Keewatin glaciation followed the Cordilleran glaciers with an interglacial period separating the two. Keele found a 500-foot section of drift on Gravel river and this section contained two boulder clays separated by stratified materials, but the pebbles from neither of the boulder clays are described, although Keele speaks of the "boulder clays from the two sources" showing "marked differences in colour, composition, and structure." McConnell[1] also found two boulder clays on Liard river, separated by interglacial material, but says "this might, however, be due to a purely local cause."

[1] McConnell, R. G., Bull. Geol. Soc. Am., vol. I, p. 542.

CLAY DEPOSITS ON ATHABASKA RIVER, ALBERTA

By G. S. Hume

Although clays of good grade have been reported from tributaries of the Athabaska, difficulties of access have prevented their use. If, however, clays of a similar or better grade were found along the Athabaska where the river affords cheap transportation to the railway it might be possible to work them profitably.

The writer was instructed to make a brief examination of the Athabaska clay deposits while on the way to Mackenzie River district and to make a rough determination of the amount of clay available, in case tests should show it to possess commercial possibilities. Only clays that would not effervesce in cold dilute acid were sampled, all others in this area containing lime being considered of no commercial value.

Clay deposits at three localities along the Athabaska were sampled, and several others were examined which proved to have too high a lime content. If it be considered that one foot of overburden for one foot of workable clay is the greatest thickness that could be stripped in working these deposits on a commercial scale, it is doubtful if any of the deposits along the Athabaska are of sufficient size to warrant development. It must be stated, however, that the determination of the amount of clay available from surface exposures was not very reliable since the clay banks slump easily, and undoubtedly considerable clay is concealed that would be disclosed by stripping. Also, in localities where the clay was either at the surface or buried under a veneer of silt, its extent was obscured by vegetation and only small patches were exposed where streams had cut into it. The only satisfactory method of determining the quantity of clay would be by a series of bore-holes or trenches suitably placed, but until something was known of the quality of clays to be expected such an extensive amount of work was not deemed to be warranted. Unfortunately, owing to the death of Mr. Joseph Keele, the report on these clays has had to be curtailed.

It was hoped some of the clays might be refractory or fire-clays. Although the term fire-clay is rather loosely used Ries[1] would restrict the name to clays which fuse above 3,038 degrees F. From the accompanying tests it will be seen none of the clays examined falls in this class.

The clay deposit from 1½ miles north of Calumet river, a tributary of the Athabaska, where some prospecting work had been done in 1922, was not sampled, as a report on it appears in Bulletin 10, Mines Branch, 1915, page 13. Although small layers of clay in this deposit are non-calcareous, or nearly so, the greater part of the deposit is so highly calcareous as to render it of no commercial value.

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[1] Ries, H., "Clays: Their Occurrence, Properties, and Uses," p. 2'05.

Deposit 1. Two Miles North of Stony Island, on East Side of Athabaska River, Tp. 91, Range 9, Sec. 17, W. of 4th Mer.

The clay bed is exposed along Athabaska river above high-water mark and is cut through by a small tributary stream. On the down-river side of this tributary the clay was traced for 400 yards and may go farther, but on the up-river side of the creek it can be traced for only 100 yards, when it thins out as the edge of a lens. At the small creek the clay forms the surface and at 20 yards from it there is an overburden of 8 feet which increases to 30 feet at the edge of the lens. The amount of clay available under less than 8 feet of overburden is small, possibly not more than 1,500 to 2,000 cubic yards.

A section of the clay in this deposit is as follows:

	Feet
Tar sands	
Grit with quartz pebbles	1 to 2
Clay—yellow and iron stained, not sampled	2 to 3
Sample No. 1—	
Yellow clay	2
Grey clay	2
Dark clay, becoming shaly in parts	2
Clay containing ironstone concretions	2
Devonian limestone	

The sharp contact between the clay and the Devonian limestone shows, for this section at least, that the clay is not residual from the disintegration of the limestone. The clay is laminated and hence belongs in the class of sedimentary deposits. The layer of grit above the clay contains quartz pebbles mostly above the size of peas, but also up to $\frac{3}{4}$-inch in diameter. Both the grit and the clay are almost free of calcareous material. The overburden of tar sands, except for a limited area, is so thick as to make this deposit unworkable.

A sample of this clay was tested by L. P. Collin of the Mines Branch, who reports as follows:

"Dark grey, non-calcareous clay. It is quite plastic when tempered with 21 per cent of water and works fairly well. The drying shrinkage is 6·3 per cent. This clay is very difficult to dry completely, as was shown by the burning tests. The samples were dried for forty-eight hours at considerably above room temperature. When burnt two or three trial pieces were broken, one shattered into small bits. This was no doubt due to hygroscopic water in the test piece.

"When burned to 1,796 degrees F. the test piece was light buff in colour and very nearly vitrified. The fusion temperature of this clay is about 2,700 degrees F., thus making it semi-refactory.

"It might be used for stiff-mud building brick, although the colour would probably not be good enough for first-class face brick. It could be used as a foundry clay, or for making stove linings and other products in which a high heat resistance is not demanded."

Deposit 2. On East Side of Athabaska River about 10 Miles North of Muskeg River, Tp. 95, Range 10, Sec. 6, W. of 4th Mer.

The bank containing the clay is badly slumped, but there is at least 6 feet of clay, and possibly more, with an overburden of tar sands, up to a maximum of 20 feet. The exposed part of the clay is 40 feet above the river, but a short distance down river the tar sands pass beneath the level of the water, showing a dip in that direction. Up river the clay is concealed by talus so that the shape of the deposit is not definitely known, although from the absence of the clay in the talus the shape is believed to be that of a lens. There is no great amount of clay available here under small overburden, but as the top of the river bank is flat prospecting away from the river might reveal considerable at a slight depth.

A sample of the clay was tested by Mr. Collin of the Mines Branch, who reports as follows:

"Light grey non-calcareous clay. It is fairly plastic when tempered with 19 per cent of water. The drying shrinkage was 6·2 per cent. This clay dries readily and without any bad results.

"The percentage of shrinkage and absorption at the different temperatures of burning is as follows:

Temperature	Fire shrinkage	Absorption
1,652 degrees F.	0·0	11·0
1,796 "	1·0	8·9
1,904 "	1·0	8·1

"The clay fuses at 2,660 degrees F.

"The colour at 1,652 degrees F. was light red and the test piece was steel hard. At 1,796 degrees F. the colour was a brownish buff. At 1,904 degrees F. the colour was cream and the test piece was nearing vitrification.

"This clay might be used for stiff-mud brick and semi-refractory purposes such as stove linings, etc. The colour for building brick is somewhat better than sample No. 1."

Deposit 3. On West Side of Athabaska River about 12 Miles North of Muskeg River, Tp. 95, Range 11, Sec. 18, W. of 4th Mer.

This deposit is peculiar in that it occurs between beds of tar sands showing the clay belongs to the McMurray formation (Tar sands) of Cretaceous age. In this deposit there are many streaks of sand separating layers of clay in which occur small pieces of lignite, each piece surrounded by a zone of yellow material presumably sulphur, the clay being discoloured for a small distance away from the lignite. A section of this deposit is as follows:

Tar sands Clay, white or grey in colour Not exposed Clay—sample from 4 feet of this	15 feet
Tar sand	1½ feet
Clay	1 inch
Tar sands	1 foot
Clay	2 inches
Tar sands—bottom not seen	

A sample of this clay was tested by L. P. Collin of the Mines Branch, who reports as follows:

"Light grey, non-calcareous clay. Fairly plastic and works well when tempered with 17 per cent of water. The clay has good drying qualities. The air shrinkage is small, being about 5 per cent.

"The per cent fire shrinkage and absorption at different burning temperatures are shown below.

Temperature	Fire shrinkage	Absorption
1,652 degrees F.	0·6	11·6
1,796 "	0·0	10·2
1,904 "	0·3	8·9

"The colour in each case was a light cream. This clay fuses at 2,730 degrees F., being slightly more refractory than the other two samples. The test pieces were steel hard at 1,796 degrees F.

"This clay might be used for making soft-mud brick. The colour would not permit its use as a face brick. It might also be used for semi-refractory purposes."

Eight hundred feet up river from the above section there is another section showing sandy clay alternating with clay. Where the layers become predominantly sand they have in some instances become impregnated with the bitumen and consequently are layers of tar sand. Thus the relationship of the tar sands to the clay deposits seems quite clear, the two representing nothing more than variations in the sediment and belonging to the same period of sedimentation.

The clay at this location forms the top of the bank, but it is not known how far it extends back from the river as there is apparently a considerable thickness of surface material, uprooted trees at some distance from the river giving no definite information. The bitumen in certain sandy layers would destroy the commercial value of this deposit, but it is doubtful if very much of this would be encountered in the top 15 feet of clay, although the clay would undoubtedly vary considerably in composition within short distances.

Conclusions Regarding the Origin of the Clay

If the clay were residual from the Devonian limestone there would be a gradation from clay through partly altered and leached limestone to unaltered limestone. In the deposit 1½ miles north of Calumet river the clay was very calcareous, but the contact with the limestone was sharp. The same was true of deposit 1, 2 miles north of Stony island, although here the clay was non-calcareous. These two deposits were the only ones seen where the underlying limestone was exposed and from them the conclusion is unavoidable that the origin of the clay is in no way connected with the limestone.

In deposit 3 on the west side of the Athabaska, 12 miles north of Muskeg river, the clay alternates with layers of sand which in certain cases has become impregnated with the tar material, and, as has been mentioned, the clay from deposit 1 is laminated. Thus the clay is sedimentary and belongs to the McMurray formation, a freshwater[1] deposit of Cretaceous age. The clays occur in lenses and their lateral extent is, therefore, not likely to be great, nor will they hold a uniform thickness over any considerable area.

[1] McLearn, F. H., Geol. Surv., Can., Sum. Rept. 1916, p. 147.

PRELIMINARY INVESTIGATION OF COAL DEPOSITS ON SMOKY, HAY, AND BERLAND RIVERS, ALBERTA[1]

By John MacVicar

CONTENTS

Illustrations

INTRODUCTION

Since 1916 it has been known that coal beds of good quality and workable thickness exist in the neighbourhood of Brûlé lake, an expansion of Athabaska river, in Jasper park, and extend to Smoky river, a tributary of Peace river, Alberta, but little more was known about them. The writer spent the summer of 1916 in this area, and the summer of 1919 in an adjacent coal-bearing area to the east. The main object was to determine what further coals of Kootenay age occur in this part of Alberta and the practicability of a railway line to them and to the Smoky River areas by way of the foothill country. The results of this preliminary work are embodied in the following report.

[1] With additions and revisions by D. B. Dowling.

Sufficient data were obtained to show that there is a considerable amount of coal in this field awaiting development.

The writer is greatly indebted to D. B. Dowling for general directions and valuable suggestions; Mr. Allan Fraser, District Engineer of the Canadian National railway, at Edmonton, the Brûlé Lake Coal Company, and others who furnished maps and other valuable information. He wishes to acknowledge courtesies and assistance received during 1919 from Mr. Finlayson and Mr. Badgley, of the Forestry Branch, Department of the Interior. R. T. Hollis, of the University of Alberta, proved a satisfactory assistant.

SUMMARY AND CONCLUSIONS

The coal varies from bituminous to semi-anthracite and is suitable for steam, metallurgical, and domestic purposes. Semi-anthracite coal outcrops on Smoky river and will give a high percentage of lump coal.

The following table is a summary of the approximate tonnage that may be obtained from the field. It is based on as many facts as are available at the present time, and in the opinion of the writer, understates rather than overstates the amount.

Southern division, possible tonnage, bituminous	425,820,000
Middle division, possible tonnage, bituminous	2,174,400,000
Northern division, semi-anthracite and semi-bituminous	58,500,000
" " bituminous	7,000,000,000
Eastern division, no estimate	
	9,658,720,000

The above estimates are based upon the thickness of coal contained in the general sections given, with reductions to offset uncertainty as to the persistence of these thicknesses. Reductions are also made for the losses incident to the ordinary mining methods. Sufficient development work, however, has not been done to determine the physical character of the coal—e.g. whether or not it is badly fractured—other than that shown by the analyses.

Any estimate of tonnage of mineral is, of course, more or less approximate, the true tonnage never being known until the field is worked out. Many factors, such as quality, thickness, depth, faults, pitch, accessibility, etc., enter into the calculations, for which allowance cannot be made. Some are subject to engineering control, whereas others have no limits except a purely economic one. A computation of reserves, therefore, is of more value, especially if the figures given understate rather than overstate the facts.

AREA AND LOCATION

The area covered by this report is an approximately oblong block of about thirty townships, or 1,080 square miles, situated in western Alberta (Figure 2). It includes a large area of land that is not coal-bearing. It is bounded on the east by Brûlé lake which lies 190 miles almost due west of Edmonton. The area mapped stretches northwest from Brûlé lake for about 80 miles and varies in width from a few miles at the south to possibly 25 miles in the north. Roughly, it lies between longitudes 117° 50′

and 119° 20′ and latitudes 53° 14′ and 54° 04′. Between Brûlé lake and Hay river the coal measures are bounded on the northwest by the first range proper of Rocky mountains. Between Hay river and Muskeg river the measures are bounded on the northwest and southeast by the first and second range of Rocky mountains. These mountains form the geological as well as the topographical boundaries of this part of the area. Between Muskeg river and Sheep creek the measures are bounded by limestones on the southwest for the most part, and to the northeast by the newer Cretaceous formations of the foothills.

ACCESS

The southern part of the map-area is easily reached from the Canadian National railway, which crosses the eastern edge of the field on the route to Yellowhead pass. The Canadian National railway has made surveys for a branch line up Solomon creek and thence up Hay river and its northern branch to near the source of the latter, a distance of about 40 miles. Any part of the coal field could be reached by a railway, although relatively steep grades would be encountered in places.

The northern part of the map-area is reached by pack trail. The Forestry Branch of the Department of the Interior has completed splendid pack trails to Grande Cache. One runs up Hay River valley and down Sulphur valley, the other passes about 30 miles in front of the mountains to Muskeg river, down it for about 12 miles, and thence to Grande Cache to join the Sulphur Valley trail. The above-mentioned outer trail to Grande Cache is used for winter freighting by sleigh. Another sleigh trail runs up Solomon creek to Hay river and thence to the summit. Other less important trails intersect the district.

The eastern division may best be reached over the Government pack trail, 175 miles in length, which runs from Entrance station, on the railway, to Grande Cache, passing about through the centre of the area. This trail, which is approximately 10 feet wide, was cut by the Forestry Branch, for the use of fire-rangers, who have cabins at intervals of about 20 miles along it. For a distance of 60 miles there is telephone connexion with headquarters at Entrance.

Since the great coal resources of this and the adjoining area can be made available only by a railway, attention was given to the character of the topography that might affect the selection of a railway route. There are no great obstacles to railway building and a satisfactory route could, probably, be selected roughly along the following line. Leaving the Canadian National railway at Solomon creek the line could follow the creek for about 6 miles with a grade of 1·75 per cent or less. Thence, turning to the right through a narrow gap, the lakes and creek valley could be followed to Hay river, beyond which the summit could be reached by way of Moberly and Pinto creeks, whence a gently sloping hillside leads to Little Berland River flat. The line could follow this stream to its junction with Berland river, continue up Big Berland flats about 8 miles to the mouth of Cabin creek, and, turning to the right, follow the right hand branch to Tepee Creek summit. Down Tepee creek about 20 miles it would reach Muskeg River bottom and thence could follow that river to its junction with Smoky river.

The steepest grade of the creek bottoms traversed seems not to exceed 2 per cent, and with development this might be lowered. Excepting a short distance on Muskeg river, this route would give earth work all the way. The stream crossings on this line are low, and with the exception of a few trestles over ravines near the mouth of Muskeg river, no high bridges would be necessary.

METHOD OF WORK

The earliest detailed work on Smoky river was done by the writer in 1909 and again in 1912, for commercial interests. During this time the Canadian Northern Railway Company had men in the field prospecting. Individual prospectors were also active in making locations throughout the district. Surveys of the sixth meridian and the fifteenth base-line were made in 1909, but with these exceptions there were no surveys in the greater part of the area explored by the writer.

GENERAL CHARACTER OF THE AREA

TOPOGRAPHY

The area under discussion falls naturally into four divisions, a Southern, a Middle, a Northern, and an Eastern.

The Southern division extends from Brûlé lake to Hay river and is situated immediately in front of the outer range of the Rockies. The upturned Devono-Carboniferous limestones form a series of rugged ridges which run parallel with the area and form its southwest border. Just west of Brûlé lake, Boule Roche mountain rises about 7,000 feet above sea-level and 4,000 feet above Brûlé lake. Northward from the lake the broad valley representing the outcrop of the Cretaceous shale rises gradually for about 15 miles to an elevation of 4,500 feet and then slopes appreciably downward for about 8 miles to Hay river. This valley is due mainly to the fact that the shale is more easily eroded than the harder adjacent rocks. The coal-bearing rocks come to the surface and form a "hogback" along the northwest side of this valley and in front of the first range of Rocky mountains. At intervals this "hogback" is dissected by small, transverse drainage streams that head in the limestones. These streams occupy deep valleys with steep, rugged sides. A considerable part of this area of rugged topography is covered with pine trees suitable for timber, railroad ties, and mine timbers. East of the main valley the foothills form a succession of ridges parallel with it, the elevation of whose crest-lines are fairly even at about 5,000 feet.

The Southern division drains partly southward into Athabaska river, and partly northward into the Hay. These rivers cross the area and enter gaps in the first limestone range. Their valleys are fringed with well-developed gravel terraces, in two distinct levels at least. From the southern end of the area Athabaska river receives the waters of Solomon creek and its tributaries. Some of the latter flow underground for considerable distances.

The Middle division lies between Hay river and Muskeg river and is occupied by the upper waters of Hay river. Northeastward it is bounded by the first range of Rocky mountains and westward by the second range. Viewed from the higher elevations it is a basin-like depression of rolling aspect between the ranges.

The basin is about 3,000 feet above Brûlé lake and about 1,000 feet lower than the bordering ranges. It is between 5 and 7 miles wide and is traversed by well-defined ridges parallel with the main ranges. These bear a strong resemblance to the foothill ridges. Toward the southern end the topography is due to the structure and erosional resistance of the rocks, and the streams tend to follow in deep, narrow valleys. The valley of the north branch of Hay river, however, is carved in the softer rocks below the 6,000-foot contour down to the 5,000-foot contour, whereas the neighbouring hills both east and west rise to over 7,000 feet above sea-level. Toward the northern end the character of the topography is largely due not only to the structure but to the drainage. In this part Little Berland and Berland rivers occupy rather small valleys that cut across the strata almost at right angles and after starting in the second range pass beyond the map-area through narrow gaps in the front range of the Rockies. There are some good stretches of merchantable timber scattered throughout the region. Some of the hills with southern exposure are bare and grassed to the summit. Hay river forms the southern boundary of this Middle division. About 6 miles below Rock lake, which is an enlargement of the river, it is joined by the south branch, a stream 50 feet wide and only about a foot deep. Hay river passes through a wide gap in the second mountain range and though it then turns northwestward its southwesterly valley continues as a wide gap through the third mountain range into Stony River basin.

Little Berland river is about 20 feet wide; it has carved a deep, narrow valley at right angles to the strike of the strata. Its gradient is very steep. Starting in a cirque in the second mountain range, it flows northeastward through a narrow and precipitous gap in the front range.

Muskeg river near its head forms the northwestern boundary of the Middle division. Here it is a small stream in a typical V-shaped valley with rugged and precipitous slopes.

The streams in the Middle division, especially toward their source, flow through narrow muskeg flats that are in places covered with short willow and buck brush.

The Northern division presents a variety of topographic features both in the foothill and mountainous areas. The altitudes range from about 3,000 feet in Smoky River valley to 8,000 feet or over in the limestone ridges. Much bare rock is exposed at the surface, and shows that the structure is complex and made up of a series of synclines and anticlines.

The upturned Cretaceous rocks form a series of ridges which run lengthwise of the division. These ridges or foothills lie in front of the second limestone range, the rocks of the first range proper having disappeared under younger rocks at Berland river. The second range, continuing its sweep west from Muskeg river, crosses Sulphur river just above the mouth of Walton creek and continues westerly up the east side of Smoky river, though back some miles from it. This range is both the geological and topographical southwestern boundary of the Northern division. In general the elevations in this division are from 1,000 to 2,000 feet lower than in the Middle division. The difference is most marked along the stream valleys.

The amount and comparative sharpness of the relief within the area itself is illustrated by the difference of elevation of the surface across a belt about 20 miles wide. This belt rises from 3,000 to 3,200 feet above sea-level, the general level of the Smoky River valley, to 7,500 or 8,000 feet on the limestone range. The general rise from the valleys to the summits of the foothills in a distance of 3 to 7 miles is from 3,500 to 4,000 feet to from 5,000 to 6,000 feet. Parts of some of the valleys and hillsides are not forested and afford good range for cattle and horses. The growth of grass and pea-vine is luxuriant. For the most part, however, the ridges are fairly thickly covered with poplar and willow brush or a dense forest of small jackpine and spruce. Large areas have been swept by fire in the not distant past and have put forth a second growth up to about 2 inches in size. Merchantable timber exists only in isolated spots.

Smoky river and its tributaries drain the entire Northern division. Smoky river occupies a broad U-shaped valley fringed with gravel terraces. It is a stream nearly 300 feet wide, with swift current, and can be forded only during very low water at a few places. The floor of the valley probably does not slope more than 50 feet to the mile. It presents, however, a very uneven surface owing to the alluvial fans each tributary throws into the valley. The elevation of the main part of the floor is between 3,100 and 3,300 feet above sea-level.

The main tributary of the Smoky in the map-area is Sulphur river, a stream about 150 feet wide and 2 feet deep which occupies the valley between the second and third ranges of Rocky mountains. In this valley, also, but near its southern end, Hay river rises and flows southward. Sulphur river follows the valley for 6 or 8 miles to its confluence with its main tributary, Monoghan creek. The valley between the second and third range is typically V-shaped. Its floor is from 100 to 300 yards in width and the mountains rise abruptly and precipitously on each side for 3,000 or 4,000 feet. At Walton creek, Sulphur river enters a canyon which continues to its mouth. The walls of this canyon are nearly vertical and from 100 to 300 feet in height.

Muskeg river, another tributary, runs along the edge of the coal area for 8 miles before joining Smoky river. About a mile above Susa creek the shales pass under the sandstones, causing a fall in the stream of about 25 feet. A short distance above this fall the river enters a canyon 100 to 300 feet deep which continues to its mouth. Muskeg river at its mouth is about 100 feet wide and 2 feet deep.

Sheep creek is about as large as the Muskeg. Its lower part occupies a narrow canyon for about 10 miles to the edge of the valley of Smoky river. The walls are precipitous and 100 to 300 feet high. Above the canyon it opens into a steep-walled, V-shaped valley.

The limestones which form the western boundary of the Eastern division examined, between Hay and Muskeg rivers, present a toothlike, mountainous wall. The rugged scenery of this rock-wall is in striking contrast with the verdure-clad slopes of the adjoining foothills. The whole series of mountains and hills form parallel ridges and valleys, trending about north 45 degrees west. Ten to twenty miles from the limestones, the hills rise about 300 feet above the valleys, and nearer the limestones this height increases between 1,000 and 2,000 feet.

The rivers that drain the Eastern division are of fair size. Hay river is entered from the north by Moberly and Pinto creeks, each about 20 feet wide and 18 inches in depth. The next stream to the north is Little Berland river, 30 to 40 feet wide and about 18 inches deep where it joins Berland river. It has its source in the trough between the two limestone folds of the outer range of Rocky mountains. A short distance from the mountains, its valley is bounded by low, well-rounded hills. Berland river is about 100 feet wide and 2 feet deep. Low hills with gentle slopes border its valley, which is about a mile wide and is forested with spruce and jackpine, small willow, and alder; occasionally an open grass meadow is met with. It is fed by a number of creeks, the more important being Cabin, Moon, and Adams.

CLIMATE AND VEGETATION

The climate is continental in character but resembles to some extent that of the coast in that moderate temperatures mark the summer. Sunshine and clear air mark the winter. The chinook winds which reach the Athabaska valley prevail also on the Smoky and prevent, in most winters, the accumulation of snow along the rivers and the adjoining uplands. The rainfall is ample and the growth of grass and pea-vine luxuriant. Stock graze out all winter on both streams.

Wild flowers are abundant and of many hues, and when in bloom add greatly to the beauty of the hills. For the most part the hills are clothed with a thick stand of spruce and jackpine. Fire has burned over large areas, but upon these a second growth of evergreen has again started. Along Hay river, particularly, the hills with southern exposure are bare of forest and are grassed to the summit. Throughout the map-area the principal trees are spruce, balsam fir, pine, aspen, balsam poplar, and some white birch.

FAUNA

Game is plentiful throughout this district, which has long been a favourite hunting ground of the Indians. Moose, caribou, deer, sheep, goat, and bear are to be seen. Trappers yearly bring out large catches of fur, comprising fox, lynx, coyotes, marten, fisher, otter, weasel, and rabbit. Fish of the trout species are caught in the streams. They are very plentiful in A la Passe lake and Muskeg river.

GENERAL GEOLOGY

Throughout the area under study, the foothills and the first and second ranges of Rocky mountains consist of sedimentary rocks which have been uplifted, folded, and faulted by the intense forces that produced the mountains. Subsequently these folded sediments were eroded by stream and climatic agencies, so that now the entire succession of beds are exposed. Along the streams and on the hillside the rocks are fairly well exposed, and from them the major structures can be deciphered with considerable certainty. Fossil evidence is inadequate to establish definitely the age of the formations, but Dowling has found the following sequence on the Athabaska, and it is used with some local formational names for the area under discussion, which lies just to the north. The following formations are represented.

Recent and Pleistocene		River deposits, sands, silts, and lake deposits Boulder clay
Cretaceous	Upper sandstone and shale, Berland shale, Sunset sandstone, Kootenay coal measures	In the foothills Upper Cretaceous sandstone and Lower Cretaceous coal measures
Jurassic		Shales and sandstone
Triassic and Permian		Siliceous shales and dolomites
Carboniferous		Limestones
Devonian		Dolomitic limestones

The distribution of these formations from the Crowsnest on the south to Smoky river on the north indicates that during the earlier geological history of the region a similar sedimentation took place under uniform conditions in a sea of probably very much larger area than is indicated by the above limits. Many problems arise in the study of a region such as this, of which those bearing on the coal measures only can be discussed in a preliminary report of this nature. The following descriptions deal briefly with the structure and physical character of the formations in the region.

CARBONIFEROUS

Limestone beds of Carboniferous age are exposed along the first and second ranges of the Rockies. The base of the series is nowhere exposed. The upper part consists of a light grey quartzite that weathers reddish brown. A few Carboniferous fossils determined by E. M. Kindle were collected from the limestone beds just below the junction of Little Berland and Berland rivers. The beds in which they were found appear to be well down in the series, for probably 2,000 feet of limestone lies above them in the fold on the mountain.

McEvoy[1] gives the following section for these rocks on Folding mountain just south of Brûlé lake:

	Feet
Grey quartzites	200
Black carboniferous shale	60
Dark flaggy limestone	100
Yellowish, fine-grained siliceous shales and some calcareous sandstone.	500
Fine-grained, grey and yellowish limestone, highly siliceous, with a few bands of a dark quartzite	500
Covered	300
Fine-grained, blue limestone	500 plus
	2,160

The outer range on Hay river is made up of pure as well as cherty limestone, which contains a large amount of siliceous material. In weathering, the limestone being soluble is gradually carried away, leaving the exposed surface rough with chert. The colour of the limestone ranges from dark grey to blue. The strata are in three anticlinal folds in which the eastern limbs are much steeper than the western limbs. The axes of the folds form the crests of the three ridges comprising the outer range.

JURA-TRIASSIC

The strata between the Devono-Carboniferous limestones and the Kootenay coal measures are thin-bedded sandstones and dark shales, the latter in many places passing into hard, slaty shales. Fossils were not found in these and no attempt was made to separate them.

KOOTENAY

The coal measures consist of a series of interbanded beds of coal, conglomerate, slate, shale, and sandstone, over 3,000 feet thick. Some of the sandstones are 200 feet or more in thickness, whereas others are only a few inches at most. They range from coarse and hard varieties down to fine, soft, sandy shales.

The shales range in thickness from a few inches to 200 feet or more: some are soft clay shales; others are hard and siliceous. The prevailing colour of the shales and sandstones is brown or greyish.

Beds of conglomerate occur within the coal measures. Some are fine, and grade into sandstone; others are coarse and massive, and can be traced almost the length of the map-area. The coarse beds are usually 100 to 200 feet thick and in one reported instance on Muskeg river, 400 feet thick. In colour the pebbles range from white through grey, green, blue, and black.

The coal beds on Hay river range in thickness from a few inches up to 30 or more feet, and this great thickness is apparently maintained over large areas. Near the summit of the north branch of Hay river a thickness of over 100 feet is reached in widely separated exposures. Except for barren zones of 700 feet at the top and 1,200 feet at the base, the coal beds are fairly well distributed through the measures in the Southern

[1] McEvoy, J., Geol. Surv., Can., "Yellowhead Pass Route," No. 703, 1900.

division of the map-area. In the Northern division the coal extends to the base of the measures. The intervals separating the coal beds vary from a few feet to a few hundred feet, the longest interval being 600 feet. The upper half of the measures contains the most coal, but the lowest seams are of the best quality.

Thickness. The Kootenay coal measures are thickest in the Southern division of the map-area, aggregating about 3,600 feet. To the westward, on Moose creek, behind the front range, a measured section shows them to be about 3,800 feet thick. Workable coal beds extend almost to the very top of this section, but in the section at Brûlé lake there is a barren interval of 700 feet at the top. In the Northern division there are about 2,500 feet of coal measures with workable coal beds extending to the base, but with a barren zone in the middle. The identity of these coal beds with any beds in the middle or southern field is quite uncertain. The distances between coal beds in the geological sections of each division vary considerably and in places decidedly, making correlation uncertain. On the other hand, the coal measures in the Northern division may represent a period of time equal to that required to deposit 3,600 feet in the southern field.

Detailed Sections. In 1911 the writer measured a section of part of the Kootenay on MacVicar creek,[1] which enters Moose creek, a tributary of Athabaska river. These measures are the eastern extension of the measures on Hay river, and consist of the following materials in descending order:

	Feet	Inches	
Shale	200	0	
Sandstone and shale	236	0	
Coal seam 1	5	9	
Shale and concealed	85	0	
Coal and shale	5	0	
Coal	1	4	
Shale	101	6	
Coal seam 2	6	10	Strike N. 40° W., mag., dip 53° SW.
Shale	69	3	
Coal seam C	14	8	Strike N. 30° W., mag., dip 68° SW.
Concealed shale and sandstone	163	0	
Conglomerate	45	6	
Coal seam B	5	6	Strike N. 49° W., dip 69° SW.
Sandstone and shale	333	6	
Coal seam A	6	2	Strike N. 34° W., mag., dip 76° SW.
Shale and sandstone	272	2	
Coal seam 3	5	8	Strike N. 47° W., mag., dip 77° to 89° SW
Sandstone with four thin coal seams	92	6	
Sandstones	136	7	
Conglomerate	40	0	
Concealed measures estimated at	2,000	0	
To conglomerate			
	3,878	11	

[1] Geol. Surv., Can., Sum. Rept., 1911, p. 215.

Details of seams in section, page 30:

	Feet	Inches	
Seam No. 1—			
Sandstone—hanging wall....................			
Shale..	0	4	
Coal...	0	7	
Shale..	0	4	
Coal...	1	6	
Shale and coal...............................	0	9	
Coal...	2	3	
	5	9	
Coal Seam No. 2—			
Shale—hanging wall			
Coal...	0	4	
Shale..	0	9	
Coal...	2	2	
Shale..	0	3	
Coal...	3	4	
	6	10	
Coal...	5	10	
Coal Seam C—			
Shale—hanging wall			
Coal...	3	6	Sample analysis by F. G. Wait:
Shale..	0	9	Per cent
Coal...	0	3	Moisture............ 8·78
Shale..	0	2	Volatile............. 31·83
Coal...	0	3	Fixed carbon....... 47·16
Shale..	0	4	Ash................. 12·23
Coal...	4	0	100·00
Shale..	0	11	
Coal and shale..............................	2	3	
Coal...	2	3	
Coal Seam B—			
Conglomerate—hanging wall			
Coal...	0	5	Sample from coal excluding shale.
Shale..	0	3	Analysis by F. G. Wait:
Coal...	0	6	Per cent
Shale..	0	5	Moisture............ 2·67
Coal...	0	4	Volatile............. 21·05
Shale..	0	4	Fixed carbon....... 72·42
Coal...	1	7	Ash................. 3·86
Shale..	0	5	100·00
Coal...	1	3	
Coal Seam A—			
Sandstone and shale roof			
Coal (dirty).................................	0	10	
Shale..	0	2	
Coal...	0	4	
Shale..	0	2	
Coal...	0	10	
Shale..	0	3	
Coal (dirty).................................	0	6	
Coal (clean).................................	0	5	
Coal (dirty).................................	0	2	
Coal (clean).................................	0	11	
Shale..	0	2	
Coal...	1	5	
	6	2	

Coal sample, probably from this seam, sent by Mr. MacVicar. Analysis by F. G. Wait:

	Per cent
Moisture	4·10
Volatile combustible	22·28
Fixed carbon	58·04
Ash	15·58
	100·00

Seam No. 3—

Shale—hanging wall	Feet	Inches
Coal	1	1
Clay	0	0¼
Coal	4	3
Clay	0	0½
Coal	0	2
Clay	0	2
	5	8¾

The following measured sections near the top of the Kootenay, on Smoky river just above the mouth of Muskeg river, are in descending order:

	Feet	Inches
Concealed	559	0
Sandstone	77	0
Concealed	34	0
Sandstone and shale	195	0
Sandstone	92	0
Shale	14	0
Coal	3	6
Shale	2	0
Concealed	38	0
Sandstone	46	0
Shale	10	0
Concealed	200	0
Coal	3	6
Sandstone	4	0
Shale	20	0
Concealed	55	0
Shale and sandstone	72	0
Coal	12	0
Shale	1	6
Coal	1	6
Shale	6	0
Coal	1	0
Shale	2	6
Coal	4	0
Shale and sandstone	30	0
Shale	45	0
Shale and sandstone	149	0
Concealed	75	0
Sandstone	39	0
Shale	75	0
Shale and sandstone	75	0
Concealed	150	0
Anticlinal fold of shale and sandstone	150	0
Sandstone and shale	75	0
Sandstone	75	0
Sandstone and shale	270	0
Coal	4	0
Shale and sandstone	50	0
Sandstone	50	0
Sandstone and shale to base of exposure	400	0
	3,165	6

About 5 miles up Smoky river in a gulch opposite Gusta's meadows the base of the Kootenay is uncovered. This is provisionally placed as a thick bed of conglomerate. Fifty feet above the conglomerate a 7-foot seam of semi-anthracite coal occurs, and in the next 350 feet are two others, 10 and 15 feet thick.[1] From Hay river northward and westward to the main Berland only the upper part of the Kootenay was observed. The lower strata that are rich in coal seams have not been exposed by erosion either to the south at Brûlé lake or to the north at Smoky river.

On the headwaters of Little Berland river a section of 722 feet of the upper members of the Kootenay formation, exposed on the western limb of an anticline, consists of the following strata:

	Feet	Inches
Thinly bedded shale (sandy)	37	0
Yellow sandstone	1	0
Thinly bedded, sandy, grey shale	6	0
Yellow sandstone	2	6
Thinly bedded, sandy, grey shale	34	0
Grey sandstone	6	0
Black shale (opposite Sta. B. 16). *See* Figure 8	65	0
Concealed	43	0
Bluish grey sandstone	24	0
Concealed	15	0
Grey sandstone	0	6
Yellow weathering sandstone	14	0
Concealed	14	0
Thinly bedded, red sandstone	29	0
Concealed	12	0
Grey, shaly sandstone	7	0
Concealed	12	0
Grey, siliceous shale	27	0
Concealed	21	0
Thinly bedded, grey sandstone	27	0
Siliceous shale	6	0
Black, shaly sandstone	86	0
Reddish sandstone	26	0
Black shale	36	0
Thinly bedded, grey sandstone	24	0
Black shale	20	0
Ironstone	1	0
Siliceous, black shale or sandy sandstone	13	0
Black sandstone	51	0
Concealed	33	0
Concealed	8	0
Sandstone apex of anticline (*See* Sta. B. 17, Figure 8)	28	0

Distribution. Since 1885, when G. M. Dawson first named and described the coal measures of the Cascade basin as Kootenay, evidence has been accumulating to show that in the region of the Rockies it is a widespread formation. The extent and continuity of the basin in which the Kootenay was deposited are not yet defined. Folding, faulting, long-continued erosion, and the overlap of later sediments effectually obscure it in some places while laying it bare in others. In the area under discussion the coal measures form long, narrow strips bounded by older or younger rocks, or both. In the southern field such a strip runs from Brûlé lake to the south branch of Solomon creek. In the Middle division of the map-area a considerable area of Kootenay rocks is exposed. The measures are here repeated more than once judging from the structure. In the Northern

[1] See Figure 7. Outcrops are marked on secs. 19 and 30, tp. 57, range 8, W. 6th mer.

division a number of long, narrow strips occur. They are as a rule the exposed eroded limbs of folds. Their position and areal extent are depicted on the accompanying map (Figure 2).

SUNSET SANDSTONE

"In the outer foothills, where the succession of formations should be more readily correlatable with that of Peace river, is a thin series of sandstones that do not appear to belong to the Kootenay, yet cannot be definitely correlated with the top beds of the Bull Head formation of Peace river. Westward, in the valley of the north branch of Hay river, Mr. MacVicar found in 1916 a thick sandstone member which he described as Dakota. The rapid thickening of this sandstone implies a steep depositional gradient and possibly something like shore-line conditions. If so, these sands may not be correlatable with any sands in the Peace River section, but may have been deposited contemporaneously with marine shales in the Peace River section, possibly those in the lower part of the Moosebar formation, which is correlated tentatively by McLearn with the lower Blairmore formation.

"Apparently the Sunset sandstone overlies the Kootenay conformably. It is essentially a sandstone formation and widely distributed in the area. Fresh surfaces are usually grey to greenish, which weather to reddish brown. It varies in grain from fine to coarse and in places passes into a conglomerate. It is probably not less than 3,000 feet thick and comparatively hard. Its beds cap most of the prominent topographic features of the North Hay River valley."[1]

BERLAND RIVER SHALES

This formation lies apparently conformably on the Sunset sandstone. It consists of a great thickness of dark, massive shales. On acount of its soft, yielding nature it is mostly found in valleys and depressions. Fresh exposures may be seen on the principal streams, where stream erosion is rapid enough to keep the weathered part removed. When exposed for a considerable time to the weather these shales become fissile, crumble to small pieces, and ultimately to clay. The formation is too much folded and faulted to be accurately determined, but it is possibly 3,000 feet thick. Bands of nodular ironstone occur in places; at other places bands of sandstone are to be found. The formation is in some places divided by a massive bed of sandstone from 75 to 100 feet in thickness. In certain localities iron rust is abundant and in other places a white crystalline salt appears on its surface.

UPPER SANDSTONES AND SHALES

A sandstone series about 250 feet thick overlies the shales. It is made up of shale and sandstone in bands a fraction of an inch up to 15 or 18 inches in thickness. No fossils were found in these beds, but their content of coal in seams up to 15 inches and their stratigraphical position seem to indicate that they are contemporaneous with the Dunvegan sandstones.

These sandstones are overlain by a brownish-black shale of marine origin, in some places apparently 1,000 feet thick, which may be a west-

[1] Note by D. B. Dowling.

ward continuation of the Smoky River shales. Shallow-water sediments, mostly of a light grey colour, rest conformably and lie either flat or with gentle dips upon the shale. These are made up of shales and sandstones with conglomerates and coal seams. They are the highest of the Cretaceous deposits and underlie the eastern edge of the area here described.

PLEISTOCENE

The superficial deposits consist of glacial debris and river deposits. The drift is chiefly boulder clay. Some of these materials were deposited during the Glacial period and subsequently rearranged during the retreating stages of the ice. The most noticeable of these deposits are the gravel terraces along the main streams. The pebbles in the gravel are well rounded and from an inch up to about 9 inches in diameter. A great many of them are of local derivation.

One gravel deposit which extends along the summit between Tepee and Cabin creeks appears to be of a different age from the others; the pebbles in it, carried probably from Rocky mountains by the ice, are of quartzite, milky in colour, smooth and round, and from 3 to 10 inches in diameter. In places as many as three terraces were observed, one above the other, along the rivers. On the Smoky the highest is 400 to 500 feet above the present flood-plain, and 200 to 300 feet on the Hay.

RECENT

The valley bottoms are covered to an unknown depth with alluvium which includes sand, gravel, and clay in various combinations, and material from the adjacent formations deposited as alluvial fans at the mouths of tributaries and small gulches which ultimately becomes incorporated into the river flood-plains. A rich soil covers a considerable part of the area where the surface is smooth. The boundaries of this part and of the Pleistocene, shown in Figure 1, are for the most part approximate.

STRUCTURAL GEOLOGY

In the foregoing discussion some details of structure have been mentioned, but a fuller account of the structure of the map-area is given here on account of its importance with respect to the coal deposits.

The cliffs along the rivers and the small canyons through which the tributaries enter the main streams afford the best opportunities to study the attitude of the beds. They also afford favourable conditions for the examination of the coal seams.

In the Southern division the dominating structure is an anticline whose axis runs northwest-southeast. It has steep dips of about 80 degrees on the northeast limb and more gentle dips of about 65 degrees on the southwest limb. Both limbs will probably be found to be corrugated with minor folds. There is a belt of vertical coal rocks on the southwest limb that may indicate some faulting. A transverse fault along the south fork of Solomon creek, downthrown to the north, conceals the coal measures as far as Hay river, where the erosion of the valley again uncovers them. The steep eastern face of the first range is developed along a longitudinal overthrust fault line.

In the Middle division the coal field forms a long and rather narrow basin containing a number of subordinate folds, the southwest side being folded vertically or overturned. The northeastern limb has much gentler dips of 30 degrees to 40 degrees. Along the boundary fault which marks the eastern scarp of the second range of the Rockies the measures are not only tilted at a high angle and overturned, but in places the limestone has been thrust forward upon the younger strata until it rests upon the coal measures as at the coal outcrop on the McConnachie claim near the summit of the north branch of Hay river. The deepest subordinate basins are on the southwest side of the field and are bounded by rocks dipping about 70 degrees. Corrugations on the sides of the major folds and strike faults are probably present. The anticlines have a marked parallelism throughout the field, the usual course being about north 45 degrees west, which is parallel to the sides of the basin. The position of the anticlines and synclines, as indicated by surface exposures, is shown in the cross-sections on the map.

In the Northern division the structure is simple. To the southwest the undulations of the strata are numerous and close, the northern limb being perpendicular or overturned. On the northeast, the front range of the Rockies has disappeared under younger formations. Along its axis the measures are less plicated than in the Middle division, the steep dips giving place to gentle ones of 20 degrees to 30 degrees. Strike faults and lesser flexures are to be found throughout the area.

In the Eastern division the most pronounced structural feature is the precipitous limestones of the outer range. Intimately associated with this range is the fault zone in front of it, which follows the mountains northwesterly across the country mapped. Carboniferous rocks have been folded and pushed up on the newer Cretaceous. The rocks nearest the limestones show most disturbance, whereas from 10 to 15 miles east only gentle flexures are to be seen. In the disturbed area the upward bends in the rocks form ridges, capped by hard sandstone or conglomerate. The downward bends or synclines form low valleys and are occupied by soft, shaly rocks.

ECONOMIC GEOLOGY

Extensive coal deposits occur in large areas of the Kootenay rocks which underlie almost the whole map-area (Figure 2). The presence of these rocks at Fernie, B.C., Blairmore, Canmore, Nordegg, Mountain Park, and Pocahontas, Alberta, has given rise to important mining industries. Though only the southern end of the map-area is reached by rail, extensive prospecting has been carried on in the more remote parts with distinctly encouraging results. The region is not difficult to examine. For the most part the rocks are well exposed or thinly covered in the banks of the streams draining the area, or on the hillsides.

Other mineral resources besides coal also await development. Of these sand, gravel, clay, shale, limestone, and gypsum may be mentioned.

A number of holdings have been staked on a gypsum deposit in the pass on Deer creek between Hay and Stony rivers.

The reservation of an area known as the Forest reserve, on the eastern slope of the Rockies, has precluded any attempts at agricultural pursuits except that of stock raising.

Coal

SOUTHERN DIVISION

Surface prospecting for coal has been along the streams where the rock formations and coal seams are exposed. The wide areas covered by wash show few exposures and the tracing of any one seam from place to place was, therefore, impossible.

Surface prospecting on the coal claims to the north of Brûlé Lake mine has shown that some of the seams maintain their thickness and character in this part of the field. No detailed section was got showing the number of workable seams, but it is assumed in making the estimate of coal reserves that the workable coal beds extend throughout the area, because the Kootenay coals are known to extend over wide areas.

At the Brûlé Lake mine considerable development has been done. The mine is connected by a railway spur with the main line of the Canadian National and about 200 tons of coal a day are shipped for use by the railway. In the following section seven coal seams are shown, all of which can be mined.

	Feet
Conglomerate	
Sandstone and shales	700
Coal	7
Sandstone and shales	400
Coal	12
Sandstone and shales	120
Coal	7
Sandstone and shales	200
Coal	7
Sandstone and shales	300
Coal	7
Sandstone and shales	100
Coal	14
Sandstone and shales	600
Coal	7
Sandstone and shales	1,200
	3,681

This group of seams may underlie an area of about 8 square miles, and if they maintain the thickness given above would contain between 400,000,000 and 500,000,000 tons of coal.

On Scovil creek, which empties into Brûlé lake, coal prospects have been staked on sec. 17, tp. 50, range 28, W. 5th mer.—Bartholomew's claim. On the Haywood claim, Scovil creek, 500 feet downstream from discovery post, on the right bank, is a 12-foot seam. An 8-foot seam is reported by Bartholomew to occur up a small creek that enters Scovil creek a short distance from his cabin.

Jasper Park Area

Description	Blue Diamond Coal Company, Ltd., Brûlé Mines, Sec. 15, tp. 50, range 27									Bartholomew claim, near Brûlé lake, sec. 17, tp. 50, range 28	
	Sample No. 1219			Sample No. 1220			Sample No. 1221			Sample No. 889	
Moisture condition[1]	Raw	Air-dried	Dry	Raw	Air-dried	Dry	Raw	Air-dried	Dry	Raw	Dry
Loss on air-drying %	0·0	....	....	0·0	....	....	0·0	....	....	....	....
Results obtained by	Anal.	Anal.	Calc.	Anal.	Anal.	Calc.	Anal.	Anal.	Calc.	Anal.	Calc.
Proximate analysis:											
Moisture %	0·5	0·5	....	0·9	0·9	....	0·5	0·5	....	2·2	......
Ash %	11·2	11·2	11·3	16·5	16·5	16·6	13·5	13·5	13·6	18·7	19·1
Volatile matter %	21·3	21·3	21·4	16·9	16·9	17·1	18·6	18·6	18·7	15·3	15·6
Fixed carbon %	67·0	67·0	67·3	65·7	65·7	66·3	67·4	67·4	67·7	63·8	65·3
Ultimate analysis:											
Carbon %	79·3	79·3	79·7	74·2	74·2	74·9	77·3	77·3	77·7	......	......
Hydrogen %	4·3	4·3	4·3	4·0	4·0	3·9	4·2	4·2	4·1	......	......
Fuel ratio		3·15			3·90			3·60		4·15	
Carbon-hydrogen ratio	18·3	18·3	18·5	18·7	18·7	19·2	18·6	18·6	18·9	....	....
Coking properties	Very swollen, rather friable coke.			Small lump of fair coke.			Good coke.			Non-coking	
Location in mine	No. 2 north seam			No. 4 south seam			....			....	
Kind of sample	Mine			Mine			Commercial; from tipple.			Prospect	
Taken by	Fire ranger, Board of Railway Commissioners			Fire ranger			Fire ranger			John MacVicar, Geological Survey, Ottawa.	
Date of sampling	November, 1917			November, 1917			November, 1917			Summer, 1916	

[1]Note. The analyses do not necessarily show the true moisture content of the coal mined.

The coal at present mined is a soft, crushed variety showing the effects of the severe strains and stresses to which it has been subjected. Some of the crushed coal is converted into lenticular flakes with a lustre and colour somewhat resembling black lead. Another effect of the slipping of the coal upon itself is the warped or twisted folding of the coal beds.

MIDDLE DIVISION

In the Middle division, on the north branch of Hay river, a number of coal claims are staked and some surface work has been done to prove the number and thickness of the coal seams. On the river about a mile below the mouth of Seep creek two seams of good clean coal, 8 feet and 40 feet thick respectively, are exposed. These seams are possibly near the base of the Kootenay measures, and occur in the following sections (*See* Figure 3):

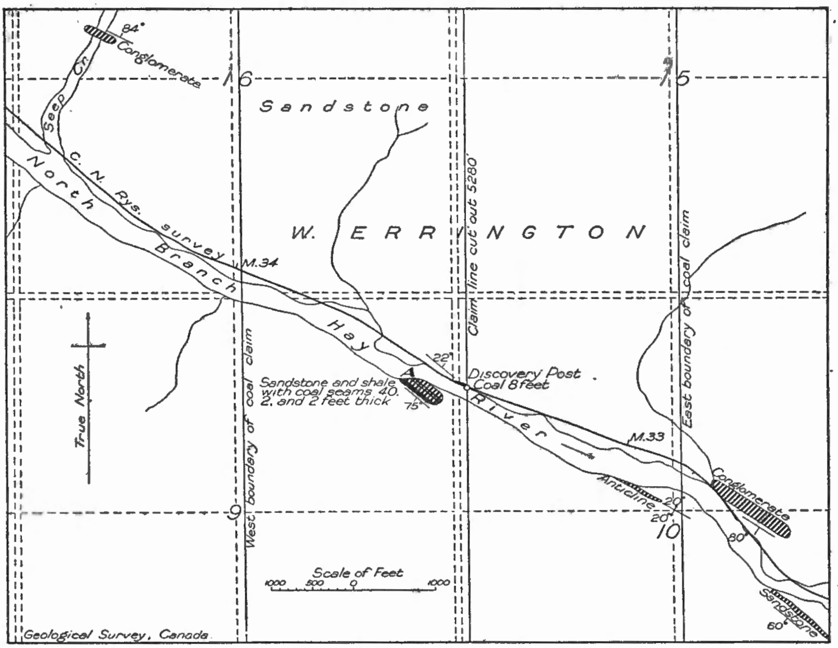

FIGURE 3. W. Errington coal claim on north branch of Hay river, below Seep creek, tp. 52, range 3, W. 6th mer. (*See also* Figure 2).

At Discovery post, W. Errington claim, N.W. sec. 10, tp. 52, range 3, W. 6th mer.

	Feet
Sandstone	50
Shale	6
Coal	8
Shale	12
Sandstone	20

N.E. sec. 9, tp. 52, range 3, W. 6th mer., 300 feet up the river from outcrop the following section is exposed (*See* A, Figure 3).

	Feet
Shale banded with sandstone	25
Coal	40
Shale	—
Sandstone	45
Coal	2
Shale	10
Sandstone	25
Coal	2

About 3 miles farther up the river, on a small stream that enters Hay river from the left, about 15 feet of coal is exposed without showing either wall. Where the creek comes through a gap in the limestone, considerable coal float was observed. As the wash was heavy, no attempt was made to expose the seams, but the float is doubtless from seams in the upturned strata in front of the limestone. A mile above this, opposite the mouth of Carson creek, on a small stream entering from the left, three seams, 2 feet, 18 feet, and 24 feet thick, were found. These seams are all clean coal.

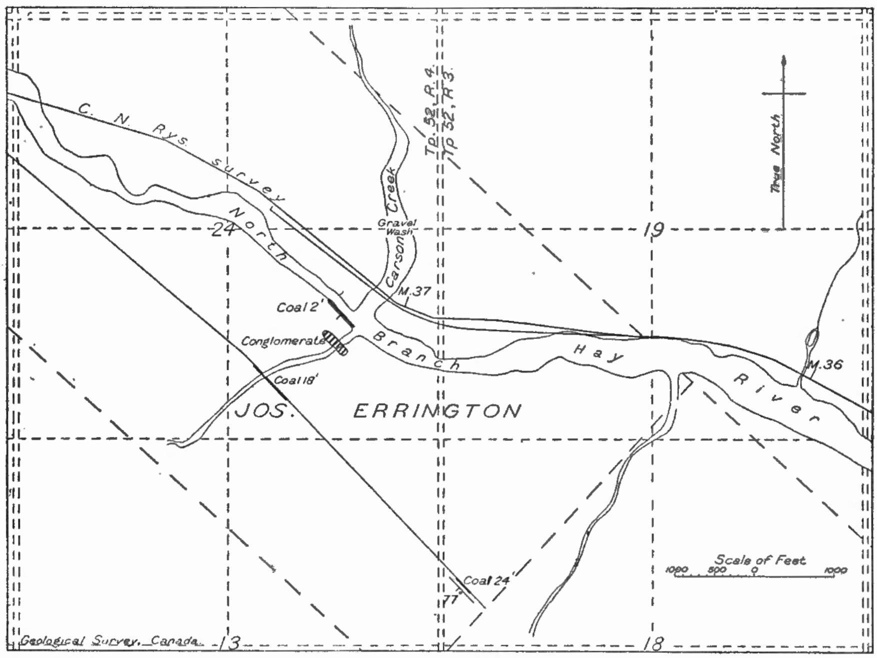

FIGURE 4. Jos. Errington coal claim on north branch of Hay river, opposite mouth of Carson creek, tp. 52, ranges 3 and 4, W. 6th mer. (*See also* Figure 2.)

On the Jos. Errington claim (*See* Figure 4), sec. 24, tp. 52, range 4, W. 6th mer., the following section is exposed.

Section		Coal as received		Calculated for dry coal at 105° C.
	Feet			
Grey shale	20	Moisture	2·2	
Coal—three or four ½-inch bands of clay	18	Volatile matter	15·3	15·6
Coaly shale	40	Fixed carbon	63·8	65·3
		Ash	18·7	19·1
		Fuel ratio	4·15	

Forms small lumps of dense hard coke. Sample taken from 6-foot face in 18-foot seam.

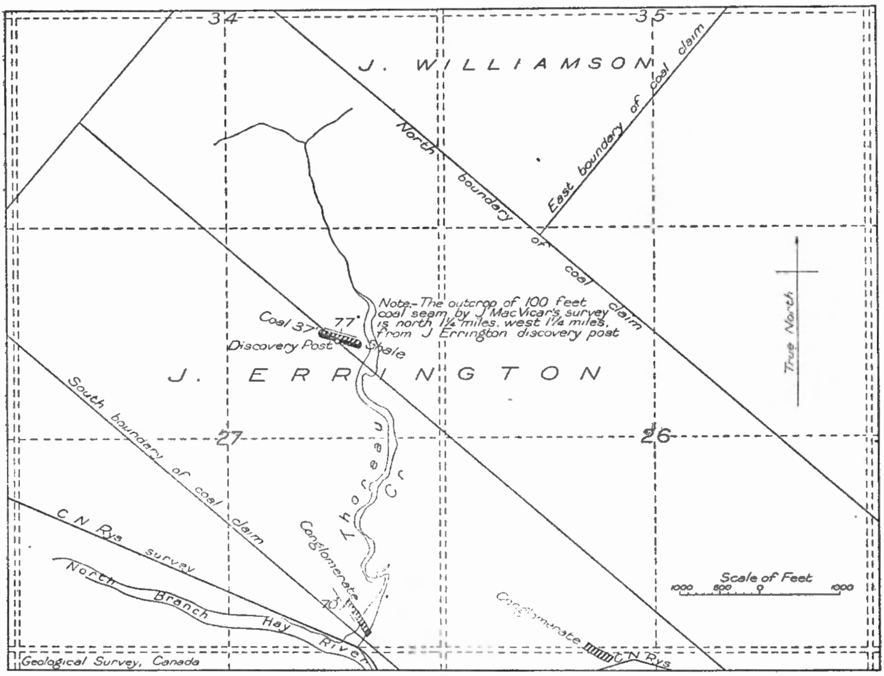

FIGURE 5. J. Errington coal claim on Thoreau creek, north branch of Hay river, tp. 52, range 4, W. 6th mer. (*See also* Figure 2).

Two miles up Hay river, on Thoreau creek entering from the right, a 37-foot seam of coal is to be found. On the J. Errington claim, three-quarters of a mile up Thoreau creek, sec. 27, tp. 52, range 4, W. 6th mer. (*See* Figure 5) the following section is exposed.

Section		Coal as received		Calculated for dry coal at 105° C.
	Feet			
Shale—hanging wall	40			
Coal	3	Moisture	2·9	
Shale	2	Volatile matter	23·6	24·3
Coal	8	Fixed carbon	56·9	58·6
Clay	6	Ash	16·6	17·1
Coal	4½	Non-coking		
Coal and shale	9	Fuel ratio	2·40	
Coal	5			
Clay shale	2	Sample taken from 13-foot seam of clean coal.		
Coal, clean (*See* analysis)	13			
Sandstone—foot-wall	6			

J. Williamson Claim

Again to the northwest at the summit between Thoreau creek and Berland river, in sec. 33, tp. 52, range 4, W. 6th mer., a coal seam is exposed for over 100 feet on the surface. No work, however, has been done on it to determine its exact thickness. It appears to be good clean coal with no large partings.

Up the north branch of Hay river from these exposures is a tributary from the northwest called Eagles Nest creek on which a small, workable seam of coal 4 feet thick was opened. This is near the southwestern border of the basin and not far from the limestone outcrop of the second range.

MacConnachie Claim, Sec. 2, Tp. 53, Range 5, W. 6th Mer.

The next important coal exposure is near the summit between the north branch of Hay river and Little Berland river. The seam there shows a width of over 100 feet. It is high up on the hillside just a few feet in front of the limestone. The measures are doubtless overridden by the limestone as the precipitous face of the latter rises over a thousand feet above the coal. (For location see legend, Figure 6.)

A section of this seam and analysis of the coal follows:

Section		Coal as received		Calculated for dry coal at 105° C.
	Feet			
Sandstone	50			
Coal, soft and friable	60	Moisture	1·9	
Coaly shale	10	Volatile matter	26·2	27·7
Coal, soft and friable	35	Fixed carbon	58·8	59·9
Coal, hard lumpy	25	Ash	13·1	13·4
Shale	10	Non-coking		
Sandstone	100	Fuel ratio	2·25	
		Sample from 25-foot exposure in seam		

Samples were also taken of carbonized and silicified wood, all lying within an horizontal distance of 5 feet in the coal seam.

A short distance below Persimmon creek an old prospect pit was found which had fallen in. The exposure is an outcrop of shale and sandstone, striking east 30 degrees south and dipping 70 degrees southwest (*See* Figure 6). Coal outcrops on the downstream side of this exposure. The old tunnel has caved in. It is possible that this is near the Lorne Mitchel claim staked by Thomas Russell in 1909, and that the following description from the report of the Rocky Mountain Collieries Limited, from Mr. Russell's notes, has reference to this locality:

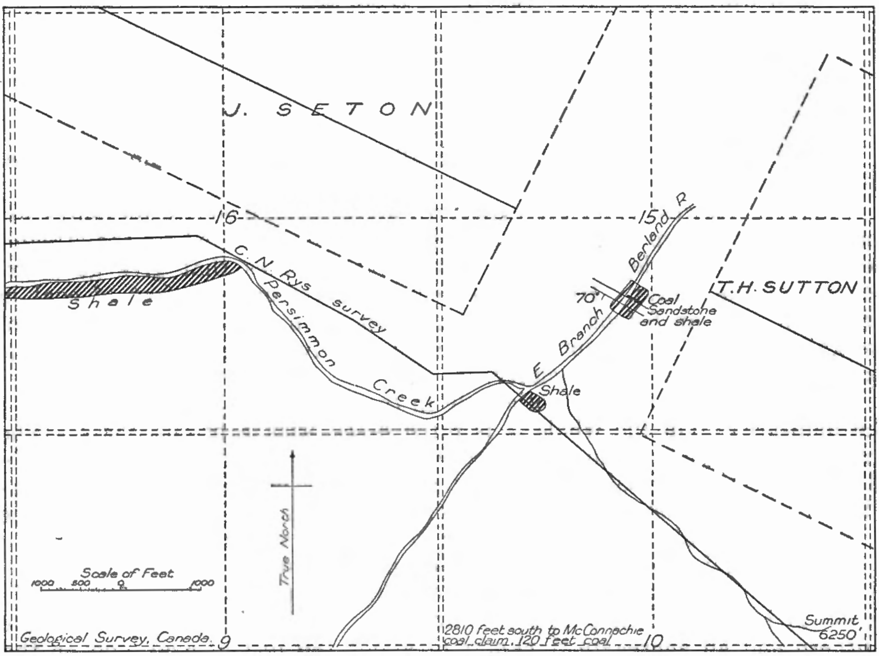

FIGURE 6. Coal claims at east branch of Berland river near Persimmon creek, tp. 53, range 5, W. 6th mer. (*See also* Figure 2).

"*Location.* Situated on the south side of the ravine on the headwaters of the south fork of the main branch of Baptiste river, within the first range of the Rockies. The ridge runs out between the main branch and this fork of the river. Russell places the claim in township 54, range 5, west of the 6th meridian. The Eaton claim is on the north side of the same ravine.

"*Topography and Geology.* Starting from the point where the trail crosses the south branch of the river, the open flat continues 100 feet above the river to the main river crossing. The ravine through the limestone is 8 miles to the property. Following the river after passing the limestone formation about a mile, the river turns to the left leaving the limestone on one side and the Kootenay measures on the other side. This continues for about a mile, then the river turns more westerly, flowing across the Kootenay measures another mile to the Carboniferous formed ridge, through which it passes at right angles to the strike. In half a mile the Fernie shales are again passed and then the coal measures continue for about 4 miles, at the head of which these claims are staked.

"*Coal Contents.* Russell only opened one seam, with the following results:

Section	Feet	Inches	*Analysis*	
Shale	2	0	Moisture	0·61
Soft coal	3	7	Vol. comb	21·53
Clay	0	4	Fixed carbon	62·97
Soft coal	8	0	Ash	14·89
Hard coal	4	0	Moisture	0·95
Shale	0	4	Vol. comb	24·88
Hard coal	1	2	Fixed carbon	69·84
Shale			Ash	4·33
Coal	17	5		

"The strike of this seam is north 80 degrees west, and dip 85 degrees southwest."

West-northwest from the exposures above described the measures are mostly concealed up to the headwaters of Muskeg river, where the streams occupy gorge-like depressions with precipitous sides that give good exposures of the strata. Here, A. Joachim reports over 20 feet of coal in one seam, also an 8-foot seam and a 4-feet seam, besides other seams of workable size. The amount of float coal in the river wash plainly shows the existence of seams in the vicinity.

A marked variation is noticeable in the coal in the Middle division of the map-area. On the whole it is pitch black with a bright lustre. The fracture is irregular, some of the coal being brittle and some tough. In places mineral charcoal is plentiful; also bright, lustrous bands or lenses which range from one-eighth of an inch to over an inch in thickness. The crushed and friable condition of some of the coal shows the great pressure it has been subjected to in the mountain-making processes.

A detailed section for this division showing the number of workable seams is lacking. There appears, however, to be in five seams at the southern end an aggregate thickness of about 186 feet of coal, and on the northern end an aggregate of about 32 feet in three seams. Both sections, however, are incomplete, the southern one, owing to local thickening, probably overstating the true thickness and the northern one understating it. It is not an easy matter, therefore, to fix an average upon which to base a tonnage estimate. It is preferable to err in underestimating rather than overestimating the quantity. A total thickness of 40 feet of coal would appear to be a conservative estimate in an area of 48 square miles, which is equivalent to 2,174,400,000 tons.

NORTHERN DIVISION

The Northern division is the largest of the four divisions which constitute the map-area (Figure 7). Its length is 30 miles from Muskeg river to Sheep creek and its width is about 20 miles. From the headwaters of

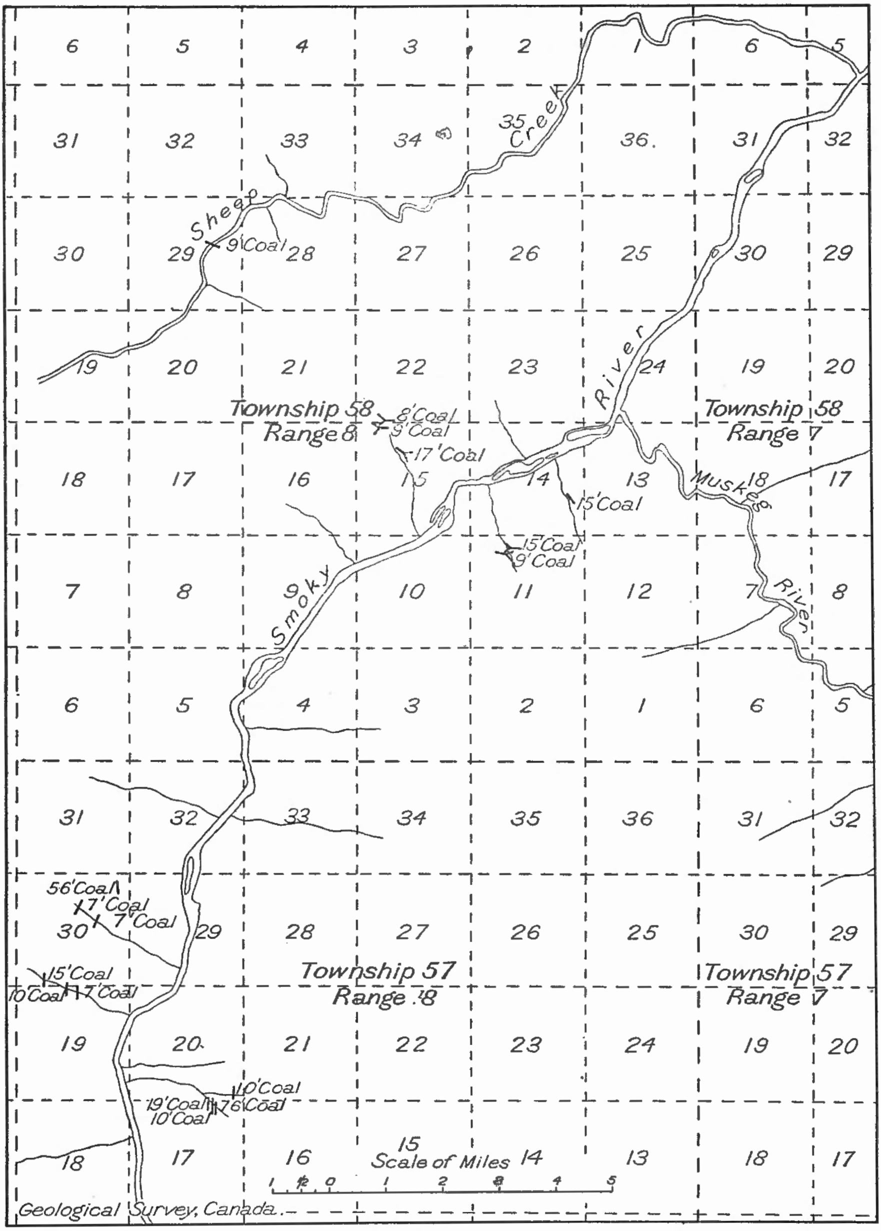

FIGURE 7. Sketch map showing occurrences of coal in the vicinity of the junction of Smoky and Muskeg rivers, Alberta.

Muskeg river it rapidly broadens into a rolling upland covered with drift and timber, that extends to Grand Cache. What little exploration has been done in this section has revealed coal beds of workable thickness.

Following the valley of Muskeg river from the confluence of the two streams forming its headwaters, few outcrops of rock are to be seen until 2 or 3 miles above A la Passe lake. Here, on a small stream that enters from the left, Thos. Russell discovered coal. He made the following partial section of the measures:

	Feet	Inches
Conglomerate	400	0
Coal	11	6
Rock strata	350	0
Coal	25	0
Rock strata	200	0
Coal	7	0
Rock strata		

About 5 miles due west of this exposure, on the bank of a small tributary of Cowlick creek and close to the Government trail, Mr. Gaetz reports an 8-foot seam of good coal. Four miles farther west several workable seams are exposed on C. C. Walton's claim, but the details are not at hand. Due west about 9 miles, coal is reported at the mouth of Muddywater river.

At the headwaters of Muskeg river were located the Turnbull and Hanna claims. The Turnbull claim is estimated to have been situated in the northwest corner of township 53, range 6, W. 6th mer. The following description of it is quoted from a report by C. L. Hower to Rocky Mountain Collieries, Ltd., 1910.

Russell identified the coal as belonging to the Kootenay coal measures. He states that "it is a continuation of the same measures that are found through the limestone range in tp. 53, range 3, W. 6th mer., and that similar outcrops have been found this year in tp. 58, ranges 8 and 9, W. 6th mer. The north fork of Baptiste (Berland) river runs its full distance through the Kootenay coal measures and also Muskeg river from where the trail connects up its headwaters where the claims are located.

"Two or three anticlines parallel the strike of the measures, which is regularly north 52 degrees west, with a slight tendency to run more westerly to north.

"Both claims are in the Kootenay formation. The limestone of the Carboniferous formation parallels the western boundary of the claims, about 100 yards distant."

Section	Ft.	Ins.	Analysis	Sample No. 1	Sample No. 2
Soft, dirty coal	3	0			
Yellow clay	0	2			
Coal and shale	8	0	Volatile matter	30·57	25·51
Soft coal	3	3	Fixed carbon	59·05	61·41
Coal and shale (sample No. 1)	5	0	Ash	10·38	13·08
Soft coal	3	0			
Hard coal (sample No. 2)	9	6			
Shale	0	4			
Hard coal	0	8			

The Hanna claim situated on the northwest corner tp. 53, range 6, W. 6th mer., shows the following section of the Kootenay.

Section	Ft.	Ins.	Analysis	Sample No. 1	Sample No. 2
Fine, shaly sandstone					
Fine sandstone			Moisture	1·46	1·32
Fine, dark, shaly sandstone			Volatile matter	25·20	27·80
Clean coal (sample No. 1)	6	0	Fixed carbon	54·92	58·38
Clay	0	3	Ash	18·42	12·50
Shale	0	3	Sulphur	0·25	0·10
Clean coal (sample No. 2)	5	6			

At the junction of Sulphur and Smoky rivers a 6-foot coal seam is exposed in the Adam Joachim claim, sec. 24, tp. 56, range 9, W. 6th mer. It strikes east 43 degrees south and dips 85 degrees southwest. A sample of the coal yielded the following results when analysed.

Coal as received		Calculated for dry coal at 105° C.
Moisture	1·3	
Volatile matter	16·9	17·1
Fixed carbon	79·3	80·3
Ash	2·3	2·6

Fuel ratio 4·70
Non-coking

Near Grand Cache lakes a coal seam 8 feet thick is exposed. Samples of this coal and some related fossils from the Abbot claims, sec. 4, tp. 57, range 7, W. 6th mer., were submitted by Mr. J. R. Akins, D.L.S., Department of the Interior. The fossils (a few leaves and bivalve shells) are identified by Mr. F. H. Knowlton of the United States Geological Survey as being *Zamites acutipennis* Heer, a plant of the Kootenay formation. The shells represent a marine genus, *Tancredia,* found also in the Jurassic. One of the samples of coal was analysed by the Mines Branch, Department of Mines. The results of this and of another analysis are given below. Both show that the coal is similar in character to that of the Brazeau field. Several seams are reported, but there appears to be on each section a seam between 8 and 10 feet thick in beds inclined at about 45 degrees to the horizontal. This occurrence is possibly the southern end of a large area which crosses Peace river in the vicinity of the mountains.

	I	II
Moisture	1·22	1·1
Volatile combustible	24·33	23·0
Fixed carbon	68·67	70·6
Ash	5·73	5·3
	100·00	100·0
Coal firm and coherent	74·40	Fuel ratio 3·05 Forms good coke

On Teare creek, sec. 2, tp. 57, range 7, W. 6th mer., five seams of coal exposed are described below by A. W. Hawkins:

"*Exposure No. 1.* Beginning at the bed of the creek, and going upward, were seen the following strata. First about 10 feet of brown sandstone, then six bands of coal and shale mixed, and from 1 to 2 feet thick; between these bands were beds of sandstone; these covered about 15 feet and afterwards there was about 60 feet of shale and sandstone, with small layers of iron clay. On top of this was about 30 feet of alternate bands of coal and highly carbonized shale; the bands of coal in these 30 feet are from 2 to 8 feet thick and above this about 60 feet of brown sandstone with a couple of bands about one foot thick of coal. The dip of these seams was about 60 degrees from the horizon towards the northeast, the strike was about south 45 degrees east.

"*Exposure No. 2.* The formations of all the exposures are very similar and much like that described in No. 1, but the outcrops of coal are different. Here was found a seam of coal from 8 to 10 feet thick; this seam was better defined than any in the preceding exposure. Part of the coal here projected out from the rocks, and it had a very good appearance. The dip was about 45 degrees towards the northeast and the strike was about south 20 degrees east.

"*Exposure No. 3.* Here was seen a seam about 6 feet in thickness, but was not nearly so well defined, nor of as good a quality as No. 2. The dip was 75 degrees towards the northeast and the strike about south 50 degrees east.

"*Exposure No. 4.* This was very similar to No. 3, but the seam was much wider, and twisted and crushed. There has evidently been a folding of the rocks here, as the dip was completely changed, being about 50 degrees towards the southwest, whereas the strike was about due north.

"*Exposure No. 5.* The coal of this exposure was the best found on Creek No. 1, but the seam was only 4 feet in thickness, and the walls were very good, the dip being about 50 degrees towards the northeast and the strike south 20 degrees east.

"*Exposure No. 6.* This was the one found on Creek No. 2 and appeared to be the most promising of any. It was about 8 to 10 feet thick, and the coal appeared to be of good quality. The dip here was nearly opposite that in Creek No. 1, being about 45 degrees towards the northwest and its strike was about north 30 degrees east.

"This coal is thought to belong to the Kootenay measures, and, if so, it is the farthest north along the Rockies that this variety has been found."[1]

In a section exposed on Sheep creek, coal seams of the following dimensions were found in natural exposures, viz., $2\frac{1}{2}$, 4, 12, 9, and 15 feet. No prospecting was done in this section, and as the bedrock is partly concealed other seams may exist.

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[1] Hawkins, A. H., Top. Surv. Br., Dept. of Interior, Ann. Rept., 1909-10, pp. 90-91.

Up Sheep creek other exposures were found and claims staked. In a canyon on the left bank in sec. 9, tp. 58, range 9, W. 6th mer., a 14-foot seam of coal on the Campbell claim is exposed, from which pieces of coal 2 feet or more square have fallen down and been exposed to the elements for years with no apparent bad effects. The seam shows jointing and bedding planes, strikes north 36 degrees west, and dips 43 degrees southwest. It consists of clean, hard coal of the following composition.

Coal as received		Calculated for coal dried at 105° C.
Moisture	1·3	
Volatile matter	17·4	17·6
Fixed carbon	78·2	79·2
Ash	3·1	3·2
Fuel ratio 4·50 Non-coking		

In the adjoining gulch about a mile above the exposures just noted is the Moberly coal claim, situated in sec. 4, tp. 58, range 9, W. 6th mer.

Section	Feet	Coal as received		Calculated for coal dried at 105° C.
Sandstone	200			
Coal exposed and not at roof	10	Moisture	1·3	
Sandstone and shale	25	Volatile matter	17·0	17·2
Coal	3	Fixed carbon	78·7	79·8
Shale and sandstone	150	Ash	3·0	3·0
Coal, clean	22			
Sandstone		Fuel ratio.....4·65 Non-coking		

The coals from the Campbell and Moberly claims are tough, hard, and free from partings or impurities.

Across Sheep creek on the right bank, in a local fold, a 6-foot seam and a 9-foot seam similar in physical qualities to the foregoing are exposed. They are in sandstone and shale that alternate in layers 1 to 10 feet thick. There is a conglomerate band about 500 feet downstream from the coal exposure, but no prospecting has been done near it to find coal seams.

Up Sheep creek a coal seam of 4 feet is exposed about a mile above Moberly coal seam. Coal indications are also reported on Compton creek about 5 miles above the trail crossing.

A good exposure of the coal measures occurs on Smoky river, above the mouth of the Muskeg, on which considerable prospecting and development has been done.

Tunnels have been driven on five of the seams, 100 feet or more into the hillside. In Figure 7 locations of outcrops and tunnels are indicated.

Analyses of the average samples taken will be found in the succeeding table. A partial section from sec. 15, tp. 58, range 8, W. 6th mer., Smoky river, follows:

	Feet
Sandstone and shale	600
Coal	3½
Sandstone and shale	175
Coal	3½
Sandstone and shale	150
Coal	12
Sandstone and shale	20
Coal	4
Sandstone and shale	1,200
Coal	4
Sandstone and shale, bottom of measures concealed	
	2,172

Analyses of Coal From Smoky, Muskeg, and Sheep Rivers, Alberta

Location			Thickness of seam	Moisture	Ash	Volatile matter	Fixed carbon	B.T.U.	—
Sec.	Tp.	Range W. 6th M.	Feet						
15	58	8	8	1·8	1·9	20·8	75·5	14,900	
			8	2·6	5·1	21·1	71·2	13,960	
			8½	2·5	11·1	17·3	69·1	13,690	
Muskeg river			4	1·6	25·8	18·9	53·7	11,020	
			15	1·3	15·9	19·7	63·1	12,790	
11	58	8	16	1·4	13·4	17·8	67·4	13,040	
			9	2·1	13·0	18·3	66·6	12,750	
			9	1·5	4·9	19·6	74·0	14,610	
			7½	1·5	9·8	21·2	67·5	13,630	
N ½ 19	57	8	7	1·2	2·8	14·6	81·4	14,830	
SW. ¼ 22	58	8	8	0·5	16·5	19·6	63·4	12,715	From the tunnels
NW. ¼15	58	8	9	0·4	8·2	21·1	69·8	14,040	" "
NW.¼ 15	58	8	17	1·1	6·5	18·4	74·0	14,100	" "
NW.¼ 11	58	8	12	0·4	11·7	18·5	69·4	13,600	" "
NW.¼ 11	58	8	9	0·3	6·9	19·8	73·0	15,070	" "
NE.¼ 30	57	8	7½	1·3	8·0	12·5	78·2	13,862	
NE.¼ 30	57	8	7	0·9	4·0	13·4	81·7	14,706	
N. ½ 19	57	8	7	2·9	2·2	14·8	80·1	13,800	
N. ½ 19	57	8	10	1·7	6·3	18·1	73·9	13,990	
SW. ¼ 30	57	8	15	1·6	7·3	19·4	71·6	13,255	
NE.¼ 30	57	8	5	0·9	1·9	14·7	82·5	14,987	
SE. ¼ 20	57	8	10	0·7	4·4	22·6	72·3	14,800	
NE.¼ 17	57	8	7½	0·5	8·2	18·5	72·8	14,300	
NE.¼ 17	57	8	10	0·7	7·8	15·3	76·2	13,913	
NE.¼ 17	57	8	13	0·5	7·6	18·4	73·5	14,220	
NE.¼ 29	58	8	9	1·0	6·7	20·3	71·9	14,160	

NOTE. A number of 50-lb. samples, carefully taken for coking trials from some of these seams, were tested in the coke ovens at Fernie, B.C., and found to yield an excellent coke.

Samples 1 to 10 were collected by O. S. Finnie, Department of the Interior, 1919, and analysed at the Mines Branch, Department of Mines.

The remainder were collected by John MacVicar. They were analysed by Mr. Graham, Provincial laboratory, Edmonton, Alberta. [1]

[1] *See* Geol. Surv., Can., Sum. Rept., 1916, p. 92.

The various locations are indicated on Figure 7. Several of these samples were taken from different exposures of the same seam.[1]

It would seem conservative to estimate the semi-anthracite area at 6 square miles and the seam 7 feet thick. The available coal would then be approximately 58,500,000 tons.

The other coal in this field is bituminous and semi-bituminous, but presents a wide variation in physical appearance and character. In regions of local disturbance it is soft and crushed, whereas away from such disturbances it is blocky and compact. Some of the coal is prominently bedded with cubical jointing. The colour is jet black with vitreous lustre. On exposure to the atmosphere it dulls somewhat.

From the above tables of analyses it will be seen that most of the coal is a bituminous or steam coal, with high carbon content, not generally high in ash, and always low in sulphur. Practical tests on sixty-pound samples at Hosmer show that a high grade of coke can be made. In most of the seams the fixed carbon content is high, approaching that of semi-anthracite. In many coals there is a serious loss from breakage in transportation and in the boiler room. The strength and hardness of some of this coal is greatly in its favour.

With few exceptions the coal beds throughout the Northern division show less fracturing and crushing as the result of the pressure to which the measures were subjected in the process of folding and uplifting. The exceptions are in loci of faulting and minor folds. The measures are situated in front of the limestone ranges and extend for about 25 miles northeastward. In this favourable position the forces were expended on a much wider area than if expended between two uplifts of the Rockies where the measures would be held as in the jaws of a vise.

Quality and Tonnage of Coal in Northern Division. Semi-anthracite and semi-bituminous coal occurs in this division, and perhaps the principal economic interest which attaches to this part of the map-area lies in the existence of a workable 7-foot semi-anthracite coal bed. The bed occurs under geological conditions similar to those which generally obtain throughout the bituminous regions of Alberta, but the composition of the coal entitles it to rank as high in the trade as that mined in the mountains to the south. It is the lowest workable seam in the measures, though underlain by smaller seams the thickest of which is 3 feet. The character of this lower coal was not determined as the seam appears to be too thin to mine under present conditions, though it may prove valuable.

[1] NOTE. For comparison of analyses and classification of coals of the southern mountain area of British Columbia, *See* "The Coal Fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia," Geol. Surv., Can., Mem. 53, p. 77, also report by D. B. Dowling, this summary, p. 63.

The semi-anthracite coal is bright, shining, and compact, with the following composition:

Sample	Moisture	Volatile matter	Fixed carbon	Ash	Sulphur
Y-5	0·9	13·4	81·7	4·0	0·72
Y-3	2·9	14·8	80·1	2·2	0·82
N-6	0·9	14·7	82·5	1·9	0·16
Seam No. 4	1·25	13·52	81·3	3·47	0·46
" No. 5	2·00	12·9	82·4	2·70	0·66
" No. 6	0·49	16·04	81·14	2·33	

From the claims on Smoky river average samples weighing about 50 pounds were carefully taken from the face of the tunnels. These were put in suitable sheet iron boxes, weighed, and placed in an oven at Hosmer, B.C., which was being charged. Thus they coked under perfectly normal conditions. The coke obtained had a light, lustrous appearance, great strength, no spongy parts, a clear metallic ring, and yielded the following results on analysis:

Analysis of Coke Made from Samples Taken from Face of Original Tunnels, Both Sides of Smoky River (near Muskeg River)

Tunnel No.	Moisture	Vol. comb.	Fixed carbon	Ash	Width of sample cut from seam
					Feet
1	0·2	0·4	81·7	17·7	8
2	0·2	0·7	86·8	12·3	9
3	0·2	0·8	84·3	14·7	17
4	0·8	1·3	87·9	10·1	15
5	0·3	0·0	77·3	22·4	9

In order to see if this coal deteriorated on exposure samples taken at the surface were analysed and compared with the results obtained from fresher samples taken at the ends of the tunnels. The following table shows the comparative results and that no marked deterioration was found.

Analyses of Samples from Surface and from End of Tunnel

Tunnel No.	Sample No.	Width	Moisture	Ash	Volatile matter	Fixed carbon	B.T.U.	
		Ft. In.						
1	1a	6 8	0·9	15·3	19·7	64·1	12,075	Outcrop
1	1b	8 0	0·5	16·5	19·6	63·4	12,715	End of tunnel
2	2a	8 0	0·4	10·2	19·3	70·1	13,903	Outcrop
2	2b	7 6	0·4	8·2	21·1	69·8	14,040	End of tunnel
3	3a	12 0	1·6	7·3	19·4	71·6	13,784	Outcrop
3	3b	11 6	1·1	6·5	18·4	74·0	14,100	End of tunnel
4	4a	12 0	1·0	7·7	19·1	72·2	14,015	Outcrop
4	4b	11 0	0·4	11·7	18·5	69·4	13,600	End of tunnel
5	5a	8 0	(Not analysed)					
5	5b	11 7	0·3	6·9	19·8	73·0	15,070	End of tunnel

Data upon which to base a computation of the quantity of coal are not as full as could be desired. That part of the field, however, upon which the least information is available is the part where the disturbances are the most profound, and the percentage of waste would be greatest. Although the seams might be expected to be as numerous and as persistent in this as in the better known areas, sufficient prospecting has not been done to prove this view. In the circumstances it seems advisable to base a computation upon the data at hand and for an area of conservative size there is approximately 148 square miles of coal land with a thickness of coal of 43 feet, or approximately 7,000,000,000 tons of coal.

EASTERN DIVISION

The coal measures within this division of the map-area have not been prospected, so far as is known. In the course of the reconnaissance under review no attempt was made to prospect them in detail, but a number of coal seams that will yield bituminous coal suitable for steam, metallurgical, and domestic use were found. The Cretaceous coal areas were followed northwesterly from where Hay river cuts through the outer ranges of Rocky mountains in tp. 53, range 1, W. 6th mer., to tp. 55, range 1, W. 6th mer. The following occurrences were observed and are of great importance as proving the existence of coal; the coal was found at three horizons.

Coal occurs in the Montana formation where beds are exposed on the bank of a creek, to the right of the trail, 12½ miles from Entrance. The seams are 15 and 18 inches thick, between beds of sandstone and shale. Coal occurs, also, on the bank of Hay river, at the trail-crossing, where two 18-inch seams are exposed. On Moberly creek considerable float is to be seen, but no seams were found, the rocks being concealed by drift. On Pinto creek a number of thin seams are exposed in the banks, the thickest, which outcrops near the trail-crossing, having a thickness of 3 feet. Thin seams, on one of which some prospecting was done, are reported to occur on the Little Berland, and on the Berland two 15-inch seams outcrop in a cut bank about a mile below the trail.

In the section of rocks exposed on the Little Berland a 15-inch seam was found which was assigned to the Colorado formation from its stratigraphical position.

Outcrops of bituminous coal of Kootenay age are sparingly represented in the greater part of the area under examination. This is probably because the seams are covered by glacial drift, or because only the barren parts of the Kootenay are exposed. When examining the adjoining areas in 1916 it was found that about 600 to 700 feet of the top of the Kootenay, and about 1,200 feet of the bottom, are barren of coal or carry only thin seams. On Moberly and Hay rivers, for example, no coal seams were seen in the Kootenay outside the first range, but on Moberly river considerable bituminous coal float was found where the formation crosses the creek. On the Little Berland two seams of coal occur enclosed in shales and sandstones. The upper seam is 3 feet thick with a 6-inch parting of grey shale. The lower seam has 3 feet of clean coal in a lower bench, then 1 foot of sand-

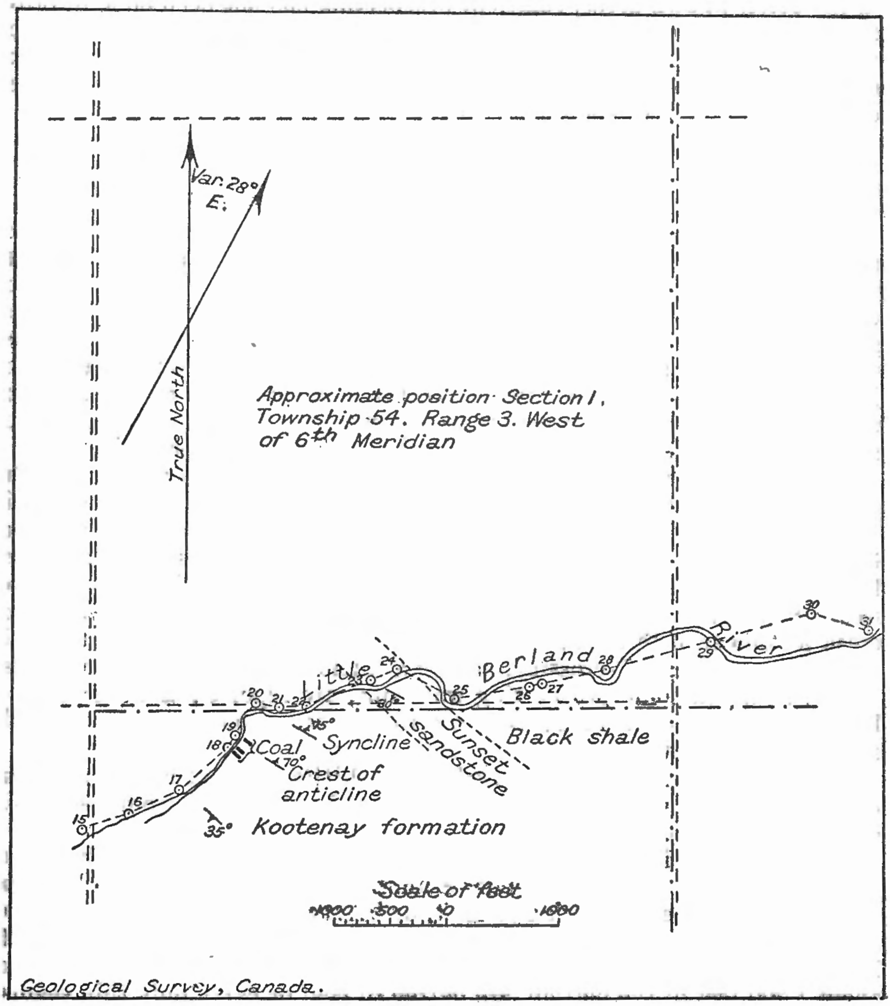


FIGURE 8. Diagram of upper part of Little Berland river (*See also* Figure 2). The numbered stations refer to survey by J. MacVicar, 1919.

stone, and then 1 foot of coal. On Moon creek two seams were found and sampled. One, a 5-foot seam with a 6-inch parting of shale in the middle, contained coal that was bright and clean but friable.

The following sections and analyses of coal are given of the exposures observed in this area:

In sec. 31, tp. 52, range 27, W. 5th mer., about 10 miles northwest of Entrance, there are two seams of coal both 18 inches thick.

In sec. 27, tp. 52, range 27, W. 5th mer., the following strata strike 85 degrees, and dip 34 degrees northwest.

	Ft.	Ins.
Sandstone	12	0
Coal	1	0
Shale	8	0
Coal, soft and rusty	1	3
Sandstone	10	0
Coal	0	3
Shale	1	0
Coal	1	6
Sandstone		

Among the early explorations for coal in this district may be mentioned that of Mr. Thos. Russell, who in 1909 staked several coal claims on Little Berland river. There the Kootenay measures occur east of the outer range in a double fold, a syncline near the mountain followed by a gentle anticline to the east. This structure occupies about 3 miles of the valley of the Little Berland in the northeast quarter of tp. 53, range 3, W. 6th mer. From Mr. MacVicar's notes on the traverse, plotted in Figure 7, the following section of the exposures of the anticlinal part of the structure is compiled. It contains two or three coal seams, two of which from section 35 were sampled and analysed.

	Section	Ft.	Ins.
Kootenay			
	Thinly bedded shale (sandy)	37	0
	Yellow sandstone	1	0
	Thinly bedded, sandy, grey shale	6	0
	Yellow sandstone	2	6
	Thinly bedded, sandy, grey shale	34	0
	Grey sandstone	6	0
	Black shale (opposite Sta. B. 16)	65	0
	Concealed	43	0
	Bluish grey sandstone	24	0
	Concealed	15	0
	Grey sandstone	0	6
	Yellow weathering sandstone	14	0
	Concealed	14	0
	Thinly bedded, red sandstone	29	0
	Concealed	12	0
	Grey, shaly sandstone	7	0
	Concealed	12	0
	Grey, siliceous shale	27	0
	Concealed	21	0
	Thinly bedded, grey sandstone	27	0
	Siliceous shale	6	0
	Black shaly sandstone	86	0
	Reddish sandstone	26	0
	Black shale	36	0
	Thinly bedded, grey sandstone	24	0
	Black shale	20	0
	Ironstone	1	0

	Section	Ft.	Ins.	Ft	Ins.	Notes
Kootenay	Siliceous black shale or shaly sandstone			13	0	
	Black sandstone			51	0	
	Concealed			33	0	
	Concealed			8	0	
	Sandstone apex of anticline (*See* Sta. B. 17)			28	0	
	Concealed			58	0	
	Black sandstone			2	0	
	Concealed			100	0	
	Thinly bedded, black shale			31	0	
	Yellow sandstone			7	0	
	Grey sandstone with thin interbeds of black shale			78	0	
	Grey shale			47	0	
	Reddish sandstone			7	0	
	Probably shale			17	0	
	Grey and reddish sandstone			50	0	
	Probably shale			22	0	
	Sandstone crumpled			13	0	
	Black shale			7	0	
	Sandstone			2	0	
	Grey shale	2	0			
	Coal	2	0			
	Grey shale	0	6			
	Coal	1	0	13	0	
	Black shale	2	0			
	Coal	0	3			(Sample No. 2)
	Black shale	5	0			(For analysis *See* p. 57)
	Grey sandstone			5	0	
	Black shale			1	0	
	Ironstone and sandstone			7	0	
	Grey sandstone with two thin bands of shale			10	0	
	Black shale			4	0	
	Grey sandstone			10	0	
	Grey shale with thin band of sandstone			6	0	
	Grey sandstone			33	0	
	Grey, thin-bedded shale			9	0	
	Grey sandstone			6	0	
	Concealed			49	0	
	Black shale			1	0	
	Sandstone			0	6	
	Black shale			1	0	
	Alternate bands 18 inches thick of shale and sandstone			20	0	
	Black shale			18	0	
	Grey sandstone			12	0	
	Black shale			7	0	
	Grey shale			18	0	
	Black shale	17 (Feet)				
	Coal	1		22	0	
	Sandstone	1				(Sample No. 1)
	Coal	3				(For analysis *See* p. 57)
	Black shale with ironstone			13	0	
	Sandstone			0	6	
	Black shale			14	0	
	Sandstone			1	0	
	Thinly bedded, black shale			15	0	
	Concealed			55	0	
	Thinly bedded, shaly, grey sandstone			18	0	
	Concealed			47	0	
	Thinly bedded, grey sandstone			50	0	
	Shale			3	0	
	Coal	0	3			
	Black sandstone	1	6	3	0	
	Coal	1	3			(Near Sta. B. 18)
	Black shale			16	0	
	Sandstone, grey			32	0	

	Section	Ft.	Ins.
Kootenay			
	Shale	10	0
	Grey sandstone	15	0
	Grey, thinly bedded, shaly sandstone, with two 1-foot seams of black shale	15	0
	Massive, grey sandstone	14	0
	Black shale	5	0
	Sandstone, grey	1	3
	Black shale	4	0
	Sandstone, grey	10	0
	Grey shale (near Sta. B. 20)	27	0
	Strike south 85 degrees east. Dip north of 75 degrees		
	Sandstone, grey	48	0
	Shale, grey	17	0
	Grey sandstone	48	0
	4-foot and 6-foot bands of grey sandstone and thinly bedded, grey shale	116	0
	Black shale	200	0
	Concealed, probably black shale over small syncline	368	0
	Bluish grey sandstone	70	0
Belongs to black shale series	Interbedded and crossbedded, grey and light shale, with sandstone beds 4 feet to 6 feet thick	100	0
	Apex of anticline		
	Concealed	270	0
	(Halfway between Stas. B. 24 and B. 25)		
	Black shale	1,000	0
	Sandstone, grey	50	0
	Concealed	500	0
	Black shale	2,500	0
	Interbedded shale and sandstone with thin (Sta. B. 31) coal seams	250	0
	Black shale	2,400	0
	. . . .		
Probably Upper Cretaceous	Thick bands of grey sandstone and grey shale (Sta. B. 35)	100	0
	Concealed	1,300	0
	Grey sandstone	20	0
	Dark grey shale (Sta. B. 37)	90	0
	Grey sandstone	15	0
	Concealed	500	0
	Thick bands of grey sandstone, grey shale (Sta. B. 38)	100	0
	Concealed	1,500	0
	Massive grey sandstone (Sta. B. 41). From below this point rocks are all concealed	80	0

Analyses

Sample No. 1			Sample No. 2		
Coal as received		Calculated for coal dried at 105°C.	Coal as received		Calculated for coal dried at 105° C.
Moisture	0·9		Moisture	1·1	
Volatile matter	17·0	17·1	Volatile matter	16·3	16·5
Fixed carbon	75·5	76·2	Fixed carbon	74·3	75·1
Ash	6·6	6·7	Ash	8·3	8·4

The following excerpts relative to the claim staked in 1919 by Thos. Russell are from a report by Chas. L. Hower to the Rocky Mountains Collieries, Limited, 1910, containing extracts from Russell's notebooks, and the analyses made. The seams found appear to be very near those of the section given above.

"*Daniel Coyle Claim, No. 3504.* Situated on the headwaters of the south branch of Little Berland river, and on the south side of the river, east of the limestone ridge. The trail crosses the river below the claim in a valley from 200 to 600 yards in width. This valley reaches to the claim.

"The strata starting at a point where the trail crosses the river, range from the Belly River series to the limestone. The Kootenay series outcrops along the river for 3 miles. The strata are on edge for the first 2 miles and are folded, giving the same measures twice. Then there is a change of dip caused by a synclinal axis in the upper part of the claim.

"There are six or seven seams, ranging from 2 feet to 4 feet thick. None of these seams appears to be of much value, but probably they have not been opened sufficiently to note their true thickness. One seam of 2 feet 6 inches, analysed, showed:

	Per cent
Volatile combustible	15·87
Fixed carbon	76·43
Ash	7·70

Seven miles from the mouth of Moon creek on sec. 6, tp. 54, range 3, W. 6th mer., the following sections are exposed.

Section			Coal as received		Calculated for dry coal at 105° C.
	Feet				
Sandstone	20				
Clean coal	3		Moisture	6·5	
Grey shale, with occasional bands of light grey sandstone up to 2 feet thick	200		Volatile matter	24·2	25·9
			Fixed carbon	31·4	33·6
			Ash	37·9	40·05
			Fuel ratio	1·30	
			Non-coking		
	Ft.	Ins.			
Black shale	2	0			
Grey shale	2	0	Moisture	1·3	
Coal	3	0	Volatile matter	10·5	10·7
Shale	0	6	Fixed carbon	39·0	39·5
Coal	2	0	Ash	49·2	49·8
Grey shale	0	6			
Sandy shale	5	0			
			Non-coking		

Just below the mouth of Cabin creek on Berland river the following section is exposed.

	Ft.	Ins.
Soft, yellow clay	0	4
Coal	0	3
Chocolate shale	1	3
Coal	0	2
Grey clay	1	0
Coal	0	4
Sandstone, soft	0	3
Coal	2	6
Clay, light grey, soft	0	3
Coal	0	2
Coaly shale	0	3
Grey clay	0	3
Coal	1	0
Coaly shale	0	5
Sandstone, light grey, soft	1	3
Coal	0	4
Clay	0	1
Coal	0	1
Dark grey shale	1	4
Coal	0	6
Clay	0	1
Coal, lignite	1	0
Dark grey shale	0	6
Yellow shale	0	3
Sandy shale, light coloured	12	0
Hard sandstone	4	0
Sandstone, soft	0	2
Sandstone, hard	0	4
Grey shale	1	0
Sandstone	2	0
Grey shale	5	0
Sandstone	1	2
Grey shale	1	0
Sandstone	0	9
Grey shale	8	0
Light grey sandstone, soft	10	0
Light grey sandstone	8	0
Grey shale	30	0

On Berland river one mile below Adams creek, sec. 15, tp. 54, range 4, W. 6th mer., the following partial section was measured.

Section		Analysis: Coal as received		Analysis: Calculated dry coal at 105° C.
	Feet			
Conglomerate	20			
Black shale	10			
Coal	2	Moisture	7·0	
Shale	1	Volatile matter	17·3	18·6
Coal	1	Fixed carbon	27·1	29·2
Black shale	21	Ash	48·6	52·2
Grey sandstone	15	Fuel ratio	1·55	
		Non-coking		
Black shale	4			
Sandstone	3			
Grey shale	1			
Grey sandstone	2			
Black shale	6			
Sandstone	10			
Concealed to conglomerate	100			
Conglomerate	200			

Coal exposures occur on Boivin creek, a small creek entering the north branch of Berland river, about 3½ miles above Sunset creek, sec. 32, tp. 53, range 5, W. 6th mer. The following sections were measured at a point one mile up from mouth of creek.

Section	Ft.	Ins.	Coal as received		Calculated for dry coal at 105° C.
Shale					
Coal, clean, soft	1	5			
Grey shale	0	8			
Coal, soft	2	0			
Shale	0	10			
Sandstone	0	4			
Dark, sandy shale	0	8			
Coal	1	0			
Dark grey shale	0	2			
Coal	2	8	Moisture	1·2	
Shale	0	3	Volatile matter	20·0	20·3
Coal, soft	0	7	Fixed carbon	73·7	74·6
Dark grey shale, 2-inch ribbons of			Ash	5·1	5·1
coal in this shale	12	0	Fuel ratio		3·70
Black shale	1	0	Very poor coke		
Sandy shale	4	0			
Dark grey shale	3	0			
Sandstone	6	0			
Concealed	30	0			
Sandstone	6	0			
Dark grey shale	2	0			
Coal, hard	3	0	Moisture	3·2	
Shale	1	6	Volatile matter	20·1	20·8
Coal, hard, clean	1	6	Fixed carbon	60·5	62·5
Black shale	1	0	Ash	16·2	16·7
Coal	0	8	Fuel ratio		3·00
Black shale	13	0	Very poor coke		

About one-half mile up creek from mouth, on right bank, is the following section:

Section	Ft.	Ins.	Coal as received		Calculated for dry coal at 105° C.
Shale }					
Yellow clay }	Cover				
Coal, soft	1	6			
Grey shale	0	2			
Coal, soft	3	0	Moisture	5·0	
Grey shale	0	2	Volatile matter	22·5	23·7
Coal	0	1	Fixed carbon	50·4	53·1
Grey shale			Ash	22·1	23·2
			Fuel ratio		2·25
			Agglomerates		

About one-quarter mile up creek from mouth is another section:

Section	Ft.	Ins.	Coal as received		Calculated for dry coal at 105° C.
Grey shale	2	0			
Coal, clean	0	7			
Grey shale	0	3			
Coal, clean	1	2	Moisture	4·7	
			Volatile matter	22·3	23·4
			Fixed carbon	57·9	60·8
			Ash	15·1	15·8
			Fuel ratio		2·60
			Agglomerates		

Below this exposure about 20 feet, in grey shale, is another coal seam.

A big seam found near the mouth of the creek occurs in the following section:

Section	Ft.	Ins.	Coal as received		Calculated dry coal at 105° C.
Coal, soft	3	0			
Shale	0	6			
Coal, soft	2	0			
Coal, dirty	2	0			
Soft, grey shale	0	3			
Coal, clean, hard	5	0	Moisture	3·5	
Sandstone	20	0	Volatile matter	20·1	20·8
			Fixed carbon	65·4	67·8
			Ash	11·0	11·4
			Fuel ratio	3·25	
			Agglomerates		

For the Eastern division no tonnage estimate is submitted, as the exploration and prospecting of the seams have not advanced to a stage which admits of estimation except for very small areas along the streams.

MINING CONDITIONS

The map-area has at present but one railway, the Canadian National, situated at its extreme southern boundary. The nearest railway to the Northern division is the Edmonton and Dunvegan railway to Grand Prairie, at a distance of about 75 miles. This part of the field is advantageously situated as to the Peace River markets on this railway. A railway to the north along Smoky river would have gentle and favourable grades all the way and would be easy of construction.

At present the Canadian National railway has a projected branch located nearly as far as the summit on the north branch of Hay river. It was planned to build this road northwestward through this northern field. The extension of this project beyond the coal field is uncertain.

It may go westward through the mountains into central British Columbia or northward to the Peace River settlement. The road as planned would traverse the map-area and it would then be comparatively easy to reach the coal by spurs. The construction of the trunk-line and spurs need involve only moderate engineering difficulties.

The streams which head in the mountains and hills give an abundant water supply to all parts of the field. In the Southern and Middle divisions certain streams, like the north branch of Hay river, and Solomon creek, flow underground in low-water stages. This occurs in the deep parts of their valleys that have been filled with gravel wash. In general the quality of the water is excellent. The deep and narrow canyons along the larger streams afford opportunity for the development of water and electrical power cheaply when the demand of the mines warrants the undertaking.

Near the mouth of Walton creek sulphur springs coming from the limestone are to be seen on Sulphur river. It is stated that the river takes its name from these springs.

The coal field lies entirely within the Dominion Forest Reserve, large areas of which are heavily forested. The timber available in different parts of the field is capable of supplying the needs of extensive mining operations.

As a rule the beds are inclined. For early development, however, mines situated upon the banks of the streams can take a large amount of coal from the outcrops above drainage level, thus avoiding the necessity of expensive machinery for pumping and hoisting.

MARKETS

The railways will be the principal markets for this coal now, and probably for some years to come. The steam coals from the mountains to the south are as a rule in small sizes, and in competition with them the uncrushed, hard coal from this field should find a market as far east as Winnipeg. Part of the coal will find a market in the metallurgical industries of British Columbia to the west.

BOW RIVER COAL BASIN WITHIN THE ROCKY MOUNTAINS, ALBERTA

By D. B. Dowling

CONTENTS

Illustrations

INTRODUCTION

General accounts, by the present writer, of the structure of the coal basins within Rocky mountains, have been published in various Summary Reports of the Geological Survey and in several Memoirs. The coal found in these basins ranges from bituminous with coking qualities to coals resembling the Welsh semi-anthracites. Most of the coal mined has been for the railways, and coal for domestic heating has been obtained largely from the less disturbed regions of the foothills and plains and small amounts of the harder coals have come from Bow River valley. The domestic consumer in the prairie provinces has a very wide choice, both in regard to quality and price, but when an attempt is made to ship Alberta coal beyond these provinces, transportation cost exceeds the cost of the coal at the mine and coal of good quality must, therefore, be selected.

The small consumer prefers coal that burns with little smoke. This property is shared by coals at either end of the scale of alteration through which coal passes in its transformation by time, pressure, or heat from peat or lignite to anthracite. Leaving out of consideration, therefore, the true, bituminous, smoky coals, domestic fuels include lignite, sub-bituminous, semi-bituminous, semi-anthracite, and anthracite. A large quantity of the grades below smoky bituminous comes from the plains and the higher grades must be looked for in the disturbed belt and the mountains. Several areas have been prospected and anthracitic varieties have been found. Many of these are remote from railway communication, and the areas nearest existing lines claim first attention.

The coal areas on the main line of the Canadian Pacific railway containing, or likely to contain, the better grades of domestic coal, are here reviewed. The first mine producing anthracitic coal was near the mouth of Cascade river, but it closed down in 1904, owing to restricted markets. Other mines in Bow valley, near Canmore, produced a smokeless steam coal which was used on the mountain division of the railway. A mine at Bankhead on Cascade river produced a coal too hard for railway use, but found a market on the plains for domestic use. Bow valley thus contains coal of the higher grade suitable for domestic use, but it has been found that flexing of the beds during the process of mountain-building caused an excessive amount of fracturing and most of the coal mined is very small and friable. The areas in which mining has been carried on are, probably, in the most disturbed part of the belt. The investigation carried out during July, 1923, was directed towards an examination of the seams in what appeared to be a less disturbed area south of Canmore, in the hope that less fractured seams might be found.

This expectation was in a measure realized as far as the appearance of the coal near the surface indicates. It is yet to be proved what the seams will yield at a distance from the outcrop where beds under pressure from the present load of overlying strata will be encountered. Owing to debris from the mountain side difficulty was experienced in finding seams and the section here reported on is incomplete in the lower part where harder coals might be expected. Details of the seams in other parts of the basin are included for comparison and for reference in future attempts at correlation.

GENERAL STRUCTURE OF THE AREA

Uniform ridges of limestones which form Rocky mountains are separated by distinct fault lines running parallel with them. There is a continuous repetition of strata comparable to overlapping blocks of ice along a lake shore. That the pressure which developed this structure was from a westward direction is indicated by the facts that where folds are overturned and broken, the blocks on the west side override the eastern limb, and in the general beds in the eastern part of the mountains dip southwestward. The section in the immediate front of the mountains includes all the strata of Cretaceous age lying on the limestones and it is certain, therefore, that the uplifted blocks now forming the ranges were at one time crowned on their westward slopes, also, by these softer Cretaceous beds. These softer beds were easily eroded, and only small remnants are left in the valleys, so that the harder beds—in this case Carboniferous limestones—show up strongly and now form the mountain ranges.

The soft Cretaceous sandstones, where any are left, are in the valleys and against the eastern edge of the next succeeding fault block to the west. Where the fault blocks are narrow the highest bed showing is generally in the harder series of pre-Cretaceous sediments. Only in the wider valleys which parallel the faults may remnants of the Cretaceous coal-bearing rocks be expected, for example, in Bow valley from Gap siding to near Banff.

A study of the general structure of the block forming this valley shows that variations occur within short distances along its length. Thus, on the divide between the Kananaskis and the Bow valley to the south of the Bow, the upthrust along the western edge was accompanied by folding in the limestone ridge to the west of the fault, whereas near Canmore foldings and crumplings occur on both sides of the fault-line. From the turn in the valley at the mouth of Cascade river the fault-line is deflected northwards 12 degrees and in a few miles changes to a slightly overturned fold which decreases as the valley northward narrows, but is traceable into the limestone range to the east. The displacement of the beds along this fault-line thus shows a change in a distance of 15 miles, from a fault with 15,000 feet upthrust to a fold with a probable vertical displacement of about 3,000 feet.

The coal measures form the upper members of the block underlying the valley and lie next to the fault-line. They change somewhat in structure along the stretch of 15 miles above mentioned. At the northern end the measures form a syncline pitching to the southeast. Before reaching Bow river in that direction the western limb is broken, and the limestone mass of Cascade mountain overrides the eastern limb which here consists of all the coal-bearing beds of the Kootenay formation. Thence, southward to near the Three Sisters, the measures are corrugated by folds pitching to the south toward the fault-line, but making an angle with it varying from 20 degrees to 30 degrees. These folds appear to have originated from two different causes. The one at the old anthracite mine near the mouth of Cascade river appears to have been caused by a bend in the basin, whereas those near Canmore are, apparently, a result of application of pressure oblique to the line of fault. The oblique folding [1] passes into the limestone range to the west at the Three Sisters and continues southward. The third section of the coal measures, extending from near Can-

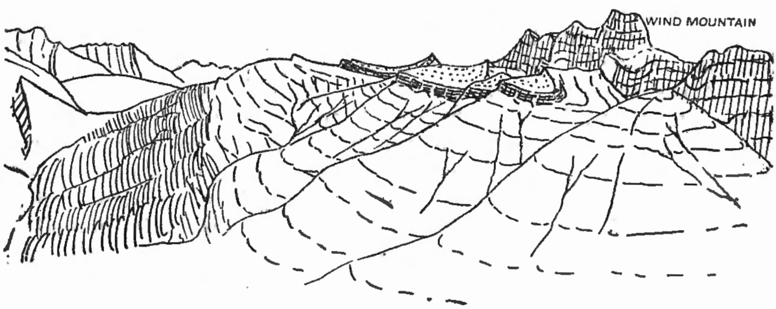


FIGURE 9. Sketch of Cretaceous coal-bearing measures east of Wind mountain.

more southward toward the Kananaskis, widens to form a broader strip of coal-bearing rocks. Less folding is noticeable, except close to the fault-line where the upper beds are folded into a syncline. This is evident in the hills in front of Wind mountain.[2]

1 Geol. Surv., Can., Pub. No. 949, p. 10.

2 *See* Geol. Surv., Can., Mem. 59, "Coal Resources of Canada," Figure 7.

The structure which continues south evidently commences as a narrow trough which is entered by the gangway of No. 2 mine south of Canmore. The mine plans show that the deep upturn on the west side maintains a fairly straight course toward the fault-line in front of the Three Sisters and the slope on the eastern side decreases in dip (Figure 10). There is a probability, therefore, that the mining operations of Canmore No. 2 mine may eventually lead to some of the seams exposed in the hills opposite The Gap station. Further prospecting may lead to the discovery of many seams, some of which have possibly been previously seen in the vicinity of Canmore. An exact correlation of the seams in the hills opposite The Gap, with those at Canmore, cannot yet be made; but, for future reference, the structure section at the latter place is summarized in the following pages.

CANMORE MINES NO. 1 (ABANDONED) AND NO. 2

The main opening in this mine was in a small gully on the west side of Bow river near Canmore. The first mine in this neighbourhood—the Cochrane—was opened on the same side of the river about a mile farther up stream, and a spur to it was made from the railway. When it was closed down, and the openings for the next mine, Canmore No. 1, were made, the spur was continued down the west side of the river. Another opening for mine No. 2 was later made a mile farther down the river and the railway spur continued to it (Figure 11).

The coal measures outcrop along a small stream that comes from the gap leading to Spray valley. The exposures near Bow river show several very sharp folds in which coal seams are exposed; but, farther back, a more uniform dip of 50 degrees obtains for some distance. The beds may eventually turn upward, near the mountains. Mining was started by a slope on what was called No. 2 seam. This slope extended downward for about 600 feet and several seams above No. 2 were mined. In the mine it was found that the measures are folded into several anticlines and synclines, the axes of which pitch about 20 degrees to the south. This folding is well brought out in the mine plans by the curves of the main gangways which in the case of the larger folds are S-shaped. On the sharper parts of many of the curves the coal was found to pinch out. There are few faults in the area opened by No. 1 mine. Crushed folds and pinched-out coal were in many cases the cause of considerable delay in extending the gangways. The coal was raised from two levels, 130 and 340 feet, respectively, below the mouth of the slope. At the lower level the first fold was encountered, and there the coal was pinched out. Another fold followed at about 500 feet along the gangway to the southeast, causing a deflexion of the roadway. On the bottom of this trough an interior slope was run to the third level, a further depth of 216 feet, which involved a total raise to the surface of 556 feet. Southward from the main hoist the measures continue fairly uniform for about a mile, where another curve or fold is found. Eastward from this fold the outcrop of a coal seam in a trough was prospected and later developed into a mine. The seam mined in No. 1 mine at this point was traced over the fold and, later, was mined from the new opening.

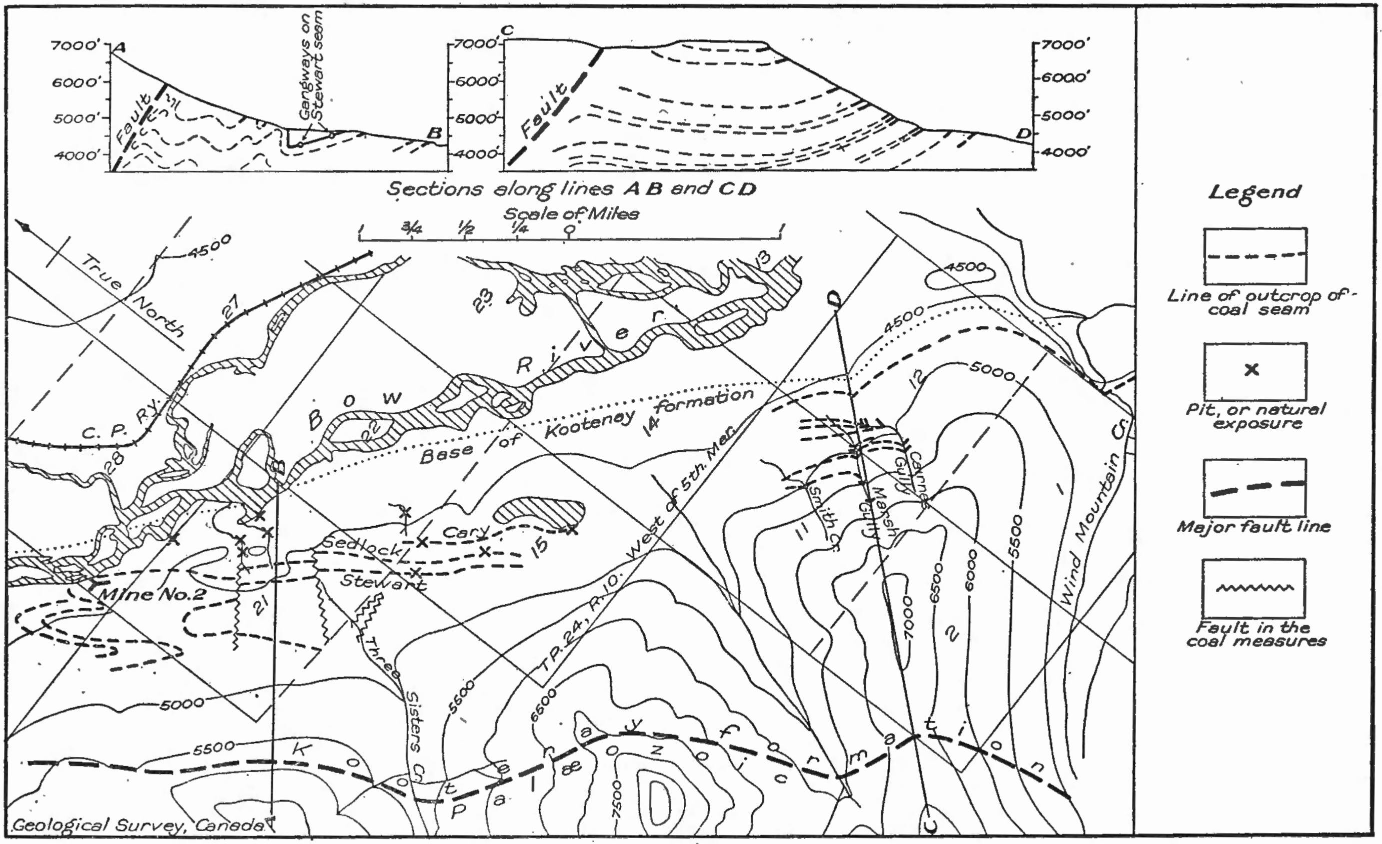


FIGURE 10. Sketch map of southern part of the Canmore coal area, Alberta.

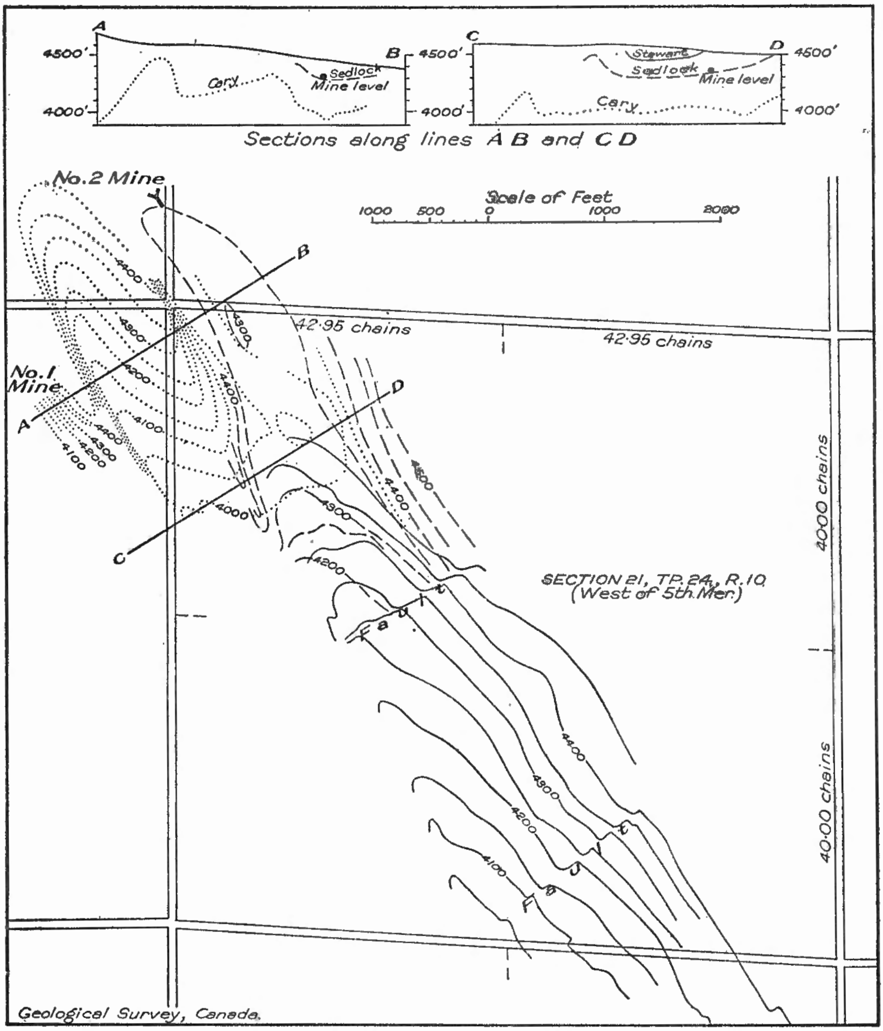


FIGURE 11. Plan and vertical sections of coal seams in Canmore Mine No. 2, showing sub-surface contours on the seams. Contours on Stewart seam shown by solid line, on Sedlock seam by broken line, and on Cary seam by dotted line.

Mining in No. 2 mine revealed two troughs, and connexion was made by tunnel from the bottom of the nearest trough. When the workings in No. 1 mine reached that point and after a considerable amount of coal had been extracted, the abandonment of No. 1 mine was effected by closing this tunnel with a concrete dam.

Mining was then concentrated on No. 2 mine, in which three seams have been worked. The lowest or Cary seam extends across part of the two troughs; the two upper seams, the Sedlock and the Stewart, extend through the outer or eastern trough as far as a fault-line that crosses the measures and displaces the seams downward about 40 feet. The trace of the seams is moved eastward about 200 feet by this fault. The main entry level is on the middle or Sedlock seam, to this point. A short deflexion to the south then brings it on the Stewart or upper seam, which is now being mined a farther distance of over a mile on the same trough. Small faults are encountered at intervals of less than half a mile, cutting across the measures at various angles. These, as well as the general shape of the basins, are shown in Figure 10.

COAL MINED AT CANMORE

The workings in No. 1 mine were on parts of several seams. In the vicinity of folds the seams were often pinched out or badly broken and at other points showed other undesirable features, thus all the seams do not appear to have been worked. The section published in 1907[1] appears to have been applicable to one part of mine No. 1. Owing to great variation in the thickness of the separating members, and to variations in the coal seams, correlation of sections in other parts has not been altogether successful. New seams appear and others are not easily traced. No 5, a large seam in the northwestern part, thins out to the southeast and gives place in mining to the Cary, which is apparently not far below it. The full list, including those not worked in No. 2 mine and probably represented by thin or dirty seams, is discussed below:

Stewart Seam. This is the highest seam worked and was first found in No. 2 mine. The thickness seems to be from 7½ to 8 feet for a distance of about a mile. It is separated from the seam below by from 60 to 150 feet of sandstone.

Sedlock Seam. This seam was prospected above No. 1 mine by a slope, but an outcrop near the river, apparently of the same seam lying in the bottom of a shallow trough, afforded an entry at an easier slope and from this No. 2 mine was started. The section at the entry is given as 5 feet 6 inches, with two small slate partings. The fuel ratio of the coal was 5·8 to 6·5. Borings from the floor of this mine cut a coal seam of 5 feet 8 inches at 204 feet.

No. 6 Seam. This seam was prospected in No. 1 mine by a tunnel from No. 5 seam. It was again prospected in No. 2 mine on tunnel No. 2, running from the southwest side of the trough to the saddle on the Cary

[1] Geol. Surv., Can., "Cascade Coal Basin, Alta.," Pub. No. 949.

seam. In No. 1 mine two other seams, a 30-inch seam and No. 5, lie below No. 6. These do not appear in No. 2 mine except in the various bore records. No mining appears to have been attempted on No. 6 seam.

Cary Seam. This seam, which was worked in No. 1 mine southeastward to opposite No. 2 mine, was pretty thoroughly extracted from the folds under the northwestern part of No. 2, and was found to lie from 200 to 380 feet below the Sedlock.

No lower seams are worked in No. 2 mine, but the section may be continued from the old records of No. 1 mine, placing the succeeding seam at 100 to 150 feet below the Cary.

No. 4 Seam. The section in the old mine gives 3 feet 1 inch of clean coal with a fuel ratio of from 6 to 6·4.

No. 1 Seam. This seam was 5 feet 8 inches thick, but was split by shale partings. The coal ranged in fuel ratio from 5·4 to 6·6.

No. 3 Seam. Thickness of seam 4 feet 8 inches, split by two bands of slate; fuel ratio 7·1.

No. 2 Seam. Several sections on this seam are given in Geol. Surv., Can., Pub. No. 949, " Cascade Coal Basin, p. 21. The seam varied from 5 feet 10 inches to 6 feet 8½ inches in thickness and the coal had a fuel ratio of 5·3.

No seams below No. 2 have been mined, except possibly the seam first mined in the Cochrane mine or those at Anthracite. Faulted ground northwest of the workings in No. 1 prevented the galleries reaching the vicinity of the Cochrane mine and no correlation was ever made. Southward the Stewart seam has been traced into section 15 and with the exception of cross-faults and small rolls, the basin form appears to continue.

The coal measures in the high hills in sections 10, 11, and 12 are evidently continuations of those at Canmore, but they seem to be less disturbed. The dip on the northeastern side of the basin continues in the same direction, but evidently flattens eastward. In sections 11 and 12 the appearance of the hills suggests that the whole section of the coal measures is present. Shales having the appearance of a lower series and containing small marine shells occur in the gorge of Wind Mountain creek at the crossing of the trail leading to the Kananaskis divide. A short distance above, on the same creek, sandstones appear which are evidently the lowest of the coal measures. The digging done by the writer in 1923, through the debris of the hill-slopes and in the deposits brought down by the streams, was largely confined to the creek beds and hillside gullies. The upper part of the Kootenay formation is well exposed in these gullies and several coal seams of workable thickness were uncovered. The lower part of the formation no doubt contains several seams that were not uncovered owing to the burden of river deposit and of material brought down by the creeks. This part may be easier to prospect by boring. Details of sections in the several creeks follow. These creeks have been given local names and are indicated on Figure 9. The part of the narrow plateau projecting from the mountains and nearest to the river is cut by three small gullies. That

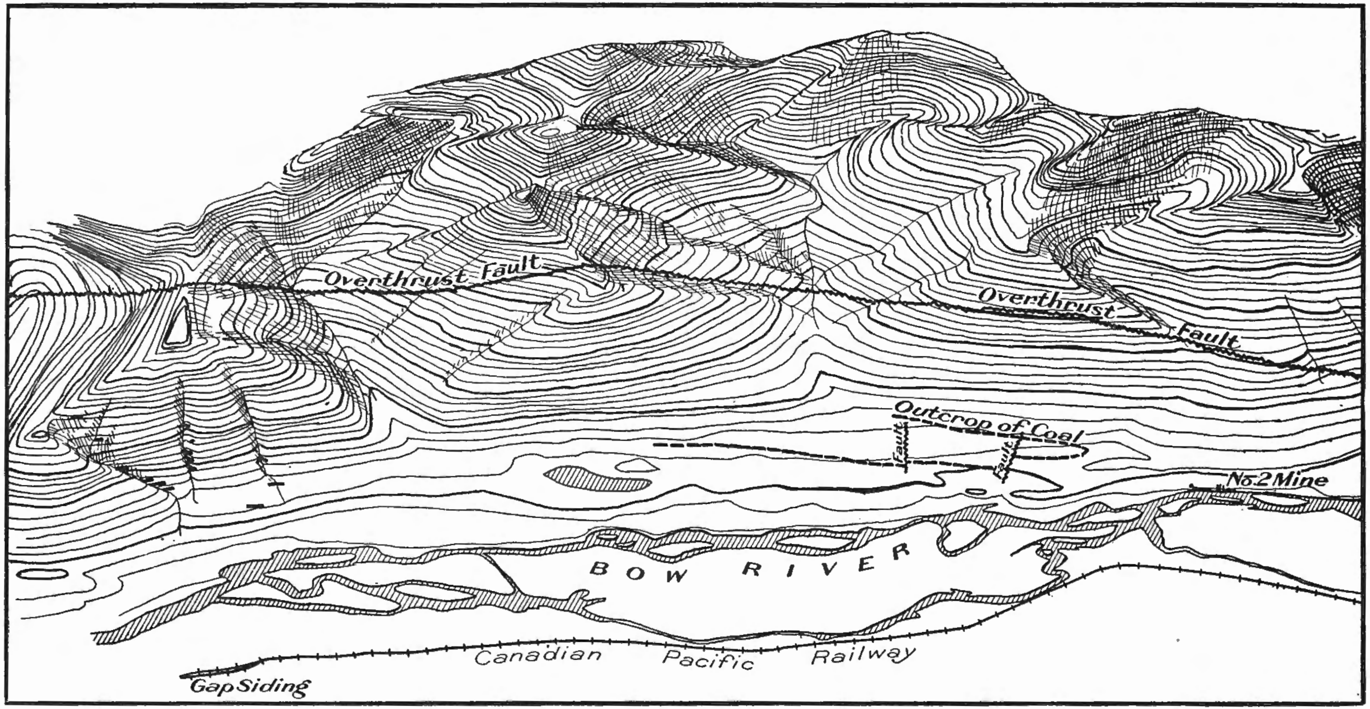


FIGURE 12. Isometric projection of coal area on western side of Bow valley, near Canmore, Alberta.

nearest to Canmore and in section 11 is called Smith creek; the centre one, on which Marsh opened a mine in the early days of railway construction, is referred to as Marsh gully; and a third just to the southeast, which was prospected in 1904 by D. D. Cairnes, is referred to as Cairnes gully.

COAL SEAMS IN SMITH CREEK

At about 5,300 feet above sea-level an exposure of coal had been opened up by the lessees of section 11. An examination of the locality shows the following descending section:

Beds dip southwest 20 degrees

	Ft.	Ins.		
Sandstone cliff with waterfall, shaly sandstone at base	100	0		
Dirty coal	2	0		
Coal	1	3		
Sandstone	1	0		
Top coal	2	4	Channel sample Laboratory No. 2405	Seam No. 3
Shale band	0	1		
Dirty coal	1	0		
Rock	0	1		
Bottom coal	4	0	Channel sample Laboratory No. 2406	
	11	9		
Floor, sandstone, about	100	0		
Concealed for about	150	0		
Sandstone ledge forming a second waterfall a short distance from foot of hill showing sandstone	100	0		
Sandstone with shaly partings	50	0		
Shaly sandstone	1	0		
Coal, top bench	2	3	Channel sample Laboratory No. 2407	Seam No. 4
Dirt band	0	1½		
Coal, lower bench	5	8		
Dirt band	0	2		
Sandstone and shale	28	0		
Yellow sandstone	35	0		
Sandstone in thin beds with shale partings	16	4		
Coal	0	6		
Sandstone	7	0		
Sandstone	3	0		
Coal, rather dirty	1	6		
Bone, black sandy shale	1	0		
Coal	1	0		
Shale	0	2		
Dirty coal	2	6		

Below this point on the creek there appear to be no rock exposures, but on the flat to the east of the creek, in the northeastern part of section 11, a small sandstone ridge outcrops in the woods. Beneath this sandstone a slope of about 18 feet had been put down on a coal seam claimed to be 8 feet in thickness. The dip here is nearly 30 degrees southwest. The roof appears to be of shale and there is 5 feet of coal exposed. This is seam No. 5 on section 11; channel sample No. 2417. Its lower part contains a larger percentage of block coal than is found in those already noted on Smith creek, i.e., seams Nos. 3 and 4. A small seam 2 feet thick, located about 150 feet horizontally east of No. 5, had also been exposed.

Following are the results of analyses of channel samples collected by D. B. Dowling, July, 1923, made by the Fuel Testing Division of the Mines Branch. Reported by C. B. Mohr.

Laboratory Sample No. 2405, Seam No. 3, Smith Creek, Upper Bench
(R, as received; A D, air dried; D, dry coal)

Moisture condition	R	A D	D
Loss on air drying	3·2	....	....
Proximate analysis—			
Moisture	8·4	5·4	....
Ash	12·9	13·3	14·1
Volatile	16·1	16·6	17·6
Fixed carbon	62·6	64·7	68·3
Sulphur	0·7	0·8	0·8
Calorific value B.T.U.	11,470	11,850	12,530
Fuel ratio $\frac{F.C.}{vol.}$	......	3·88	....
		Non-coking	

Laboratory Sample No. 2406, Seam No. 3, Smith Creek, Bottom Bench

Moisture condition	R	A D	D
Loss on air drying	4·5	....	....
Proximate analysis—			
Moisture	7·3	2·9	....
Ash	10·1	10·5	10·9
Volatile matter	14·0	14·7	15·2
Fixed carbon (by difference)	68·6	71·9	73·9
Sulphur	0·8	0·8	0·8
Calorific value B.T.U.	12,480	13,075	13,470
Fuel ratio $\frac{F.C.}{vol.}$	....	4·88	....

Laboratory Sample No. 2407, Seam No. 4, Smith Creek

Moisture condition	R	A D	D
Loss on air drying	1·1	....	....
Proximate analysis—			
Moisture	6·0	4·9	....
Ash	5·8	5·9	6·2
Volatile matter	14·1	14·3	15·0
Fixed carbon	74·1	74·9	78·8
Sulphur	0·8	0·8	0·9
Calorific value B.T.U.	12,940	13,085	13,765
Fuel ratio $\frac{F.C.}{vol.}$	....	5·25	....
		Non-coking	

Laboratory Sample No. 2417, Seam No. 5, N.E.¼ · Section 11

Moisture condition	R	A D	D
Loss on air drying	1·7	....	....
Proximate analysis—			
Moisture	6·0	4·4	....
Ash	9·7	9·8	10·3
Volatile matter	13·2	13·5	14·1
Fixed carbon	71·1	72·3	75·6
Sulphur	0·7	0·7	0·7
Calorific value B.T.U.	12,350	12,550	13,130
Fuel ratio $\frac{F.C.}{vol.}$	....	5·37	....
		Non-coking	

COAL SEAMS IN MARSH GULLY

Reference to the section attached to Figure 10 will show that near the top of this gully the beds are almost horizontal; but that, lower down, the dip increases gradually to about 30 degrees. Owing to a few undulations in the softer beds this gradual increase is maintained only in the heavy sandstone ledges. About 2,000 feet of beds are included in the exposures from the foot of the hill to the summit. The upper half of this section consists of a conglomerate followed below by sandstones lying nearly horizontal. Few signs of coal were found on the almost vertical face of this upper part. The first workable coal seam (seam A) occurs at a point 1,220 feet (estimated) below the top at an elevation of 5,720 feet above sea. It is badly decomposed on the surface and gives no lump coal in the part shovelled out. There appears to be 4 feet of coal in the seam, which has a slight dip to the southwest. The analysis of sample 2404 made by the Fuel Testing Division of the Mines Branch shows the effect of the weathering, but the coal under cover may possibly be bituminous.

Three hundred and sixty-five feet of sandstone divide this seam from the next beneath (seam B) which was prospected many years ago. The opening has, in spite of timbering, fallen in, and it could only be surmised that a seam possibly 6 feet in thickness occurs there.

The section down the gulley is as follows:

	Feet
Sandstone	40
Shale	10
Sandstone	40

	Ft.	In.
(*Seam C*)		
Coal (not sampled)	2	0
Sandstone	225	0
Sandstone, with seams of shale 6 inches thick	60	0
Shale	4	0
(*Seam D*)		
Clean coal (not sampled)	2	6
Sandstones forming steep cascades in stream	30	0

	Ft.	In.		Ft.	In.
(*Seam E*) Upper Marsh seam				5	10
	Ft.	In.			
Coal	0	2			
Shale	0	1			
Coal	0	4			
Rock	0	3			
Coal	0	8			
Coaly shale	0	11			
Coal	1	7			
Sandstone	0	11			
Coal	2	7	Channel sample (Laboratory No. 2408)		
Dirt	0	1			
Coal	3	2			
Sandstone generally thick beds				75	0
(*Seams F and G*) Friable sandstone and shale				1	6
(*Seam F*) Upper tunnel				6	9
	Ft.	In.			
Coal, bright	4	5	Channel sample (Laboratory No. 2409)		
Dull coal	0	1			
Coal, lower bench	2	3			
Sandstone				6	6
Shales and sandstones				3	5
Sandstones				3	6
(*Seam G*) Lower tunnel				13	0
	Ft.	In.			
Coal	1	0	Channel samples (Laboratory No. 2410)		
Bone	0	6			
Clean coal	2	2			
Dirt	0	2	(Laboratory (No. 2411		
Coal	1	6			
Dull coal and rock	0	5	(Laboratory No. 2412)		
Coal	7	3			
Dark shales				30	0
Shaly sandstone				11	0
Sandstone				23	0
Shaly sandstone				10	0
(*Seam H*) Dirty coal seam				6	2
	Ft.	In.			
Coal	0	10			
Dirty coal	0	4			
Coal	0	2			
Rock	0	3			
Coal	2	0			
Rock	0	2			
Coal	0	8			
Rock	0	3			
Coal	1	6			

From this point (elevation given on plans of Canmore Coal Company as about 4,900 feet) gravel brought down the hill forms a large fan and no exposures occur in the bed of the creek.

Analyses by the Fuel Testing Division, Mines Branch, of channel samples collected in Marsh gully, by D. B. Dowling, July, 1923. Reported by C. B. Mohr.

Laboratory Sample No. 2404, Seam A, Marsh Gully

Moisture condition	R	A D	D
Loss on air drying	4·8	....	....
Proximate analysis—			
Moisture	23·3	19·4	....
Ash	36·4	36·3	45·0
Volatile matter	18·2	19·1	23·7
Fixed carbon	23·9	25·2	31·3
Sulphur	0·4	0·5	0·6
Calorific value B.T.U.	4,585	4,815	5,980
Fuel ratio $\frac{\text{F.C.}}{\text{vol.}}$	....	1·38	....
Hoffman potash test 1		Non-coking	

NOTE. No. 2404 was originally air dried in an atmosphere containing 68 per cent moisture (60 per cent being considered normal). The *ground* sample on which analysis was made was subsequently further air dried in an atmosphere of 32 per cent to a moisture of 7·7 per cent.

Laboratory Sample No. 2408, Seam E (Upper Marsh Seam)

Moisture condition	R	A D	D
Proximate analysis—			
Moisture	4·5	....	....
Ash	7·4	....	7·7
Volatile matter	13·1	....	13·7
Fixed carbon	75·0	....	78·6
Sulphur	0·9	....	1·0
Calorific value B.T.U.	13,070	....	13,680
Fuel ratio $\frac{\text{F.C.}}{\text{vol.}}$	....	5·74	....
		Non-coking	

Laboratory Sample No. 2409, Seam F (Upper Tunnel on Marsh Double Seam)

Moisture condition	R	A D	D
Loss on air drying	1·2	....	....
Proximate analysis—			
Moisture	4·4	3·2	....
Ash	12·0	11·8	12·2
Volatile matter	12·3	12·0	12·4
Fixed carbon	71·3	73·0	75·4
Sulphur	1·1	1·1	1·2
Calorific value B.T.U.	12,680	12,835	13,260
Fuel ratio $\frac{\text{F.C.}}{\text{vol.}}$	....	5·83	....
		Non-coking	

Laboratory Sample No. 2410, Upper Part Seam G (Marsh Seam)

Moisture condition	R	A D	D
Proximate analysis—			
Moisture	3·9	....	....
Ash	4·0	....	4·2
Volatile matter	13·5	....	14·0
Fixed carbon	78·6	....	81·8
Sulphur	0·9	....	0·9
Calorific value B.T.U.	13,840	....	14,405
Fuel ratio $\frac{F.C.}{vol.}$	....	5·83	....
		Non-coking	

Laboratory Sample No. 2411, Middle Part Seam G

Moisture condition	R	A D	D
Loss on air drying	1·26	....	....
Proximate analysis—			
Moisture	3·7	2·5	....
Ash	12·0	12·2	12·5
Volatile matter	12·9	13·1	13·4
Fixed carbon	71·4	72·2	74·1
Sulphur	1·1	1·2	1·2
Calorific value B.T.U.	12,835	13,000	13,330
Fuel ratio $\frac{F.C.}{vol.}$	....	5·55	....

Laboratory Sample No. 2412, Lower Part Seam G

Moisture condition	R	A D	D
Loss on air drying	....	....	....
Proximate analysis—			
Moisture	2·9	....	....
Ash	20·6	....	21·1
Volatile matter	11·2	....	11·5
Fixed carbon	65·3	....	67·4
Sulphur	0·8	....	0·9
Calorific value B.T.U.	11,290	....	11,630
Fuel ratio $\frac{F.C.}{vol.}$	....	5·83	....
		Non-coking	

COAL SEAMS IN CAIRNES GULLY

As this gully in its lower part cuts through lower measures than those exposed in Marsh gully the section downwards starts on what appears to be the continuation of beds from the vicinity of the Marsh seam. Seam

D of the Marsh Gully section may be represented by the seam at the top in Cairnes gully, for in both cases there are nearly 300 feet of sandstones above showing no coal.

	Ft.	In.		Ft.	In.
Coal				2	2
Black slate		10	Correlated with seam D of Marsh gully		
Coal		6			
Shales and sands		10			
Sandstone				50	0
Thin-bedded sandstone				30	0
Coal (Correlated with seam E)				16	0
Dark sandstones				30	0
Coal				2	3
Dark sandstone				20	0
Double coal seam				14	5
Coal	8	3	Correlated with seams F and G		
Sandstone	3	0			
Coal	3	2			
Dark sandstone and shale				75	0
Dirty coal (correlated with seam H)				1	0
Shaly sandstone				30	0
Black shale				10	0
Black shales with small sandstone streaks				50	0
Dark shales with a few streaks of coal				20	0
Dark sandstones				75	0
Dark shales with three streaks of coal				15	0
Thin-bedded sandstone				30	0
Black shale				10	0
Black sandstone and shale				20	0
Sandstone with streaks of black shale				40	0
Black shale				2	0
Brown sandstones and shales, a few black streaks				60	0
Sandstone forms waterfall				50	0
Sandstones (Valley here turns north)				60	0
Hard coal (Channel sample, Laboratory No. 2413)				4	6
Thin-bedded sandstone				6	0
Cairnes seam (channel sample, top half and bottom half, Laboratory Nos. 2414, 2415)				7	2
Sandstone				10	0
Coal				1	6
Sandstone				12	0
Black shale				2	0
Sandstone and shale				15	0
Black shale, some coal probably				1	0
Sandstones and shales				15	0
Black shale				2	0
Coal				0	6
Black shale				4	0
Flaggy sandstone				12	0
Shales with one inch coal				3	0
Shales with sandstone at bottom				10	0
Slate with streak of coal at top				3	0
Joe seam (Channel sample, Laboratory No. 2416)				6	2
Concealed				140	0
Sandstone, forms waterfall in creek				20	0
Occasional exposures of sandstone				200 to 300	

Further search by digging may disclose several other seams, particularly those found to the east in Wind Mountain creek. Mr. Musgrove, Manager of the Canmore mine, suggested to the writer that there is some resemblance between the seams of the lower part of this section and those of the old Canmore mine No. 1 and that the Cairnes seam can be compared with No. 6 of the mine, and the Joe seam resembles the Cary seam.

Analyses by the Fuel Testing Division, Mines Branch, of channel samples collected in Cairnes gully by D. B. Dowling, July, 1923. Reported by C. B. Mohr.

Laboratory Sample No. 2413

Moisture condition	R	A D	D
Proximate analysis—			
Moisture	4·6	....	....
Ash	11·5	....	12·0
Volatile matter	12·2	....	12·8
Fixed carbon	71·7	....	75·2
Sulphur	0·8	....	0·9
Calorific value B.T.U	12,600	....	13,210
Fuel ratio $\frac{F.C.}{vol.}$	5·90	....	....
	Non-coking		

Laboratory Sample No. 2414, Upper Half of Cairnes Seam

Moisture condition	R	A D	D
Loss on air drying	4·5	....	....
Proximate analysis—			
Moisture	7·2	2·9	....
Ash	8·3	8·7	8·9
Volatile matter	10·2	10·7	11·0
Fixed carbon	74·3	77·7	80·1
Sulphur	0·8	0·8	0·8
Calorific value B.T.U	12,940	13,555	13,950
Fuel ratio $\frac{F.C.}{vol.}$	7·30	....	....
	Non-coking		

Laboratory Sample No. 2415, Lower Half of Cairnes Seam

Moisture condition	R	A D	D
Loss on air drying	5·0	....	....
Proximate analysis—			
Moisture	6·7	1·9	....
Ash	11·3	11·9	12·1
Volatile matter	9·4	9·9	10·1
Fixed carbon	72·6	73·6	77·8
Sulphur	0·7	0·8	0·8
Calorific value B.T.U	12,740	13,400	13,660
Fuel ratio $\frac{F.C.}{vol.}$	7·72	....	....
	Non-coking		

Laboratory Sample No. 2416, Joe Seam, Cairnes Gully

Moisture condition	R	A D	D
Loss on air drying	1·7	....	....
Proximate analysis—			
Moisture	6·0	4·4	....
Ash	13·1	13·4	14·0
Volatile matter	11·2	11·4	12·0
Fixed carbon	69·7	70·8	74·0
Sulphur	1·0	1·0	1·0
Calorific value B.T.U.	11,990	12,200	12,760
Fuel ratio $\frac{F.C.}{vol.}$	6·20	....	....
	Non-coking		

COAL SEAMS IN WIND MOUNTAIN CREEK

Immediately south of Sap siding on the Canadian Pacific railway, a wide valley heads from Bow river southwestward toward the mountains. The head of this valley is distinguished from the others by its maintaining its width up to the limestone, where there is a large cirque with almost perpendicular walls. In this valley the bedrock structure of the plateau is seen and corresponds with that sketched on the section C.D., Figure 9. Shales are exposed in the creek bed where it is crossed by Forrester's trail to Kananaskis river. These appear to be below the coal measures. A short distance up the creek ribs of sandstone are exposed. The lower ones are not prominent. Two which form small cliffs at the creek are located just to the east of the surveyed line between ranges 9 and 10 and appear to be on section 6, township 24, range 9. Beneath each of these sandstone ledges coal seams were found. The lower one, that is the first one reached in going up the creek, is 3 feet thick and gives the following analysis as reported by the Fuel Testing Division of the Mines Branch.

Laboratory Sample No. 2421, Lower Part of Seam

Moisture condition	R	A D	D
Loss on air drying	4·7	....	....
Proximate analysis—			
Moisture	7·4	2·8	....
Ash	9·2	9·7	9·9
Volatile matter	10·2	10·7	11·0
Fixed carbon	73·2	76·8	79·1
Sulphur	0·9	0·9	0·9
Calorific value B.T.U.	12,770	13,400	13,780
Fuel ratio $\frac{F.C.}{vol.}$	7·06	....	....
	Non-coking		

Laboratory Sample No. 2422, Upper Part of Seam

Moisture condition	R	A D	D
Loss on air drying	3·6	....	....
Proximate analysis—			
Moisture	7·7	4·3	....
Ash	18·7	19·4	20·3
Volatile matter	11·1	11·5	12·0
Fixed carbon	62·5	64·8	67·7
Sulphur	0·9	0·9	0·9
Calorific value B.T.U	10,870	11,270	11,780
Fuel ratio $\frac{\text{F.C.}}{\text{vol.}}$	5·65	....	....
	Non-coking		

About 25 feet of sandstone overlies this seam and at the foot of the second rib, probably 75 feet away horizontally, the second seam is found. This has the following section:

	Ft.	In.
Roof, slaty sandstone.		
Upper bench *coal* (Lab. samples Nos. 2418, 2419)	3	9½
Bone and niggerheads	0	2
Lower bench *coal* (Lab. sample No. 2420)	1	11

This coal mines out in large lumps and resembles the Welsh coal in appearance. The outcrop samples show much more ash and about as much volatile matter as in the higher seams.

Laboratory Sample No. 2418, Upper Bench

Moisture condition	R	A D	D
Loss on air drying	3·6	....	....
Proximate analysis—			
Moisture	6·5	3·0	....
Ash	18·7	19·4	20·0
Volatile matter	9·7	10·0	10·4
Fixed carbon	65·1	67·6	69·6
Sulphur	0·6	0·7	0·7
Calorific value B.T.U	11,180	11,590	11,960
Fuel ratio	6·74	....	....

Laboratory Sample No. 2419, Upper Bench

Moisture condition	R	A D	D
Loss on air drying	4·4	....	....
Proximate analysis—			
Moisture	7·5	3·2	....
Ash	15·4	16·1	16·6
Volatile matter	9·3	9·8	10·1
Fixed carbon	67·8	70·9	73·3
Sulphur	0·6	0·7	0·7
Calorific value B.T.U	11,715	12,250	12,660
Fuel ratio $\frac{\text{F.C.}}{\text{vol.}}$	7·27	....	....

Laboratory Sample No. 2420, Lower Bench

Moisture condition	R	A D	D
Loss on air drying	2·0	....	....
Proximate analysis—			
Moisture	4·0	2·1	....
Ash	12·7	13·0	13·3
Volatile matter	11·0	11·2	11·5
Fixed carbon	72·3	73·7	75·2
Sulphur	0·9	0·9	0·9
Calorific value B.T.U	12,790	13,050	13,325
Fuel ratio $\frac{\text{F.C.}}{\text{vol.}}$	6·59	....	....
		Non-coking	

A notable feature of the coals of this section is the general increase in fixed carbon in the lower seams. This indicates that much of the alteration of the coaly material was due to the load of superincumbent strata rather than to the pressure of mountain building. In the northern part of the field where mining has been carried on, the greater alteration is found in the synclines. This is noticeable in the Anthracite area and probably to a similar extent in the Canmore area. In Mine No. 2 the available analyses show that the harder coals are not the lowest; as noted below, the Stewart seam, the highest one mined, appears to be more highly altered than the Cary or Sedlock seams below it.

For comparison of the seams here explored with those of other mountain areas a complete series of analyses would be essential; but, as an indication of the amount of alteration which the material is supposed to have sustained, the relation of the volatile hydrocarbons to the fixed carbon in the coal is perhaps the simplest form of comparison. This fuel ratio has long been in use in classifying the coals of eastern Pennsylvania where the following classification has been used:

	$\frac{F.C.}{vol.}$
Anthracite	= 12 to 100
Semi-anthracite	= 8 to 12
Semi-bituminous	= 5 to 8
Bituminous	= 0 to 5

The general practice of late years has been to lower the grades somewhat and the following classification [1] is accepted:

	$\frac{F.C.}{vol.}$
Anthracite	= 10 to 50 or 60
Semi-anthracite	= 6 to 10
Semi-bituminous	= 3 to 6
Bituminous	= about 3

According to this classification the coals of Bow valley are partly semi-bituminous and partly semi-anthracite. Analyses of many of the coals of the mountain areas have been consulted and the following list may be taken as typical and shows the relative alteration to be found in these coals.

BOW VALLEY COAL

Fuel Ratio	
4·10	Canmore Mine No. 1, commercial sample[2]
4·35	Georgetown Colliery[2]
4·80	Canmore Mine No. 2, Cary seam[2]
4·88	*No. 3 seam, Smith creek*
5·05	Canmore Mine No. 2, Sedlock seam[2]
5·25	*No. 4 seam, Smith creek*
5·37	*No. 5 seam, sec. 11, tp. 24, range 10, W. 5th mer.*
5·40	Canmore Mine No. 2, 2nd Rept. Scientific and Industrial Research Council, Alberta, p. 62
5·45	Georgetown collieries, commercial sample[2]
5·55	*Marsh seam. Lower tunnel, Middle bench*
5·65	*Lowest seam on Wind Mountain creek*
5·70	Canmore Mine No. 2, Cary seam[2]
5·74	*Upper Marsh seam*
5·83	*Marsh seam, Lower tunnel*
5·90	*Cairnes gully, 4-foot seam above Cairnes seam*
6·20	*Cairnes gully, "Joe" seam*
6·59	*Wind Mountain creek, lowest seam, lower bench*
6·74	*Wind Mountain creek, second seam, upper bench*
7·27	*Wind Mountain creek, second seam, lower bench*
7·30	*Cairnes gully, Cairnes seam*
7·72	*Cairnes gully, Cairnes seam*
8·35	Canmore Mine No. 2, Stewart seam[2]

Bankhead Mine

4·00	Briquettes[2]
5·65	Commercial, buckwheat size[2]
6·45	Commercial, pea size[2]
6·80	Channel samples. 2nd Rept. Scientific and Industrial Research Council, Alberta, p. 62.
7·10	Commercial sample pea coal[2]
8·70	No. 0 seam, B. level gangway[2]
9·95	No. 2 seam, C. level gangway[2]

[1] Campbell, M. R., "The Coal Fields of the United States," U.S.G.S., Prof. Paper 100-A.
[2] Mines Branch, Dept. of Mines, Bull. No. 25.

Anthracite Mine (abandoned)

Fuel Ratio	
4·85	Seam No. 2. Geol. Surv., Can., Ann. Rept., vol. XI, p. 61 S
5·06	" No. 3. " " " "
6·03	" No. 1. " " " "
11·61	" A. Geol. Surv., Can., Publication No. 949, p. 26

COLLIERIES IN MOUNTAIN AREAS MINING COAL NOT DISTINCTLY COKING COAL

Brazeau Collieries

Fuel Ratio	
3·40	No. 3 seam. Poor coke—sampled 1915[1]
4·20	No. 3 seam. Fair coke—sampled 1915[1]
4·20	No. 2 seam. Fair coke—mine sample 1915[1]
4·25	Mine run. Fair coke[1]
4·30	No. 2 mine. No. 2 seam main entry. Poor coke[1]
4·40	No. 2 seam. Good coke[1]
4·65	No. 3 seam. Poor coke—sampled 1916[1]
5·85	No. 3 mine. No. 3 seam, average of 14-foot seam. Poor coke[1]

Mountain Park Colliery

2·15	Seam No. 1. Commercial. Good coke. 1918[1]
2·20	Seam No. 3. Mine sample. Fair coke. 1914[1]
2·30	Seam No. 3. Lower portion. Poor coke. 1916[1]
2·35	Seam No. 2. Prospect. Fair coke. 1916[1]
2·35	Seam No. 5. Poor coke. 1916[1]
2·45	Commercial sample. Fair coke. 1918[1]
2·50	Seams Nos. 1 and 3. Commercial. Fair coke. 1916[1]

Cadomin Coal Company, Limited

2·45	Commercial sample. Fair coke. 1918[1]

Blue Diamond Coal Company, Brûlé

3·10	Mine sample, 1915. Poor coke[1]
3·15	No. 2 north seam, 1917. Friable coke[1]
3·60	Commercial sample from tipple, 1917. Good coke[1]
3·90	No. 4 south seam, 1917. Fair coke[1]

Jasper Park Colliery

3·10	Commercial output, 1914. Good coke[1]
3·90	Channel samples, 1921. 2nd Rept. Scientific and Industrial Research Council, Alberta, p. 65.

COLLIERIES IN MOUNTAIN AREAS, MINING, STEAM, AND COKING COALS.

Fuel Ratio	
2·05	Leitch collieries, Passburg. Fair coke. 1913[1]
2·05	Bellevue colliery, No. 1 seam. 1908[1]
2·10	" " No. 1 seam. Poor coke. 1915[1]
2·95	" " No. 1 seam. Poor coke. 1914[1]
1·90	Hillcrest colliery. Run of mine. 1908[1]
2.35	" " No. 1 seam. Good coke. 1916[1]
2·05	Franco-Canadian colliery, Frank. No. 1 seam. Fair coke 1914[1]
2·10	" " " No. 1 seam. Good coke[1]
2·15	" " " No. 1 seam. Good coke[1]
2·35	West Can. colliery, Lille. Fair coke. 1908[1]
2·45	Greenhill colliery, Blairmore. Fair coke. 1914 and 1915[1]
2·75	" " " Blacksmith coal, hard coke[1]
2·35	Carbondale mine, Coleman. No.2 seam. Poor coke. 1915[1]
2·40	" " Run of mine. Fair coke. 1918[1]

[1] Mines Branch, Dept. of Mines, Bull. No. 25.

COLLIERIES IN MOUNTAIN AREAS, MINING, STEAM, AND COKING COALS
—Continued

Fuel Ratio	
2·20	Denison colliery, Coleman. No. 2 seam. 1908[1]
2·35	“ “ No. 2 seam. 1909[1]
2·50	“ “ No. 4 seam. Fair coke. 1908[1]
2·55	“ “ No. 4 seam. 1909[1]
2·15	Corbin, B.C. No. 4 mine, 500-foot level. Fair coke[2]
2·50	“ “ 600-foot level. Poor coke[2]
2·50	“ “ 200-foot level. Poor coke[2]
2·55	“ “ 400-foot level. Poor coke[2]
2·65	“ “ 300-foot level. Fair coke[2]
2·70	“ “ 100-foot level. Poor coke[2]
2·70	“ “ A level. Poor coke[2]
2·55	Michel colliery, B.C. No. 3 mine, east level. Good coke[2]
2·70	“ “ No. 8 mine. Commercial sample[2]
2·90	“ “ No. 7 mine. Fair coke[2]
2·30	Hosmer, B.C. No. 8 seam south. Commercial[2]
2·40	“ “ No. 6 seam south. Commercial[2]
2·95	“ “ No. 2 seam south. Commercial[2]
2·45	Fernie, B.C. No. 2 mine. Commercial[2]
2·65	“ No. 2 mine. Picking table[2]
2·65	“ No. 5 mine. Picking table[2]
2·70	“ No. 5 mine. Commercial[2]

PROSPECTED AREAS

2·25	Flathead river. Seam No. 7. Townsite[2]
2·45	“ “ Butts, 31-foot seam, top[2]
2·95	“ “ Butts, 31-foot seam, bottom[2]
3·65	Highwood river, Cat creek. 10-foot seam[1]
3·95	“ “ 7-foot seam[1]
4·30	“ “ Upper seam[1]
4·75	“ “ 22-foot seam[1]
5·00	“ “ 17-foot seam[1]
4·80	Sheep creek, Burns' area, 12-foot seam in tunnel. Geol. Surv., Can., Sum. Rept., 1921, p. 93 B
5·27	Sheep creek, Burns' area, on Sharp creek. Geol. Surv., Can., Sum. Rept., 1921, p. 93 B
5·91	Panther river, Costigan seam, near Red Deer river. Geol. Surv., Can., Sum. Rept., 1921, p. 120
2·25	Hay river, Alta., MacConnachie claim, 100-foot seam[1]
2·40	Hay river, Alta., Errington claim, 18-foot seam[1]
2·25 2·60 3·00	Berland river, near Sunset creek[1]
3·70	Moon creek, Berland river[1]
4·45	Little Berland river[1]
4·55	Little Berland river[1]
3·05	Grande Cache, Abbott claim[1]
2·85	Muskeg river, near Smoky river[1]
3·20	“ “ “ [1]
4·00	“ “ “ [1]
3·20	Smoky river, upper seam 7½ feet[1]
3·40	“ 8-foot seam[1]
3·65	“ 8-foot seam[1]
3·80	“ 16-foot seam[1]
3·90	“ 17-foot seam[1]
4·50	“ Sheep Creek branch, Campbell claim[1]
4·65	“ Sheep Creek branch, Moberly claim[1]
4·70	“ Joachim claim[1]
5·55	“ Barrett claim[1]

In the canyon of Peace river the coal seams vary in their fuel ratio from 2.25 to 4.00.

[1] Mines Branch, Dept. of Mines, Bull. No. 25.
[2] Mines Branch, Dept. of Mines, Bull. No. 26.

GEOLOGY AND MINERAL PROSPECTS OF THE NORTHERN PART OF BERESFORD LAKE MAP-AREA, SOUTHEAST MANITOBA

By J. F. Wright

CONTENTS

Illustrations

INTRODUCTION

In the summer of 1923 the detailed geological mapping and examination of the mineral prospects of Rice Lake gold area, begun in 1922, were extended southeast to the Manitoba-Ontario boundary, and with the exception of the possible extension to the northwest beyond Wanipigow lake, this whole mineral belt is now mapped in fairly close detail. The area begun in 1923 is called Beresford Lake map-area after Beresford lake near its centre, but, since the field work in the southwest corner is not yet completed, only a preliminary map and report on the northern part are published this year. At many places the rocks in the southeast end of this belt of Precambrian sediments and lavas—Beresford Lake map-area—are not so badly metamorphosed as were those described last year from the western end—Rice Lake map-area—and, therefore, much new information is added concerning the origin of the various metamorphic rocks, and the structure and stratigraphy of the whole mineral belt. It is hoped that the thick series of sediments and lavas which underlie the Beresford Lake map-area can be traced and correlated over a considerable area, and that the results of this detailed investigation will be applicable to other nearby areas, especially to the south and east.

PROSPECTING IN SOUTHEAST MANITOBA

Prospecting was fairly active in southeast Manitoba during the summer of 1923. Many prospectors visited Beresford and Long lakes to do assessment work on their claims, and several small but very rich veins were uncovered. The difficult route to this area is a very serious handicap to intense prospecting and preliminary development.

At Selkirk mine, Rice Lake map-area,[1] the Selkirk Gold Mining Company, Inc., employed about forty men throughout the year. The shaft was sunk from the 125-foot level to the 320-foot level, and more than 800 feet of drifting was completed on the second and third levels. In August, a five-stamp test-mill was completed, and since then about 25 tons of ore per day have been milled. Test runs from the different levels and slopes have already been made, and the company are pushing their development work as fast as is possible under present transportation conditions.

On the Mayville copper-nickel claim, Maskwa River area, approximately 15 miles south of Beresford Lake area, Smith and Travers, of Sudbury, completed about 2,000 feet of diamond drilling for the Martin-Devlin Development Company. The drilling proved a considerable body of low-grade ore in very coarse-grained gabbro, along a gabbro-andesite contact, which dips between 30 and 40 degrees to the southeast.

In Oiseau River area, about 30 miles south of Beresford Lake area, twelve men under the direction of Mr. H. A. Wentworth did considerable prospecting on two copper-silver claims and it is intended to diamond drill these claims during the winter of 1924. Chalcopyrite is the abundant ore mineral here, and is in lenses, or disseminated along sheared and fractured zones in quartzose sediments.

In view of the active prospecting in the Maskwa and Oiseau River areas, a few weeks were spent in each, in a preliminary study of the geology and mineral deposits. As far as is known, the country between these areas is underlain by granite and granite gneiss with many schist inclusions, and, therefore, it is impossible to correlate the geology of the three areas at present.

ACKNOWLEDGMENTS

The field assistants, R. H. Taschereau and W. S. Yarwood, were very efficient, and the writer is indebted to them for their interest in the progress of the work and the painstaking manner in which they carried out their duties.

In Beresford Lake map-area, Messrs. William Walton, William Quesnel, and George Edmonds assisted the progress of the mapping by pointing out important prospects, and by many other kindnesses. Thanks are due to the Martin-Devlin Development Company for the use of their comfortable cabins on the Mayville claim, Maskwa river. In Oiseau River area, Mr. H. A. Wentworth, Major T. C. Anderson, and Mr. H. D. MacDonald, mining engineers supervising the prospecting, extended many courtesies to the party. It is a pleasure to acknowledge the above assistance, and the writer is grateful to many others not mentioned, for their help and interest in the progress of the work.

The Royal Canadian Air Force transported the parties, provisions, and mail from Victoria Beach to Long lake. Owing to bad weather conditions and other unfortunate and unforeseen events, the Air Force could not give as much assistance as had been hoped, but the writer wishes to express his indebtedness to Major D. B. Hobbs, Squadron Leader, for the assistance rendered and for his keen desire and efforts to do whatever was possible.

[1] Geol. Surv., Can., Sum. Rept., pt. C, 1922, pp. 64-67.

LOCATION AND ACCESS

The part of Beresford Lake map-area, described in this report, extends west 14 miles along Manigotagan river and its tributaries from near the southeast corner of Rice Lake map-area, mapped in 1922, and is 7 miles wide.

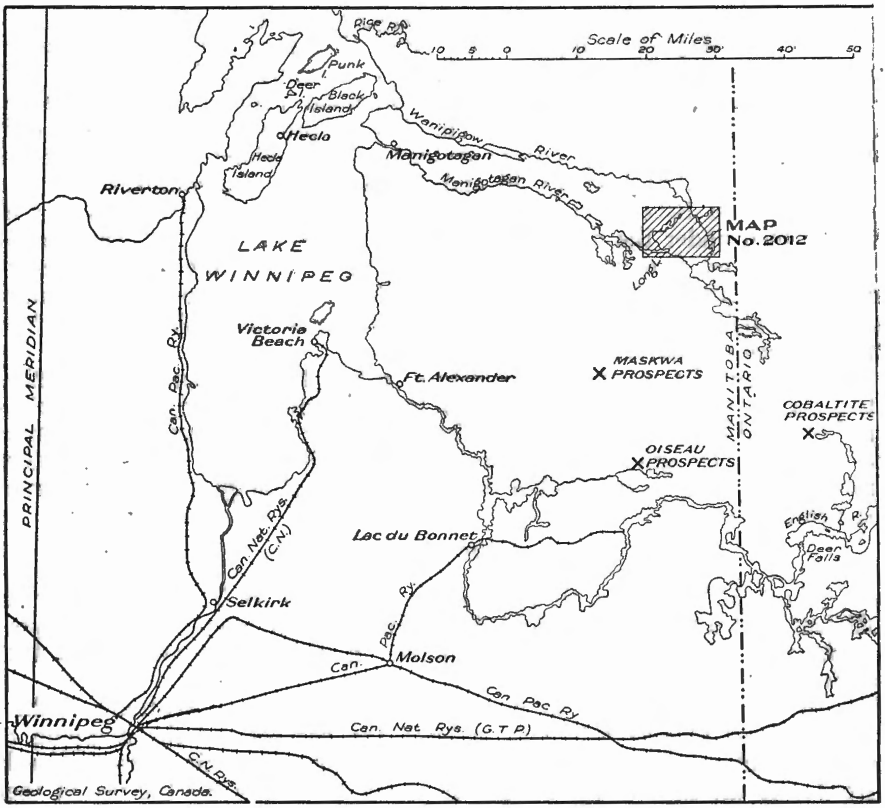
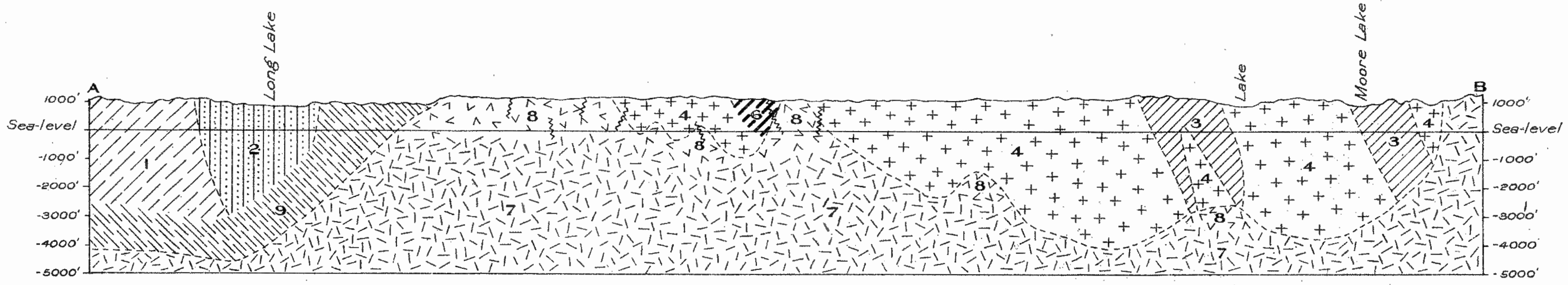
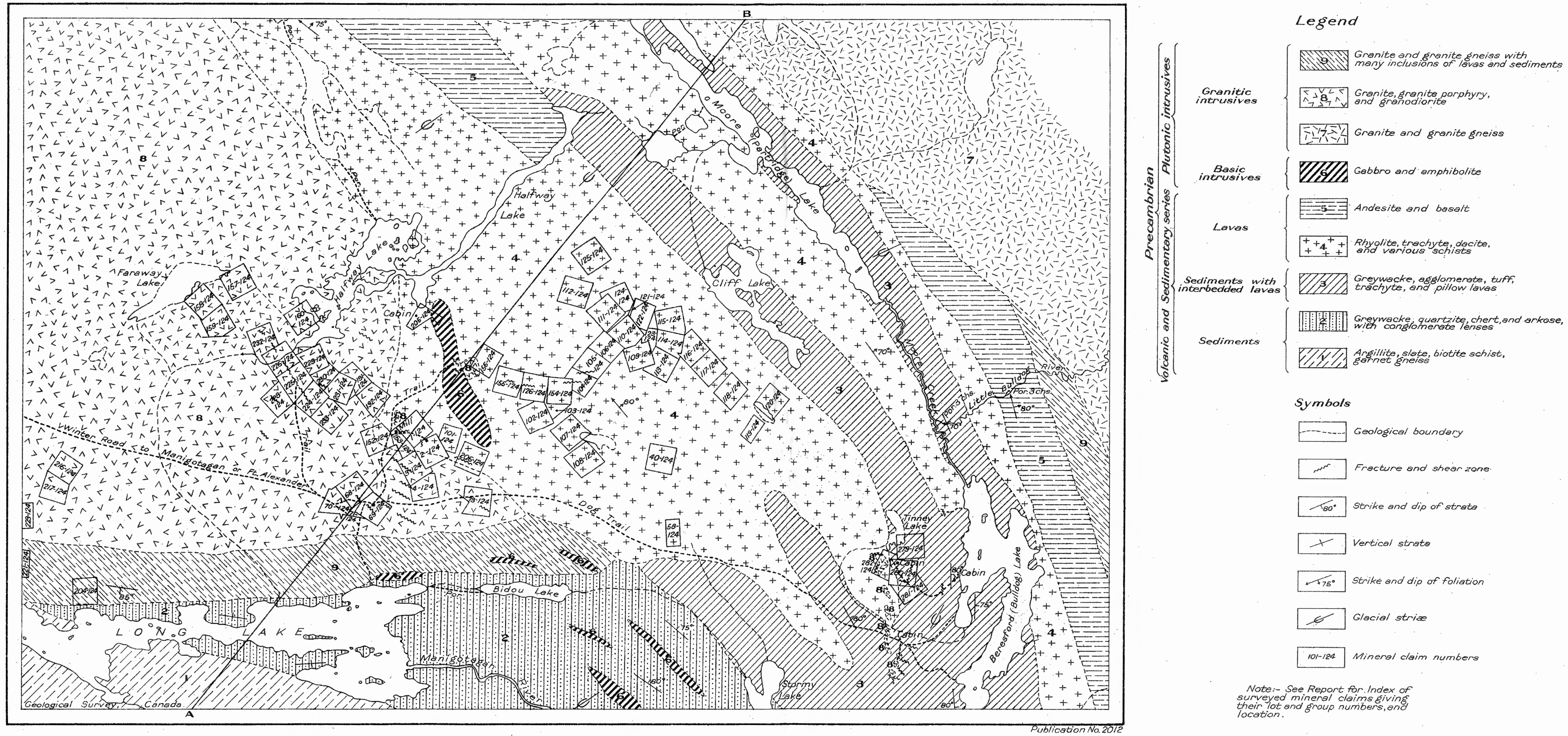


FIGURE 13. Index map showing location of Beresford Lake area (Map 2012), southeastern Manitoba.

Beresford Lake map-area is not readily accessible, but may be reached by canoe either from Lac du Bonnet or Manigotagan village. Lac du Bonnet, at the end of the Canadian Pacific branch from Winnipeg lies about 50 miles southwest of the map-area, and from there to either Beresford lake or Long lake there are twenty-seven portages, two of which are slightly over one mile each in length. The route is by motor-boat from Lac du Bonnet station to the first falls on Oiseau river, thence by canoe up Oiseau river to the east end of Oiseau lake, and thence northeast across a series of lakes connected by a small stream. At about 500 feet east of the



Structural section along line AB



Beresford Lake Area, Rice Lake Mining District, Southeast Manitoba.

Scale of Miles

1 ½ 0 1 2

To accompany report by J. F. Wright, in Summary Report, Part B, 1923.

eastern end of Snowshoe lake the route turns north across Alga and Wingiskoos lakes to Bee lake on the southwest branch of Manigotagan river. This river is followed west of Long lake, 6 miles east of which a branch leads northeast to Beresford lake. Long lake can be reached more easily from Manigotagan village, because, unless the water be high, Manigotagan river west of Bee lake is shallow. On Manigotagan river, between the village and Long lake, there are thirty portages and the distance by canoe is about 45 miles. The area can be reached by winter roads either from Fort Alexander or Manigotagan village.

BASE MAP AND PREVIOUS GEOLOGICAL WORK

The map (No. 2012) accompanying this report was compiled from stadia traverses of the principal lakes and rivers of Rice Lake mining district made by B. W. Waugh, D.L.S., in 1919, mineral claim surveys made by H. G. Beresford, D.L.S., and telemeter traverses made by the writer in 1923. The geological boundaries are located by closed pace and compass traverses.

Beresford Lake area was traversed in the reconnaissance geological survey of Manigotagan, Wanipigow, and Oiseau rivers, by Moore and Wallace in 1912.[1] Marshall[2] spent the summer of 1917 in the area, and DeLury,[3] in 1920, examined and described the gold prospects. In the summer of 1921, Dr. E. M. Burwash,[4] for the Ontario Department of Mines, examined the eastern part of the area adjacent to the Manitoba-Ontario boundary line.

TOPOGRAPHY

Beresford Lake map-area lies 40 miles within the southwestern edge of the extensive Canadian Precambrian shield, the topographical features of which are remarkably uniform over wide areas and have been described in great detail in many reports on small local areas within this physiographic province. There is a close relationship between topography and underlying bedrock and the outstanding topographical features of this great area as emphasized in previous reports are: (1) even sky-line and apparently plain-like surface when viewed from any hilltop; (2) small local relief, but rough surface, due to many low hills and narrow valleys; (3) numerous picturesque lakes with irregular outline and numerous islands; (4) rivers and brooks with many rapids and waterfalls.

Beresford Lake map-area lies within the drainage basin of Manigotagan river. About 6 miles east of Long lake, Manigotagan river divides into a southwest branch which drains Island lake and Bee lake, and a northern branch, which, about 2 miles above this junction, divides into a central branch draining Garner lake, and a northern branch draining Beresford

[1] Moore, Elwood, S., "Region East of the South End of Lake Winnipeg," Geol. Surv., Can., Sum. Rept., 1912, pp. 262-270.

[2] "Gold-bearing District of Southeastern Manitoba," Geol. Surv., Can., Sum. Rept., 1917, pt. D, pp. 17-21.

[3] "Mineral Prospects of Southeastern Manitoba," Manitoba Bull., 1920.

[4] "Geology of the Ontario-Manitoba Boundary," Ont. Dept. of Mines, vol. XXXII, pt. II, 1923, pp. 1-48.

and Moore lakes. These rivers are typical of the rivers of the Precambrian area in general, and consist of still-water or smooth-flowing stretches connected by rapids and falls.

In many local areas within the Precambrian shield, there is a noticeable uniformity in the elevation of the hilltops over considerable areas. In Beresford Lake area this feature is fairly noticeable, the average general elevation of the hilltops being between 1,150 and 1,170 feet above sea-level. Long lake occupies a long, narrow depression and is 983 feet above sea-level, and Garner lake, 15 miles to the west, is 1,050 feet above sea-level. Elevations along the Manitoba-Ontario boundary about 5 miles to the east of the area average from 1,040 to 1,222 feet. In areas underlain by granite the local relief varies from 10 to 100 feet, but in areas underlain by sediments the relief is somewhat greater, averaging from 25 to 175 feet.

In Beresford Lake map-area, as in Rice Lake map-area, the bedrock topography has been but slightly modified by glacial erosion and deposition, and the close relation of topography to underlying rock structure is especially noteworthy in this area underlain by lavas, sediments, and granite. Physiographically the map-area, therefore, naturally falls into two divisions, the one outlined by the distribution of the lavas and sediments and the other by that of the granites.

The topography of the area underlain by sediments and lavas, especially east of Long lake, is characterized by parallel northwest-southeast trending ridges separated by nearly continuous steep-walled valleys. Sections of these valleys are occupied by streams and lakes as illustrated by Manigotagan River valley west of the first forks. The linear feature of the topography is directly related to the structure and type of underlying rock, the valleys being parallel to the strike of the steeply-dipping, thick, resistant beds of arkose, greywacke, and schist.

In contrast with the long parallel ridges of the areas underlain by sediments are the irregularly shaped, discontinuous knobs and ridges of the granite areas. These granite knobs are, in most cases, covered with small jackpines, and rise out of the surrounding swamps and muskegs as do islands above the water of a lake. Small lakes with irregular shorelines and numerous islands are abundant in these areas.

PRECAMBRIAN GEOLOGY

All the bedrock of Beresford Lake area is Precambrian and consists of metamorphosed sediments and lavas intruded by small bosses or sills of gabbro and very large masses of granite. These rocks may be arranged in five groups as shown in the following table.

Group and relation	Component rock
Granitic intrusives *Intrusive contact*	Granite, granite porphyry, and granodiorite Granite and granite gneiss
Basic intrusives *Intrusive contact*	Gabbro and amphibolite
Volcanic series *Apparently conformable contact*	Andesite and basalt Rhyolite, trachyte, dacite
Sedimentary and interbedded volcanic series *Apparently conformable contact*	Rhyolite, trachyte, pillow lavas, agglomerate grit, tuff, and greywacke
Sedimentary series Base not exposed	Quartzite, greywacke, and arkose, with conglomerate lenses Argillite, slate, garnet gneiss, and biotite schist

Most of the rocks in the above table were described in some detail last year and only general descriptions are given in this report. The succession of sediments and lavas has been determined for this local area, but no formational names for the three groups of rocks recognized are introduced at present, because it may be found advisable after more extended field work to subdivide this thick series of rocks in more detail, or to reduce the three groups to two. The fine-grained clayey rocks near the present exposed base of the sedimentary series are separated to the east of the Beresford Lake area by a conglomerate horizon, which is followed by coarse-grained quartzose and arkose sediments. These two contrasted types of sediments indicate a marked change in the conditions under which these rocks originated, but there is no evidence of a marked time interval or structural unconformity between them, or between the sediments and lavas. It is hoped in the near future to establish a general classification of the Precambrian rocks of southeast Manitoba, as has already been done in Timiskaming district and the region north of lake Huron.

SEDIMENTARY SERIES

The rocks of this series fall into two divisions, a lower, fine-grained, argillaceous group, and an upper, coarse-grained, sandy group. About 10 miles southeast of Long lake these two groups are separated by a conglomerate-grit horizon over 1,000 feet thick, which gradually thins out to the west; and at the east end of Long lake argillite is followed directly by arkose and greywacke. The lower argillaceous members of the series were traced and found equivalent to the biotite schists and garnet gneisses described last year as a probable sedimentary series, and the upper, sandy members undoubtedly correspond to the sedimentary series outcropping west of Rice lake.[1]

Sedimentary rocks outcrop on the shore of Long lake and for 20 miles or more to the east and southeast. The areal extent and thickness of this series have not yet been determined; but the series must have been over 30,000 feet in thickness originally. Everywhere these sediments now stand vertically or dip steeply—60 degrees or more—to the north.

Argillite and Slate. These are fine-grained, black or dark grey, fissile rocks having in places a well-developed slaty cleavage; other beds are only slightly metamorphosed and still show stratification lines and, in a few places, ripple-marks. Some of the thin, clayey beds between sandy beds are compressed into a series of northwestward-plunging, drag folds, the axial planes of which dip to the north. Thin sections of these rocks show under the microscope a mosaic of small quartz grains with areas of dark green or dark grey, chloritic-looking material.

Garnet Gneiss and Biotite Schists. To the northwest and approaching the granite contact to the south, the argillite and slate described above gradually grade into highly metamorphosed gneiss and schist. About a mile from the granite contact the clayey beds contain abundant, small, red garnets, but the quartzose beds are very little altered. However, as the granite contact is approached the whole rock becomes gneissoid or schistose and is intruded by numerous granite and pegmatite dykes. Near the actual contact these sedimentary materials are so thoroughly recrystallized that in many places it is impossible to differentiate them from gneissoid granite.

These sedimentary gneisses and schists are medium-grained, greyish rocks and under the microscope appear fairly coarse, with unaltered quartz grains, biotite, white mica, and chlorite. In addition to these minerals some thin sections contain light red garnets, microcline, and a twinned plagioclase approaching oligoclase. The minerals are all fresh and are only slightly granulated. The quartz and biotite grains are intimately intergrown, and inclusions of quartz in biotite, or biotite in quartz, are abundant. The proportions of the minerals present in the different thin sections vary considerably.

Quartzite, Arkose, and Conglomerate. The fine-grained, argillaceous sediments described above are followed by quartzose sediments, the most

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[1] Geol. Surv., Can., Sum. Rept., 1922, pt. C, pp. 54-56.

abundant type of which is arkose; but near the base there are a number of quartzite and chert beds and conglomerate lenses. These rocks outcrop from the east end of Long lake southeast to Island lake. The beds are thick and massive, and the typical rock weathers greyish-white, but many beds have a greenish, granular appearance. In some specimens both quartz and feldspar are recognizable, and thin sections under the microscope show rounded quartz fragments with irregular outline, together with some cloudy-looking orthoclase and oligoclase-albite in a fine-grained matrix of quartz, calcite, and white mica. The conglomerate lenses are seldom over 20 feet in thickness, and the pebbles are well rounded and consist for the most part of quartzite.

Greywacke. This rock type is abundant near the top of the series and consists of fine-grained, dense, greyish-looking material, which in places shows evidence of stratification. Thin sections examined consist of about 50 per cent quartz and 40 per cent greenish or greyish chloritic material and some calcite, a few feldspar grains, and a little brown biotite. The fine-grained, dense varieties consist of a micro-crystalline aggregate of quartz, with minor amounts of pyrite, epidote, and calcite. In places, this greywacke rock grades into typical quartzite or coarser arkose material. This whole series is very quartzose and originally was a fine to coarse-grained, sandstone series.

SEDIMENTARY AND INTERBEDDED VOLCANIC SERIES

The rocks of this series are heterogeneous in character, comprising from the base upwards a succession of thick greywacke beds with thin lava flows and pyroclastic beds, the lavas and pyroclastic material increasing until volcanic material predominates. Between the flows there are only thin chert and greywacke beds or lenses. In areal mapping, it is difficult, owing to the interbedded character of these rocks, to decide a definite contact at the base and top of this series, but the base was arbitrarily fixed where the first definitely recognized volcanic material was encountered, and the top where the sedimentary material formed 10 per cent or less of the rock. The lavas are more abundant along the strike to the northwest, and to the southeast the sediments and pyroclastic materials predominate, until near Island lake the lavas are very scarce or are absent.

Agglomerate and Tuff. Coarse fragmental rocks predominate near the base and gradually give place to tuffs and cherty beds near the top of the series. However, along the same general horizon these materials show all degrees of coarseness and sorting from fine-grained, well-bedded tuffs formed from volcanic ash material to agglomerate beds formed from large volcanic bombs. The bed, about 200 feet in thickness, that outcrops about three-quarters of a mile west of Tiney lake, is a good example of a coarse fragmental rock. This bed can be traced about 3,000 feet along the strike and consists of fragmental pieces of quartz and feldspar porphyry in a groundmass of schisted pillow lava and ashy volcanic material. The porphyry fragments are angular and vary from 1 inch to 2 feet in length. This agglomerate bed is followed by greywacke, which is followed by pillow lava with large, rounded lumps of what appears to be included sedimentary material. It looks as if the pillow lava in flowing along the surface had gathered up and included masses of the sediments. Dark grey, fine-grained, dense rocks, probably for the most part formed of ash blown from volcanic vents, are common in this series. In a few places these rocks are banded or finely laminated, and are undoubtedly tuffs. As a rule, it is impossible either in the field or after microscopic study of thin sections to determine whether a particular outcrop of this type of rock is a lava or a tuff. In most cases this doubtful material is classed as tuffaceous sediments.

Rhyolite, Trachyte, and Pillow Lavas. Interbedded with the sedimentary materials described above are flows of acidic lavas. In places these lavas are slightly porphyritic and small quartz and feldspar phenocrysts stand out on the white or greyish weathered surfaces. Some of the dark grey flows have poorly-developed pillows, but where no phenocrysts or pillows are recognizable in the field, it is difficult to decide whether a particular outcrop is a lava or greywacke-like sediment.

The rhyolites are white or grey rocks, some with small, bluish, rounded, quartz phenocrysts, but as a rule they are felsitic-looking rocks, thin sections of which consist of a microcrystalline aggregate of quartz, feldspar, and sericite with considerable glassy-looking material. The trachytes are greyish-weathering rocks consisting of a finely crystalline aggregate of greyish kaolinized feldspar with abundant chlorite and some brown biotite. The pillow lavas are dark grey, schistose rocks, the mineralogical composition of which is difficult to determine, but they are evidently fairly basic, possibly near andesites.

VOLCANIC SERIES

In areal mapping the rocks included in this series were divided into a light-coloured, acidic group and a dark-coloured basic group. In many places light and dark-coloured lavas are interbanded, and such areas are mapped under the acidic group. The lavas are fairly massive, fine-grained to dense rocks, and often show pillows or other evidence of their volcanic origin. Basic and acidic intrusives, very similar in appearance to the lavas, outcrop as dykes, sills, or small bosses in the areas mapped as lavas, but in a low, flat, muskeg country with widely scattered outcrops, it is in many cases impossible in the field to prove the intrusive relations or areal extent of these intrusives, and, therefore, it was found impossible in most places to map them separately from the lavas which are similar in composition and texture.

Rhyolite, Trachyte, and Dacite Flows. Most of the rocks of this group are similar to the acidic lavas already described as interbedded with sediments, but a very abundant type of lava included in this group is a greyish to black, fine-grained, massive rock with the following approximate mineralogical composition: hornblende 40 per cent; plagioclase (between albite and oligoclase) 30 per cent; quartz 15 per cent; chlorite

8 per cent; brown biotite 5 per cent; and accessories 2 per cent. A large proportion of the quartz is, probably, secondary. The inclusion of one mineral within another, and the irregular shape and interlocking character of the mineral grains suggest that this rock is, to some extent at least, a recrystallized product. In places, the outcrops show poorly-defined pillows and the rock perhaps was originally a hornblende-rich dacite.

Andesite and Basalt. These are dark grey to black, fine to medium-grained lavas. They are fairly massive, fresh-looking rocks, but in places are schisted and weathered to a reddish colour. Thin sections examined consist of abundant hornblende and plagioclase, ranging from oligoclase to andesine. There is always considerable chlorite and greyish glassy-looking material. Some thin sections contain considerable secondary quartz, and augite is fairly abundant in thin sections of the medium-grained, massive varieties.

SUCCESSION OF SEDIMENTS AND LAVAS

All the field evidence to date indicates that the younger beds of this series lie to the north and the succession from north to south and nearly at right angles to the strike is lavas, lavas with interbedded sediments, and sediments. The strata and lava flows now strike from north 30 degrees west to north 80 degrees west, and stand vertical or dip steeply to the north, but the dips are so steep—from 60 to 90 degrees—that it is possible that the beds might have been overturned, in which case the succession would be the reverse of that indicated. However, the ripple-marks, dip of the cleavage, and the dip of the axial planes of the drag folds all indicate that such is not the case, and that the top of the strata and flows is to the north.

Many of the sandy argillaceous beds near the top of the argillite-slate series are rippled-marked, and at several horizons these ripple-marks are still well preserved. All the ripple-marks observed were symmetrical and in twelve cases the sharp crests and broad troughs are still noticeable. Many of the ripple-marked beds are now standing nearly vertical, and at the localities where the crest and trough of the ripple-mark were definitely determined the younger bed was always to the north, showing that the structure was not overturned.

Cleavage and drag folds are well developed in numerous outcrops of the slaty argillaceous beds, in a number of the greywacke-like beds interbedded with quartzite and arkose, and in some of the tuffaceous sediments interbedded with the lava flows. It is evident that these rocks were folded in the zone of combined flow and fracture, since the soft weaker beds flowed and drag folded, whereas adjoining thick quartzose beds fractured. In every observed case the cleavage is inclined at an acute angle to the bedding and dips towards the north, and the drag folds plunge slightly to the northwest with their axial planes dipping about 75 degrees to the north. The inclination of both the cleavage and the axial planes of the drag folds indicates that the southerly beds have moved upwards relative to the adjoining northerly beds, hence they are on the south limb of a large syncline with its axis to the north. In traversing this fold at right angles progressively older beds will be crossed in going from north to south.[1]

CONDITIONS OF ORIGIN OF SEDIMENTS AND LAVAS

The argillite, slate, garnet gneiss, and various schists outcropping along the south side of Beresford Lake area and at the present exposed base of the sedimentary series were originally fine, argillaceous, and sandy materials. Although near the top of the series some beds are ripple-marked, the great bulk of the series is thought to have been formed in fairly deep water. To the south these sediments are intruded by granite, which possibly digested a considerable thickness of sedimentary material. Contemporaneously with this intrusion the clay rocks were metamorphosed to various types of gneisses and schists, for at least one mile north of the granite contact.

To the east of Beresford lake these clayey rocks are followed by a conglomerate horizon about 1,000 feet in thickness east of Bee lake, but along the strike to the northwest this bed thins and disappears just south of Island lake, so that east of Long lake the clayey rocks are followed directly by arkose and greywacke with only small conglomerate lenses. As compared with the clayey sediments at the base, this series is predominantly quartzose, fairly coarse grained, and the materials are angular; and although the quartzite, arkose, and greywacke are interbedded or are in lens-shaped beds, the arkose and conglomerate-like materials predominate near the base, and greywacke near the top. It is very probable that the materials forming these rocks were deposited in shallow water, under near-shore or possibly continental conditions. Undoubtedly there was a marked change in the conditions under which the clayey and quartzose rocks formed, yet there is no apparent evidence of a structural unconformity or a long time interval between these two markedly different formations.

The quartzose greywacke-like sediments are followed by agglomerates, grits, and tuffs with interbedded acid lava flows. Near the top of this series the lava flows become more abundant, and the sediments are finely-bedded tuffs and cherts. Also, to the northwest along the strike and apparently along the same horizon, lavas are more abundant, whereas to the southwest sedimentary materials predominate, and near Island lake there is little volcanic material in this series. Pillow lavas are not characteristic of these lava flows, but a few flows do show poorly-developed pillows. There is little evidence to indicate whether the lava flowed over a land surface or under the water.

The conditions under which these sediments and lavas are thought to have originated may be summarized as: (1) deposition of clayey material in fairly deep quiet water; (2) deposition of sandy material in shallow water and near shore, followed by intermittent acidic lava flows

[1] For a detailed discussion on the use of ripple-marks, cleavage, and drag folds in determining structure see "Leith's Structural Geology" (revised edition) pp. 176-189.

and continued deposition of quartzose and pyroclastic materials; and (3) outpouring of acidic and basic lavas possibly over a land surface.

The total thickness of these sedimentary and volcanic rocks has not been accurately determined, but it originally must have been very great. A thickness determined last summer measures over 5 miles providing there be no repetition of beds by overturned isoclinal folding or strike faulting, and no field evidence of such folding or faulting was noted. Both the bottom and top of the series have been cut off by granitic intrusions, so that the original thickness is not exposed in this area at present. The quartzose sediments outcropping east of Long lake are about 10,000 feet in thickness, or of about the same thickness as the lithologically similar series outcropping west of Rice lake, and with which this series is correlated.

BASIC INTRUSIVES

Basic intrusives (anorthosite, gabbro, and diorite) cutting the (Keewatin) lavas and sediments and older than the granitic (Laurentian) intrusives have been recognized in many areas in western Ontario, but in most cases these intrusives have not been mapped separately from the lavas. Lawson[1] describes sills and laccolithic lenses of hornblende gabbro and anorthosite intruding the sediments and lavas (Couchiching and Keewatin) and older than the granitic (Laurentian) intrusives. In southeast Manitoba similar basic intrusives were recognized and mapped by McCann[2] in Maskwa River area. McCann found no definite evidence for fixing the age of these basic intrusives, but believed they were Keweenawan. Cooke,[3] in Oiseau River area, mapped a large gabbro sill as younger than the granitic intrusives of that area, and in Maskwa River area described the gabbro as older than the granite. In Rice Lake map-area some of the medium-grained, massive rocks outcropping with the basic volcanics were thought by the present writer to be intrusives, but they were not mapped separately because of their marked similarity in appearance to the basic volcanics.[4] However, in Beresford Lake area, basic intrusives cut the sediments to the southeast of Long lake, and are easily recognized and mapped separately from the older sediments. These intrusives are older than the granite north of Long lake, as this granite cuts across a gabbro dyke or sill. The gabbro is cut by granite dykes, and is also fractured, sheared, and impregnated with gold-bearing quartz from the granite.

The most abundant rock type is a hornblende gabbro, which, in many places, is metamorphosed to amphibolite. In the thin sections of the massive, coarse-grained rock examined under the microscope the minerals are unaltered, the plagioclase feldspar being labradorite or basic andesine, and the ferromagnesian mineral a green, highly-pleochroic hornblende. Minor amounts of magnetite, titanite, and chlorite are always present, and

1 "Archæan Geology of Rainy Lake Re-studied," Geol. Surv., Can., Mem. 40, 1913, p. 38 and p. 42.

2 "The Maskwa River Copper-nickel Deposits, Southeast Manitoba," Geol. Surv., Can., Sum. Rept., pt. C, 1920, pp. 19-29.

3 "Geology and Mineral Resources of Rice Lake and Oiseau River Areas, Manitoba," Geol. Surv., Can., Sum. Rept., pt. C, 1921, pp. 14-21.

4 Geol. Surv., Can., Sum. Rept., pt. C, 1922, p. 50.

in a few thin sections there is considerable biotite. Thin sections of the amphibolite have the following approximate mineralogical compositions: 50 per cent green hornblende in long needles; 25 per cent plagioclase recrystallized and altered to epidote and calcite; 10 per cent secondary quartz; considerable chlorite and magnetite.

In crossing certain gabbro masses the compass indicates marked local attraction, due apparently to considerable segregations of magnetite or pyrrhotite in the gabbro. No sulphide deposits of possible economic value have yet been found associated with these intrusives in Beresford or Rice Lake map-areas, but in the Maskwa and Oiseau River areas to the south, deposits of copper-nickel and copper-silver-bearing sulphides, possibly of considerable economic importance, are evidently associated with gabbros. In view of this known association of copper-nickel-silver-bearing sulphides with rocks belonging probably to this period of intrusion, it is of considerable economic importance to differentiate and to map the areal extent of these basic intrusives, wherever possible.

GRANITIC INTRUSIVES

Granitic intrusives are widespread in southeast Manitoba. In the areal mapping of Beresford Lake map-area these intrusives have been divided into two groups on the basis of lithology and general appearance. The more widespread of these two groups is a massive or gneissic, grey or pink, medium-grained, microcline-rich, oligoclase-albite, biotite granite with approximately 25 per cent quartz. This granite is cut by numerous pegmatite and aplite dykes, but no gold-bearing quartz veins have yet been found associated with it. The other variety of granitic intrusives mapped in Beresford Lake area is represented by massive, coarse-grained, frequently porphyritic, light to dark grey rocks, thin sections of which consist of oligoclase, orthoclase, green hornblende, and about 15 per cent quartz. Many thin sections of this intrusive have the composition of granodiorite, whereas others contain a large proportion of orthoclase feldspar, but microcline is absent or only sparingly present. The gold-quartz veins of the area are associated in origin and distribution with this type of granitic intrusive, but no typical pegmatite or aplite phases have been recognized.

Although represented by different symbols on the map, these two phases of granitic intrusives are thought to be of the same age and to belong to the same granitic mass. The structure section accompanying the map (No. 2012) of Beresford Lake area shows a probable interpretation of the relationship of these two types. It is thought that the massive granodiorite type of intrusive represents the tops of bosses from a large, nearly flat-topped, granite mass below. It has been described from many areas and by different geologists, who have recognized that the rocks of the small, boss-shaped, granitic masses near and around the edge of the large granitic masses are massive and slightly more basic in composition than are the rocks of the nearby large granitic masses themselves. Also, when these granodioritic masses are large, as is the case between Long and Gold lakes, erosion has cut deeper near the centre of the mass, and typical granite or granite gneiss is exposed. These more basic, massive, small, boss-shaped masses have been described as younger in age than the typical granite, but it seems very probable that instead of being younger they represent the roof phases of large, comparatively flat-topped intrusive masses. The magma squeezed up in these small domes and along the top of the mass would naturally cool and crystallize first. This would slow cooling and crystallization below, with the result that conditions were favourable for the formation of typical granite. In most Precambrian areas erosion has removed this outer shell, and typical granite and granite gneiss are now exposed over very wide areas.

GLACIAL DEPOSITS

East of lake Winnipeg the Precambrian formations are partly covered by glacial deposits, and stratified clay, formed in glacial Lake Agassiz, is widespread, reaching an elevation of 900 feet above sea-level. It is very probable that Palæozoic and Mesozoic formations once covered this area, but they evidently were all removed by erosion before the end of Pleistocene time. In Pleistocene time the country was undoubtedly covered by two or three different continental ice-sheets, but evidence of only the last ice advance and retreat has been found in any of the local areas studied in this particular region.

Glacial deposits are not thick in Beresford Lake area, but erratics and thin deposits of sand and boulder clay are irregularly distributed over the area. Bedrock has been well exposed in over one-half the area by forest fires that have denuded the ridges of moss. The boulder clay is thin, except locally in protected places along a few valleys. The few, small, flat sand areas possibly represent outwash materials. The absence of eskers or terminal moraine deposits is noticeable. No Lake Agassiz stratified clays were noted in Beresford Lake area.

The general direction of ice movement across Beresford Lake area was south 45 degrees west magnetic, but many striæ vary in direction as much as 25 degrees either south or west, this variation being due perhaps to the effect of local topographical features.

GOLD PROSPECTS

In Beresford Lake area gold-bearing quartz deposits outcrop north of Long lake and west of Beresford lake. These deposits are similar in origin to those of Rice Lake map-area, which were described in detail last year.[1] Their geological features may be summarized as follows:

The gold quartz deposits outcrop along fracture and shear zones in massive, coarse-grained, granodioritic phases of the granitic intrusive, and in the lavas and sediments near the contacts with these intrusives.

These fractures and shear zones originated through local forces associated with the intrusion of the granitic magma, and are not long, continuous, well-developed fault zones.

They are characterized by pinches and swells along their entire length, and are only partly replaced with quartz, various sulphides, and gold.

[1] Geol. Surv., Can., Sum. Rept., 1922, pt. C, pp. 63-73.

The quartz, sulphides, and gold represent a residual magma or residual solutions from the granitic magma that concentrated along these local fracture and shear zones.

In general character and mineralogy, these deposits resemble gold quartz deposits formed under conditions of intermediate depth and temperature.

The deposits of greatest known economic importance occur within or near the contact of the coarse-grained, massive, dioritic phases of the granitic intrusives, and particular attention to such areas should be given by prospectors and development companies.

Because of the lens-shaped distribution of the gold-bearing quartz, a great deal of expensive, systematic exploratory work must be done on each individual property to prove the size and value of the ore-body.

PROSPECTS NORTH OF EAST END OF LONG LAKE

Prospecting has been active in this area since the summer of 1916. The first prospect was opened by Mr. A. M. Stewart near the middle of the southeast side of the Dardanelles mineral claim. At this point a pit about 15 feet in depth was sunk along a fracture zone striking north 30 degrees west and dipping 40 degrees east. The country rock in the vicinity of this pit is trachyte and andesite lavas, but the mineralized zone is in the andesitic rock, of which the foot-wall is massive and the hanging-wall is fractured and schisted. There is little or no quartz in sight and the fracture apparently does not extend over 200 feet along the strike. The contact of the lavas and granitic intrusives is about 800 feet directly south.

About 1,000 feet to the west of this pit and on the Elora Fractional mineral claim, Mr. Stewart in 1922 installed a two-stamp amalgamation mill, and produced several thousand dollars worth of gold bullion from a small but very rich deposit. This deposit was worked by open-cut methods, and a trench striking north 70 degrees west and about 100 feet long, 15 feet deep, and 2½ feet wide was dug. Considerable arsenopyrite was noted in pockets irregularly distributed through the quartz, and associated with this arsenopyrite were some very rich specimens with free gold.

On the Red Top mineral claim and about 500 feet west of the Elora Fractional workings is another sheared zone striking north 50 degrees west. This shear zone is in the lavas, but is near the contact of the granitic intrusives to the west. It is very small and cannot be traced over 100 feet. On the Valley Vein mineral claim, about 1,000 feet to the southeast and across a large swamp, there is another shear in the granitic intrusives. This shear is on the strike of the Red Top shear and possibly may represent its continuation in this direction. On both these claims, there are small quartz lenses carrying free gold.

On the Blenn claim, and about 500 feet north of the Elora Fractional workings, a gold-bearing quartz vein was discovered in June, 1923. The deposit is near the top of a small hill and is in andesitic lavas, but a small boss of granodiorite outcrops on top of the hill about 100 feet to the north. The quartz mass strikes south 20 degrees east and is 8 feet wide in its widest place, but averages 4 feet for about 100 feet along the strike. The quartz is fractured and free gold is abundant in small local areas within this quartz. Not enough stripping had been completed in July, 1923, to indicate the size of this quartz lens. Although along the trail, this deposit was not discovered before, as the southwest side of this hill is covered with glacial outwash materials and only a small, low outcrop of quartz about one foot square was originally exposed.

On the North Star mineral claim, which is about 3,000 feet northeast of the Blenn mineral claim, there is a fractured, sheared, quartz-impregnated zone in the gabbro. This zone strikes south 75 degrees east and has been traced about 200 feet. About 250 feet to the southeast are two parallel shears about 100 feet apart, but neither of these shears is a continuation of the main zone. In the main zone the quartz is 3 feet wide in the widest place and averages about 1 foot in width for a distance of about 75 feet along the strike. A number of specimens on the dump contain free gold.

A boss-shaped mass of granite porphyry outcrops about 800 feet northeast of the North Star workings, and on the Joffre and Growler mineral claims on the north side of this granite porphyry mass there are small fractured zones with quartz stringers. Near the north side of the Kitchener mineral claim, which adjoins the Growler mineral claim on the southeast, is a well-defined shear zone striking south 85 degrees east. The country rock is andesite lava, but the sheared zone appears to follow a chert or clayey sedimentary bed. This shear has been traced 1,000 feet along the strike, and in places the quartz lenses are up to 4 feet in width. The quartz is dark-coloured and specimens of it were seen that carried free gold, pyrite, and chalcopyrite. Two small shear zones with some quartz carrying free gold were noted on the claim to the east of the Kitchener.

To the east of the original discovery on the Dardanelles mineral claim there are several claims with fracture zones impregnated with some gold-bearing quartz. On the Gold Hill mineral claim, No. 206-124, and about 3,000 feet southeast of the Dardanelles claim, a shaft has been sunk 25 feet in a sheared zone impregnated with quartz stringers. This zone strikes south 60 degrees east and is covered by a swamp to the southeast, but about 200 feet to the northeast narrows and disappears. The material on the dump contains a little pyrite, chalcopyrite, ankerite, and free gold. A number of other small shears with free gold were noted in this vicinity, but little or no prospecting or assessment work has been done on any of these claims.

In the vicinity of Walton's cabin, which is about 4,000 feet north of Walton's landing near the east end of Long lake, there are several small but very rich outcrops of gold-bearing quartz. The rock here is granite porphyry and granodiorite and represents the beginning of a tongue-like projection from the southeast corner of the large granitic mass that extends from Gold lake. All the deposits north of Long lake, with free gold, are either a short distance within this intrusive mass or in the lavas less than one mile from this contact.

On the north slope of the hill and about 300 feet southwest of Walton's cabin the granite porphyry rock is fractured and impregnated with quartz lenses carrying free gold. This zone has a width of 10 to 15 feet and is exposed 100 to 150 feet along the strike, which is north 70 degrees west. To the northwest along this strike and about 300 feet across a sand-covered depression is another shear striking in the same direction and with about 3 feet of quartz for 100 feet along the strike. Here, the quartz is dark-coloured and carries pyrite, molybdenite, and a little free gold. To the southeast of the cabin the granite porphyry is sheared and impregnated with quartz and a short distance farther to the east a very rich but small quartz lens was discovered in August, 1923. Very rich specimens can be collected from a number of these small quartz lenses. About 1,000 feet north of Walton's cabin there is a quartz lens about 4 feet wide and 500 feet or more in length, but no free gold has yet been found in this quartz and the assay returns from it are very low.

From an economic standpoint possibly the most important group of claims north of Long lake is the Eldorado group just southeast of the southwest end of Halfway lake. The country rock is massive granodiorite and is well exposed. There is one well-developed fracture and shear zone, with several smaller parallel fractures on each side. The general strike of these fracture and shear zones is north 55 degrees west, and the main zone can be traced at least 1,800 feet and possibly extends 1,200 feet or more to the northwest. Along this distance the deposit has been well exposed by pits and trenches. Along this zone massive, granodiorite rock has been completely altered to quartz-sericite schist, except in a few places where the feldspar crystals have not been completely destroyed and remain as white, rounded phenocrysts in a schistose groundmass. The contact between massive and schistose rock is sharp. The quartz occurs as lens-shaped masses distributed at intervals along the schisted zone, and at places contains pyrite, some chalcopyrite, and free gold.

Near the southeast exposed end of the main shear zone, which is near the centre of the Eldorado mineral claim, the granodiorite rock is fractured across a width of 4 feet, but is not badly sheared. A lens of quartz averaging about 2 feet in width for 100 feet along the strike was exposed by the three shallow pits. To the southeast, this fracture zone is covered by a big swamp. Along the strike for about 500 feet to the northwest, the fractured and sheared zone varies from 1 foot to 5 feet in width and quartz is irregularly distributed in small lenses, none of which is over 2 feet in width and 100 feet in length. Just southeast of the west boundary of the Eldorado mineral claim a shaft has been sunk to a depth of 20 feet and the quartz is 2½ feet in width at the bottom of this shaft and carries free gold along the walls. Along the strike 100 feet northwest of this shaft the quartz lens ends, but for another 50 feet the schisted granite is impregnated with small quartz lenses carrying free gold. In places, the schisted granite itself carries a little free gold and assays across schisted zones are reported to run as high as $25 gold to the ton. This shear and fractured zone is exposed almost continuously across the Eldorado No. 1 mineral claim and averages possibly 3 feet in width. In this distance there are two fairly large quartz lenses carrying some free gold. Northwest of the Eldorado

No. 1 mineral claim the shear is drift-covered, but across the creek from Halfway lake and along the same strike a narrow, sheared zone outcrops and has been traced about 1,000 feet. However, in this area there is little quartz and the fractured zone is very narrow.

From 1,000 to 2,000 feet south of the main Eldorado shear are two narrow, short, fracture zones. A shaft about 20 feet in depth was sunk along one of these shears, but no quartz lens of any width was found, and no quartz body of any size was noted in this vicinity. Within 1,000 feet north of the main Eldorado shear there are several, small, discontinuous, sheared zones impregnated with quartz, but these occurrences are all too small to be of any economic importance. However, about 3,500 feet to the north, and on the Nugget mineral claim, a fracture zone striking north 60 degrees west is exposed for about 600 feet and passes under a large swamp to the west. This fracture zone is narrow, averaging about 2 feet, but the narrow quartz lenses contain considerable free gold. On the Sunshine mineral claim, near the southwest end of the long straight stretch of Halfway lake, a shaft was started in a white quartz lens in sheared gabbro. This sheared and quartz-impregnated zone can be traced only 50 feet on the surface, and no free gold was noted in the quartz on the dump.

PROSPECTS WEST OF BERESFORD LAKE

A number of small boss and dyke-shaped masses of granodiorite and granite porphyry outcrop along a line about one mile long and striking in a general southeast direction from near the south end of Tiney lake. It is believed that these small masses of granitic rock represent small projections or knobs from the roof of a larger mass a short distance below the surface. Fracture and shear zones impregnated with quartz carrying sulphides and free gold are associated with these small intrusive masses.

Considerable prospecting has been completed on the Madeline mineral claim, which is about 4,000 feet west of the small island near the south end of Beresford lake. The country rock on this claim is greywacke-like sediments and trachyte lavas cut by granitic rocks. The prospecting has exposed a schisted zone in the granitic rock, which strikes about north 40 degrees east for 200 feet. The quartz is a dark-coloured smoky variety and is distributed in lenses and pockets throughout this schisted zone which is in one place 6 feet in width, but which probably averages 3 feet in width for the distance exposed. Free gold was seen at a number of places in these pits and samples taken across the pits are reported to average $8 a ton in gold.

On the Gunner Fractional mineral claim, about 1,000 feet south of the workings on the Madeline mineral claim, there is another well-defined sheared zone about 6 feet in width in its widest place, striking north 40 degrees east. This zone is exposed for over 250 feet along the strike and consists of sheared lava and granitic rock impregnated with quartz, which in places carries free gold. Between the prospect pits on the Madeline and Gunner fractional claims are a number of small granite outcrops with which are associated small fractures, but little evidence of mineralization was observed in them. About 300 feet to the southeast of the workings on Gunner fractional mineral claim two shears are exposed, which strike at right angles to each other, but they contain little quartz. A number of small bosses of granitic rock outcrop in this vicinity, and around their edges the rocks are fractured, schisted, and impregnated with quartz, but the exposed surface outcrops of these zones are all very small.

Small masses of granitic rock, similar to that exposed on the Madeline mineral claim, outcrop along a line from the workings on this claim to near the south end of Tiney lake. No fractures containing mineralized quartz lenses of importance have yet been found between the Madeline mineral claim near the south outcrop of these intrusives, and the Tiney and Edna mineral claim near the north end, although the Tiney group, owned by the Deep Rock Gold Mines, Ltd., has been prospected quite thoroughly. The country rock is trachyte and andesite lava intruded by a granite dyke on the Tiney claim. Along the contact of this intrusive rock the lava has been fractured and schisted. This zone has a general strike of south 30 degrees east and can be followed about 500 feet. A shaft 30 feet in depth was sunk on one of the large quartz lenses, but is now full of water. There is considerable quartz on the dump, but no free gold was noted. This zone is irregular in strike and continuity and the quartz carries little pyrite or chalcopyrite. About 500 feet north of the shaft on the Tiney claim and on the Edna mineral claim there is a mass of quartz along the north side of a granitic mass. This sheared zone has been traced about 500 feet, and strikes south 60 degrees east. At the point where most of the assessment work has been done, there is a block of massive, granitic rock about ten feet in width, with quartz on each side of it. These two quartz lenses average about 2 feet in width, but can be traced only a short distance along the strike. Free gold was noted in a number of specimens on the dump, and high assays are reported from some of this quartz.

On the Tiney No. 1 mineral claim, about 1,000 feet east of the workings on the Tiney mineral claim, a shaft has been sunk 15 feet in depth. At the surface a mass of white quartz about 4 feet in width was exposed. This quartz was on the anticlinal axis of a small drag fold, and was only about 2 feet in thickness, so that 3 feet below the surface only fractured rock with a few quartz stringers was found, and at the bottom of the shaft there was no quartz. About 150 feet to the northeast from the shaft there is another small fracture zone, but there is little quartz along it and it is not exposed over 150 feet along the strike.

On the Oro Grande mineral claim, about 1,500 feet west of the north end of Beresford lake, is a sheared zone cutting andesite lava. This zone strikes north 25 degrees west and has been traced for about 300 feet along the strike, but on top of the hill to the northwest gradually ends and to the southeast passes under a swamp. Near where the sheared zone passes under the swamp there are lenses of quartz about 2 feet in width and one is about 75 feet long. Free gold was noted in this quartz at several places.

No samples were collected for assays from these deposits, as it is very hard to get any idea of the average value of the mineralized zone unless a great many samples are collected. Only extensive development work accompanied by systematic assaying will give an idea of the possible size and value of these mineralized zones.

OTHER FIELD WORK

E. J. Whittaker and M. Y. Williams. Mr. Whittaker and Mr. Williams continued a systematic re-survey of the geological succession, structure, and mineral resources of an area in southern Alberta and adjacent parts of Saskatchewan and British Columbia, extending from the International Boundary north to latitude 52° and from longitude 109° west to 115° 30′.

Of this territory Mr. Williams surveyed a strip 48 miles wide extending from the Saskatchewan boundary westward to beyond Lethbridge and Mr. Whittaker surveyed a similar strip adjacent on the north. It is proposed to continue this investigation in 1924.

P. S. Warren. At the request of the Director of the Parks Branch, Department of the Interior, an investigation was made by P. S. Warren, of the hot springs near Banff, Alberta. Of late years the flow of the upper hot spring has been increasingly irregular and intermittent, and an opinion was desired as to whether measures could be taken to restore and maintain the flow. A report has been rendered to the Director of the Parks Branch in which the opinion is advanced that the springs are fed from the surface, that the irregular flow has been due to abnormal meteorological conditions during the last few years, and that remedial engineering operations will probably prove to be unnecessary.

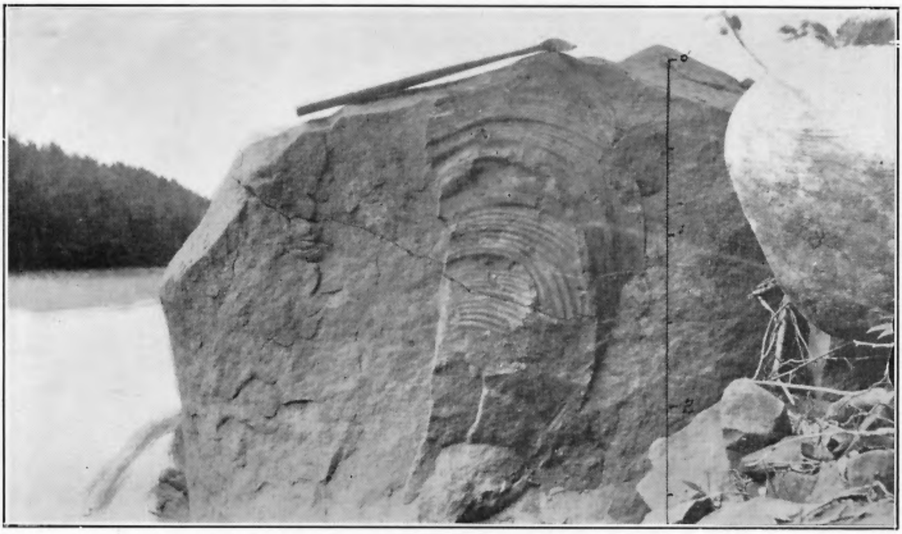
Concurrently with this investigation a detailed geological survey of about 50 square miles of the surrounding country was made. A report and map are in course of preparation.

C. M. Sternberg. Mr. Sternberg continued the collecting of vertebrate fossils from the Edmonton formation in the Red Deer valley above Drumheller, Alberta. Five valuable dinosaur specimens were discovered. These include the most complete specimen so far found of Edmontosaurus, over 30 feet of the skeleton being preserved, and the tail and much of the body being covered with a remarkably well-preserved skin impression. The remaining finds comprise an Ornithomimus and three partial skeletons of Hadrosaurs, one of the latter having the body, tail, and limbs present and partly covered with patches of skin impression and the ribs expanded as in life. A reported occurrence of vertebrate fossils in Jasper park was also examined, but with negative results.

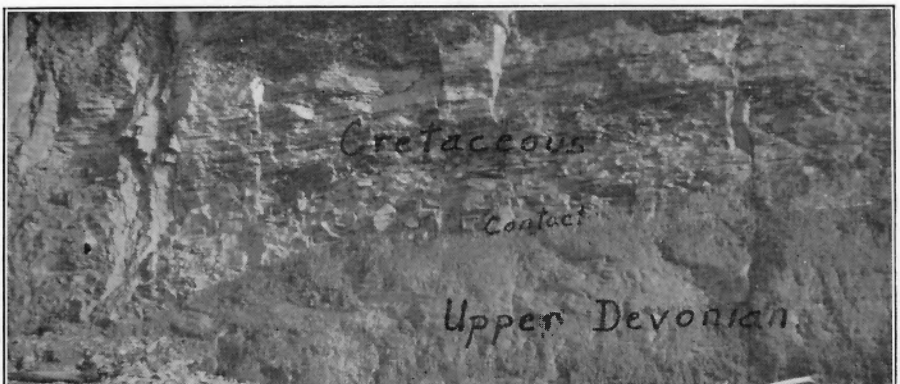
J. S. DeLury. During the past season Mr. DeLury commenced a geological survey of an area of Precambrian schists situated north and east of La-Ronge, Saskatchewan. This area is geologically similar to others in northern Manitoba, Ontario, and Quebec, and is believed to be favourable for the occurrence of mineral deposits. It is expected that this survey will be continued and completed in 1924.

R. C. McDonald. Mr. McDonald carried out geographical control surveys of an area in northern Manitoba lying between the 54th and 56th parallels of latitude and the 96th and 99th meridians of longitude. Approximately 2,000 miles of shoreline were mapped, based on a transit and micrometer traverse 1,000 miles in length. The traverse was checked at frequent intervals by astronomic observations for azimuth, latitude, and longitude, a portable radio receiving set being employed for obtaining correct time. Permanent posts were established along the route traversed, to serve as control for future work. The traverse was plotted on a scale of 8,000 feet = 1 inch and is to serve as a base for a contemplated geological investigation.

PLATE I

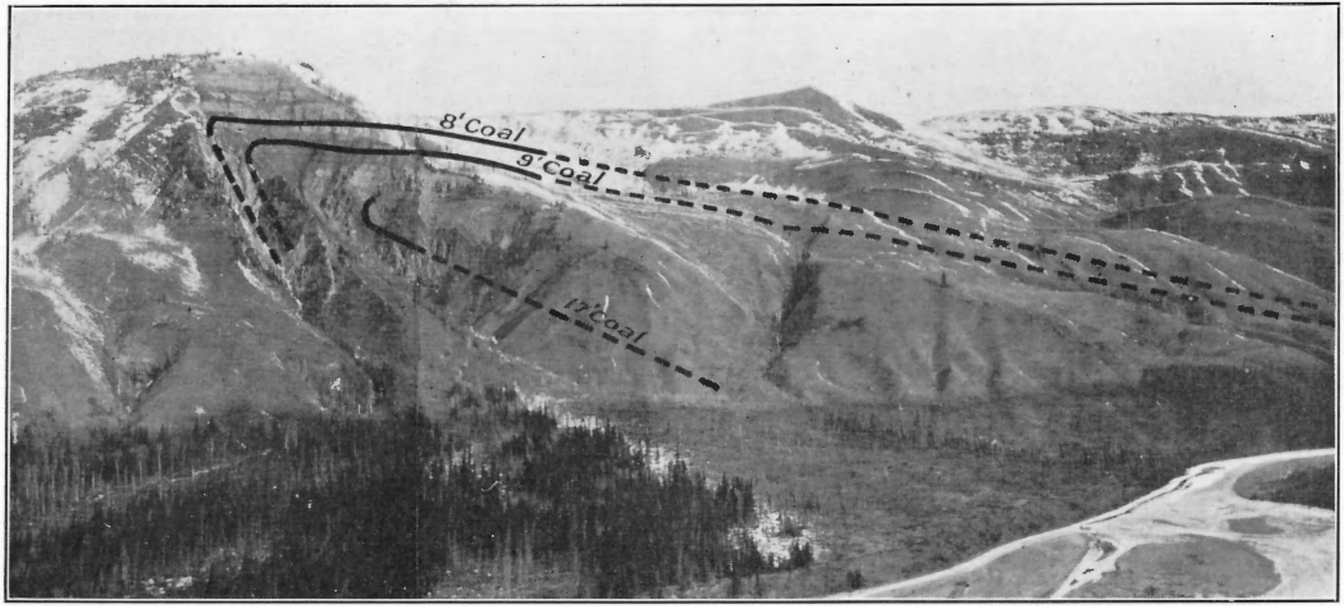


A. An *Inoceramus* about 2½ feet long found in the Cretaceous sandstone of Little Bear river. (Page 4.)



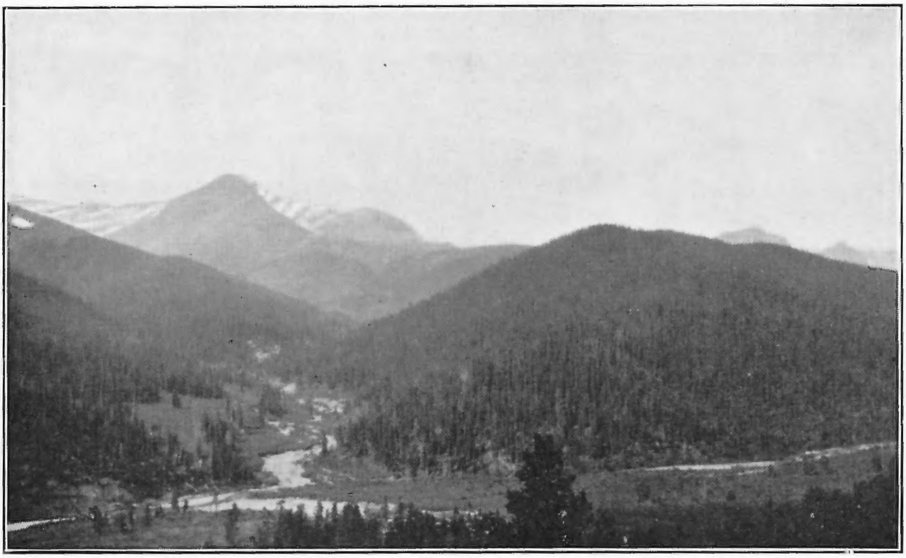
B. Devonian-Cretaceous contact at the north end of Wolverine anticline, Mackenzie river. (Page 10.)

PLATE II



Left bank of Smoky river about 1 mile above Muskeg river. (Pages 32, 49.)

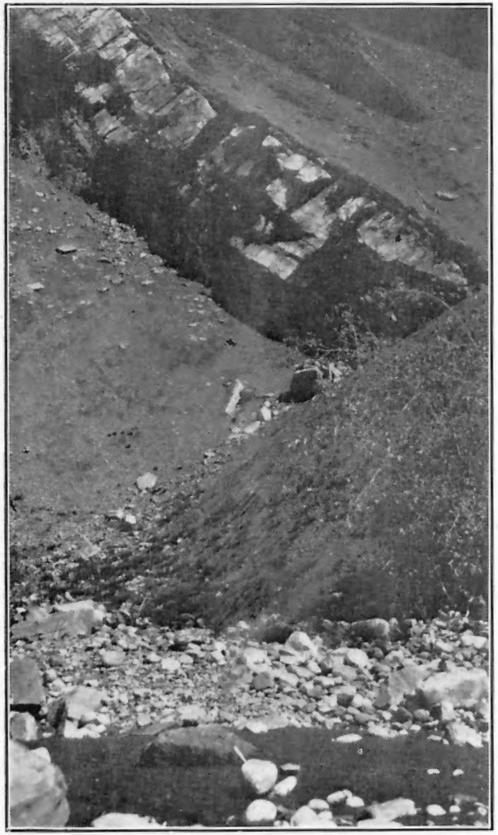
PLATE III



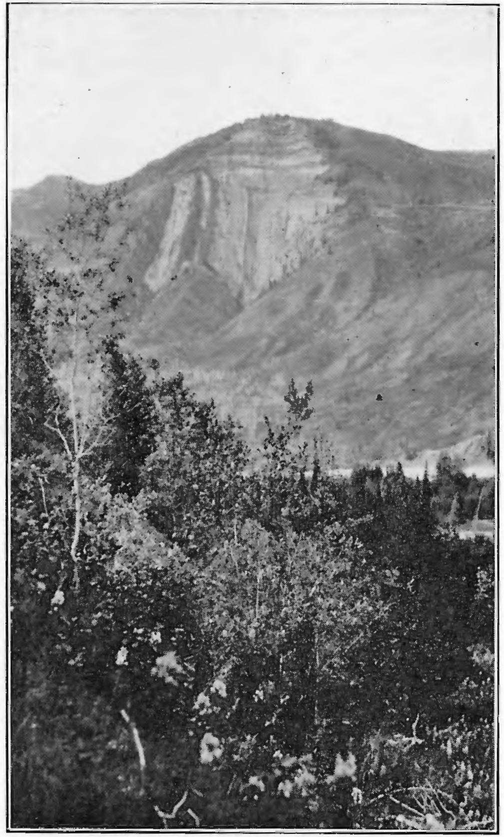
A. Creek entering north branch Hay river opposite Carson creek. (Page 41.)

B. Thoreau creek, north branch Hay river. (Page 41.)

PLATE IV

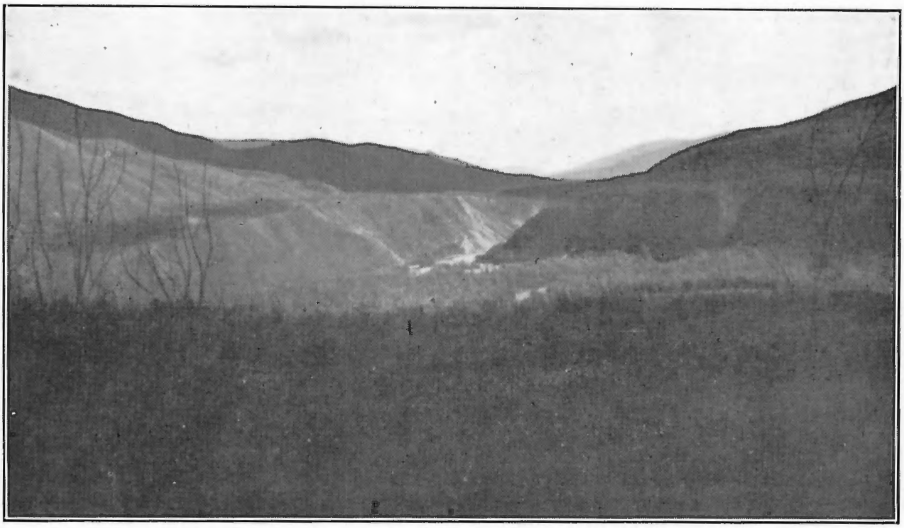


A. Left bank Smoky river, where many of the exposures occur. (O. S. Finnie.) (Page 49.)

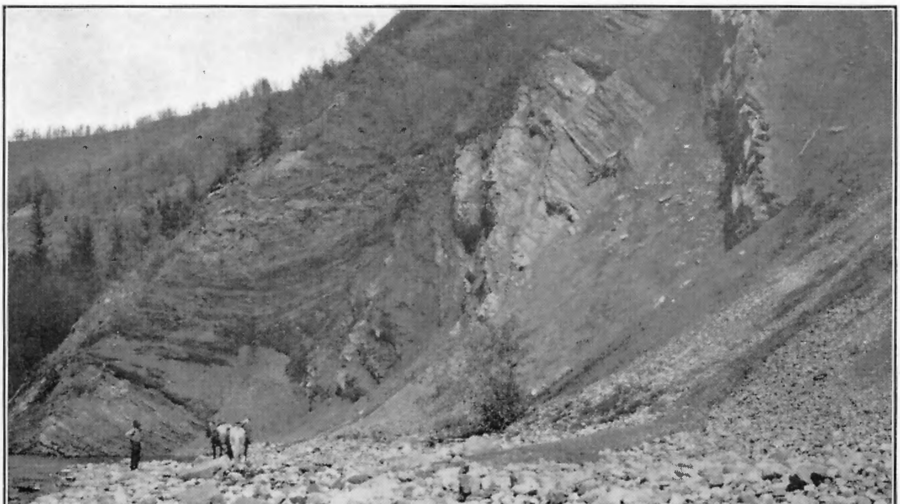


B. Seven-foot seam on Barrett gulch, Smoky river.

PLATE V



A. Looking up valley of Muskeg river from opposite bank of Smoky river.



B. Outcropping of three seams on Muskeg river near mouth.

INDEX