MEMOIR 87

GEOLOGY OF A PORTION OF THE FLATHEAD COAL AREA BRITISH COLUMBIA

BY

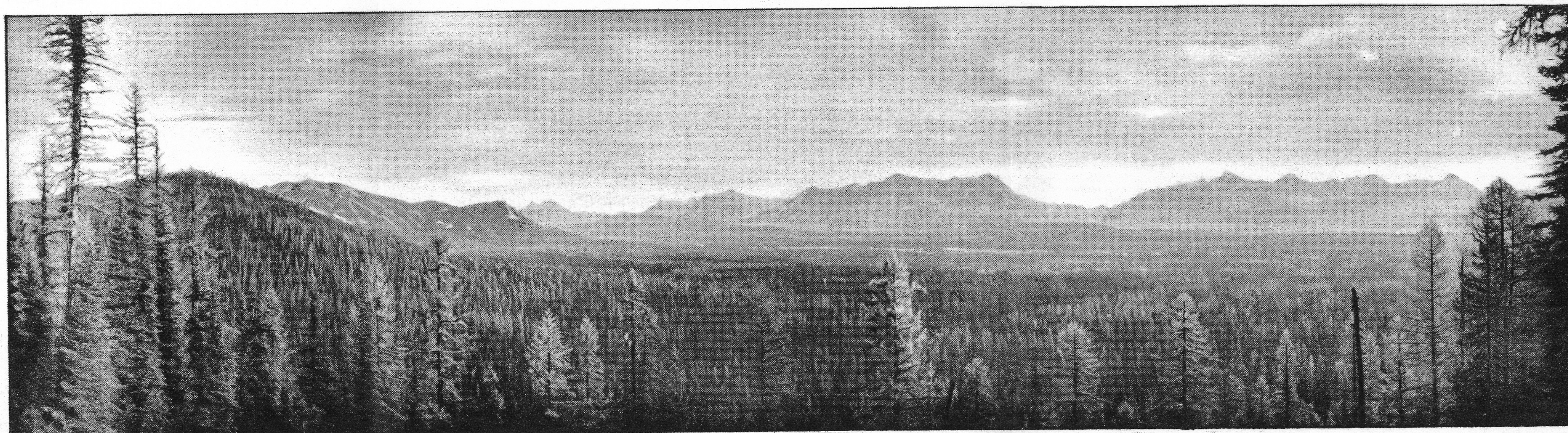
J. D. MACKENZIE

GEOLOGICAL SURVEY

DEPARTMENT OF MINES

OTTAWA

1916



View from above coal prospects, south of Cabin creek, looking northeastward over the densely forested alluvial plain of Flathead river toward the Clarke range. The cutbanks of the river appear in the middle distance. The ridge on the left in which strata can be seen dipping eastward is the "buttress projected forward into the valley from the mountains on the west." (See page 5.)

CANADA

DEPARTMENT OF MINES

HON. P. E. BLONDIN, MINISTER; R. G. MCCONNELL, DEPUTY MINISTER.

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CONTENTS.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

ILLUSTRATIONS.

Geology of a Portion of the Flathead Coal Area, British Columbia.

CHAPTER I.

INTRODUCTION.

GENERAL STATEMENT.

While the larger coal-bearing areas of the Rocky mountains in Canada are known in a general way, there are smaller districts the value of which as future coal producers is virtually unknown, or has only lately been recognized. For example, the large coal fields of the Crowsnest Pass region, one in the heart of the mountains in British Columbia, and one in the foothills of Alberta, have been known and worked for a number of years; but only recently has attention been directed to the smaller districts of Corbin, and to those in the valley of the Flathead river. The mines at Corbin are now producing coal, but the Flathead areas are still in the prospecting stage. The Flathead areas are three in number; the most northerly situated at what is locally termed "the Townsite," 13 miles south of Corbin by the road; the next about 5 miles farther south;[1] and the most southerly a few miles north of the International Boundary. It is with the last area that this report deals.

SITUATION AND MEANS OF ACCESS.

The Flathead river drains the extreme southeast corner of British Columbia, flowing in a valley the general direction of which is a few degrees east of south. The area here reported on consists of a quadrangle of 47½ square miles, bounded by parallels and meridians, and lying almost wholly on the west side of the Flathead river. The southern boundary of the area is a little

[1] Geol. Surv., Can., Sum. Rept., 1913, p. 139.

over 2 miles north of the forty-ninth parallel; the length from north to south is 7⅝ miles, and the width from east to west 6¼ miles. Although little is known of the other coal bearing areas in the Flathead valley, there is little doubt that the Flathead coal area here described is the largest and most important of the three.

The nearest railway station in Canada is Corbin, about 35 miles by wagon road from the northern boundary of the area. In dry weather this road is usually in good condition; but in wet weather it can be traversed by wagons only with great difficulty. The road continues down the Flathead valley to Belton, Montana, a station on the Great Northern railway, 39 miles south of the International Boundary. Besides this road, trails passable for pack animals lead over the Boundary, or South Kootenay pass, and the Middle and North Kootenay passes from Alberta; and local trails give access to various parts of the district. Pack animals or wagons for transportation cannot ordinarily be obtained at Corbin, but can be procured at Crowsnest station on the Crowsnest branch of the Canadian Pacific railway and at Coleman and Blairmore, Alberta.

FIELD WORK AND ACKNOWLEDGMENTS.

The time spent in geological investigation in the field was from September 3 to September 17, 1914. So short a time would be insufficient for the detailed investigation of a district of this size were it not that the structure as interpreted is relatively simple in its major features. Besides, much of the area is covered with stream drift and outcrops are few. It is believed, however, that none of the essential surface data have been overlooked and that the maps and sections delineate the distribution and structure of the formations with an accuracy consistent with the information derived from the outcrops and with the scale of publication. In certain parts of the area to be pointed out later, complications of structure exist, the elucidation of which can not be made sure without more information than can be obtained from surface exposures and the present prospect openings. Such information is vital as a preliminary to mining operations; but, in the present state of development of the field, it is not the province of an investigation like the one now reported on to collect specialized data of that sort. The general relationships and structure are here pointed out, and it is the task of the individual owners or prospective operators to determine the character of their property in detail.

The excellent topographical map of the area was made in the summer of 1913 by F. S. Falconer of the Geological Survey, on a scale of about one inch to three-fourths of a mile, with a contour interval of 50 feet. This map was made use of in the field in delimiting the various geological features.

The writer wishes to acknowledge the assistance given by Mr. A. M. Allen of the Corbin Coal and Coke Company; Mr. E. W. Butts of Colgate; Mr. O. V. Greene; and Mr. W. S. Earle. The geological department of the Massachusetts Institute of Technology has kindly allowed the writer many facilities in the preparation of this report, which are here gratefully acknowledged.

PREVIOUS WORK.

Except for the information gained during a brief reconnaissance of the coal deposits of the Flathead valley, made by D. B. Dowling and the writer in 1912,[1] virtually nothing was known of the geology of the district at the time this investigation was begun. Dawson, during his reconnaissance of the Rocky mountains, found the Flathead valley too greatly blocked with windfalls and obscured by smoke[2] to traverse it. Daly, during his investigation of the geology of the Cordillera at the forty-ninth parallel,[3] mapped the country in this vicinity for about 2½ miles north of the International Boundary, and his valuable work will be referred to later.

Other reports dealing with adjacent regions may be found in the publications of the Geological Surveys of Canada and the United States. The following publications, while not speci-

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[1] Dowling, D. B. Geol. Surv., Can., Sum. Rept., 1913, pp. 139–141.
[2] Geol. Surv., Can., Ann. Rept., 1885, Pt. B, p. 51.
[3] Geol. Surv., Can., Mem. 38, 1912.

fically referring to the region treated in the present report, are of interest in connexion with the broader features of its geology.

Willis, Bailey., "Stratigraphy and structure, Lewis and Livingston ranges, Montana," Bull. Geol. Soc. Am., vol. 13, 1902, pp. 305–352.

Twelfth Inter. Geol. Cong., 1913, Guide Book No. 9, pp. 18–61.

CHAPTER II.

GENERAL DESCRIPTION OF THE DISTRICT.

TOPOGRAPHY.

Regional.

The Rocky mountains in the vicinity of the forty-ninth parallel have been grouped by Daly in four divisions on topographical grounds.[1] These divisions are, from east to west, the Lewis, Clarke, Macdonald, and Galton ranges. The Lewis range lies principally in Montana, so that in Canada, the Clarke range forms the easternmost subdivision of the Rocky Mountain system. Lying west of this rugged series of alpine peaks and separating it from the Macdonald range, is the pronounced valley of the Flathead river (Plate I). This topographical depression is a geological boundary, in a double sense—between rocks of different age and between two different types of geological structure.[2]

The part of the Flathead valley dealt with here is located on a great normal fault, or faulted zone, which strikes a few degrees west of north with strong downthrows to the west. This relation at the forty-ninth parallel was pointed out by Willis[3] in 1902; and the same structure probably characterizes the valley as far north as the North Kootenay pass, about 25 miles from the boundary. The stream, which from its source to the pass flows easterly, turns abruptly nearly due south at that point. This change in direction is connected with rather complicated faulting which brings a block of Cretaceous strata into contact with much lower rocks. From the International Boundary to the North Kootenay pass the

[1] Daly, R. A. Geol. Surv., Can., Mem. 38, p. 27, *et seq.*
[2] *Idem*, Map sheets 1 and 2.
[3] Bull. Geol. Soc. Am., vol. 13, 1902, p. 343.

eastern side of the Flathead valley is thus bounded by a normal fault, or group of faults. The western side of the valley also seems to be determined largely by faults, but has a more complicated structure, a part of which will be described in this report. For reasons that will later appear, the valley has apparently existed as a depression ever since the faulting was initiated; in other words, it is a graben, and was so characterized by Daly.[1]

At the International Boundary, the valley is about 8 miles wide, with the river lying close to its western wall. The eastern portion of the valley is occupied by accumulations of glacial drift in the form of large moraines accumulated by local glaciers which carried their load of rock debris from the western valleys of the Clarke range.[2] Above these moraines rises abruptly the eastern wall of the valley—a steep rampart of bedded limestone lying in masonry-like courses and with a northeasterly dip. The peaks of the western wall of the valley are also of limestone; but it is of a different character to that on the eastern side and much younger than it. About 2 miles north of the Boundary, beyond the easterly flowing Couldrey creek, these sharp, bare, 7,000-foot summits of the Macdonald range are replaced on their trend by a series of lower, rounded, tree-clad hills extending northward for over 7 miles. Here the hills abruptly give way in their turn to higher peaks of bare limestone, forming a buttress projected forward into the valley from the mountains on the west. At the same locality, the eastern rampart is thrust forward, so that the Flathead valley is constricted to about a third of its width at the Boundary. The lower hills mentioned above gradually rise to the westward and, at a distance of about 6 miles from the Flathead river, regain the higher altitudes of the Macdonald range. Thus a marked recess or niche is formed in the lower Flathead valley, about 7 miles north and south by 6 east and west. It is bounded on the north and south by abrupt limestone walls, and the floor rises gradually westward and merges into the mountains, while the open Flathead valley is the eastern boundary. This recess is occupied by Cretaceous and

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[1] Geol. Surv., Can., Mem. 38, 1912, pp. 117 and 599.

[2] *Idem*, p. 583.

other rocks, which have been dropped by normal faulting between the walls of older limestones, so it also represents a graben; and on account of these relations, the valley in this vicinity may be described as a "compound graben." The other blocks of Cretaceous strata known in the valley have almost surely downfaulted relations to their bounding rocks also, so that the term "compound graben" may be applied to the whole valley from the International Boundary to the North Kootenay pass.

In the recess in the western wall, and almost exactly filling it, is situated the district included in the Flathead map-area.

Local.

The lowest point in the area examined is where the Flathead river leaves its confines near the southeast corner, and is 4,050 feet above sea-level. The highest altitude is near the northwest corner, where a steep limestone ridge attains a height of over 6,800 feet; and there are several eminences in the western part of the district which nearly approach that elevation.

A north-south line, drawn a little east of the centre of the map-area, divides it into two portions with very different surface features. The eastern portion is extremely flat over wide areas, and thinly wooded, while the western portion is rough, mountainous, and densely forested.

The eastern portion of the map-area is largely underlain by loose or partially consolidated Tertiary sediments, and is almost everywhere veneered with river deposits of sand and gravel, which have been carved by meandering streams into flat terraces. Some of these terraces may be recognized on the topographical map, with its contour interval of 50 feet. Bedrock exposures are rare, and are confined to the trenches of the larger streams. The principal topographical feature of this alluvial plain is the trench of the Flathead river. The stream meanders through the plain in a general direction due south, forming in many cases steep cut banks over 150 feet high, and in numerous parts of its course flowing in a braided channel. The gradient of the river for the 16 miles of its tortuous course within the area is about 170 feet, or over 10 feet to a mile.

Marshy areas are common in poorly drained portions of the alluvial plain. In its northern part numerous, steep-sided, undrained depressions occur, some of them simulating kettle-holes in ice laid deposits and the larger occupied by shallow lakes. These depressions resemble ice-block holes; but their number, gradation in size, and particularly their localization in the northern portion under the shadow of the limestone cliffs, point strongly to the conclusion that they represent a sink-hole or "karst" topography on the bedrock floor of the valley. This supposition is strengthened by the finding of a large sink-hole in similar limestone near the northwest corner of the area.

The alluvial plain is thinly wooded with jackpine, balsam fir, tamarack, cotton-wood, aspen, poplar, and balm-of-Gilead. In the mountainous, western part of the district are thicker stands of Englemann spruce and Douglas fir. Occasional western white pine are to be seen. Along the stream courses and in marshy areas are thickets of willow.

A rough, mountainous country, with a topography that at first glance seems chaotic, lies west of the alluvial plain just described. On referring to the geological map, the double influence of geology on topography is at once apparent—the primary control being structural, and the secondary lithological. Thus, the northwestern portion of the district north of Cabin creek is underlain by gently dipping or flat, hard sandstones, lying on massive limestones; and the large valley tributary to Cabin creek from the north, located on the axis of a broad, flat anticline, exhibits the typical form caused by stream erosion of flat lying sediments. Near the extreme northwest corner, the sandstone cover has been eroded through, and in one place a large, undrained depression, grassed over and bare of trees, shows outcrops of limestone and a funnel-shaped hole in the lowest part, typical of the limestone sink-hole. Rimmed as it is on the west and south by beetling cliffs of flaggy and thick-bedded sandstone, this sink-hole has the aspect of a giant amphitheatre. South of Cabin creek, the large pyramidal hill, whose eastern face is traversed by the coal-bearing rocks, owes its prominence to a protective cap of hard, massive Kootenay sandstone, disposed in a minor synclinal roll at the summit. In the underlying, softer, Fernie shales, minor valleys have been formed both on the north and south sides of the hill. Burnham creek, throughout much of its course, follows along the normal fault which cuts off the Cretaceous rocks on the south, and is thus a fault line stream. Southwest of Burnham creek are rough hills, carved from folded limestone which has a general northwest strike and southwest dip, the attitude of the strata composing the Macdonald range for miles northwest and southeast of this locality.

Although the region possesses considerable relief, outcrops are less numerous and more difficult to find than would be expected, owing to the dense forest cover and continuous mantle of drift. For this reason it is not possible to locate closely many of the geological boundaries, though, fortunately, the character of the rocks of the coal measures facilitates their accurate delimitation. For the same reason, structural details are not made evident on the surface, though the general attitude of the beds in most cases may be readily deciphered.

CLIMATE, FAUNA, AND FLORA.

The summer climate of the Flathead valley is very pleasant with abundant sunshine, warm days, and cool nights, and without great extremes of heat. Night frosts begin late in August and light snowfalls usually occur in September. The winter is said to be cold, with heavy snows.

Deer and grouse are plentiful in the valley, and sheep and goats are found in the adjacent mountains. Grizzly bears occasionally descend from the mountains to the lower lands and the coyote, though seldom seen, is often heard. Beavers, martens, rabbits, chipmunks, and other small mammals are found.

The distribution of trees and their relation to topography has been referred to above.

CHAPTER III.

SUMMARY.

GENERAL GEOLOGY.[1]

The southern Rocky mountains of Canada are composed of a great mass of sedimentary rocks, from Pre-Cambrian to Upper Cretaceous in age, and representing many different conditions of deposition. In the Flathead map-area the rocks range in age from probably Devonian to Eocene; the Eocene rocks in the mountains being almost wholly confined to this area.

The Palæozoic and Mesozoic rocks constitute an assemblage of apparently conformable formations which have been placed in their present attitudes by folding and faulting, and subsequently bared by erosion. The conformity is only structural, however, for at least two disconformities, or breaks in sedimentation without noticeable folding, are recognized in the district.

The so-called Devono-Carboniferous consists of black and brown calcareous shales, black calcareous sandstones, and dark grey limestones, together making a thickness of at least 3,000 feet. They are conformably overlain by rocks assigned to the upper Mississippian or lower Pennsylvanian on fossil evidence. These are mostly grey to black calcitic limestones, frequently bituminous, and of varying texture and structure, in all about 2,000 feet thick. Overlying these limestones, with what is thought to be disconformable relation, is a formation composed of very fine, white and light grey, even-grained sandstone, which is tentatively assigned to the Triassic. Its thickness is in the neighbourhood of 2,500 feet. Above this sandstone and probably conformable to it are about 1,000 feet of grey and brown shales which are correlated with the Fernie formation. Overlying the Fernie is the Kootenay, well known as the great coal-bearing formation of British Columbia and Alberta. In the

[1] See also the table of formations, page 15.

area investigated the Kootenay consists of 1,147 feet of grey and brown sandstones and shales, including 81 feet 7 inches of coal, nearly all of which is in five seams. The lithology and stratigraphy of the Kootenay in this area are strikingly similar to the same features of the formation in southwest Alberta. Forming a cap to the Kootenay rocks is a bed of hard, siliceous conglomerate, 85 feet thick, which is correlated with a very similar bed widespread in southern British Columbia and Alberta. This conglomerate is probably disconformable on the Kootenay, and serves as the base of the Upper Cretaceous rocks, which are probably soft sandstones and shales, as they are not exposed in the limited area in which they might outcrop. Unconformably lying on the rocks so far described is the Kishinena formation. It is made up of an aggregation of unconsolidated or partially consolidated sands, clays, and gravels, with lignite, and soft freshwater limestones which carry fossils probably Eocene in age.

The rocks of the area have been much folded and faulted; their structure may be briefly described as that of a downfolded, monoclinal fault block, with northeast strikes, and for the most part, southeast dips. The fault block is bounded on the northeast and southwest by normal faults with a northwest strike, the upthrown sides being on the northeast and southwest respectively.

ECONOMIC GEOLOGY.

Coal is the principal mineral resource of the area, and the seams represent deposits of considerable value. The 400 feet of coal-bearing measures occur in the lower part of the Kootenay formation, and five seams, 4, 7, 8, 25, and 36 feet thick respectively give promise of future production. The quality of most of the coal is good, and the general structure and attitude of the seams is such that mining may be readily carried on under present economic conditions when railway transportation becomes available.

Thin seams of lignite of Tertiary age also occur in the area; but they are considered of negligible importance commercially.

A little prospecting for petroleum has been done in the district, but the indications observed lead to the conclusion that the chances for the occurrence of commercial petroleum deposits are very small.

CHAPTER IV.

GENERAL GEOLOGY.

REGIONAL.

The southern Rocky mountains of Canada are sculptured from a mass of sedimentary rocks whose period of accumulation represents most of the known geological history of the world. Three eras of sedimentation may be recognized in this district: the Pre-Cambrian, the Palæozoic, and the Mesozoic. The rocks from the Pre-Cambrian to the Cretaceous are virtually parallel stratigraphically and the breaks between the eras are, therefore, disconformities.

The result of this enormous periodic sedimentation has been to form a tremendous mass of bedded sediments from Pre-Cambrian to Cretaceous in age; this mass has been called the Rocky Mountain geosynclinal prism. In this prism igneous rocks are characteristically of limited occurrence, so that during the accumulation of the sediments igneous activity played a very minor part. However, in the late Pre-Cambrian, volcanic action culminated in the extensive fissure eruptions of the Purcell lava;[1] but from the Pre-Cambrian to the Upper Cretaceous no igneous manifestations are known. In the latter epoch an explosive ejection on a small scale took place in what is now southwestern Alberta, forming pyroclastics representing a highly specialized alkaline type of magma.[2]

Later in the Upper Cretaceous an igneous intrusion, also of a specialized alkaline type, occurred in the Ice River district of British Columbia.[3]

Throughout the eras during which the sediments were accumulating various conditions prevailed, ranging from marine to lacustrine and continental. Virtually all types of sedi-

[1] Daly, R. A. Geol. Surv., Can., Mem. 38, 1912, p. 568; see also pp. 207 *et seq.*

[2] MacKenzie, J. D. Geol. Surv., Can., Mus. Bull. No. 4, 1914.

[3] Allan, J. A. Geol. Surv., Can., Mem. 55, 1914.

mentary rocks are, therefore, represented in this prism, and limestones, dolomites, shales, argillites, sandstones, quartzites, and conglomerates are found in varied and recurrent succession. Coal-forming conditions prevailed over wide areas during a limited epoch—the Lower Cretaceous—and the coal then formed is to-day the most important mineral resource of the Rocky Mountain region in Canada.

While the composition of the Rocky mountains was determined by the extensive periodic sedimentation just described, their present form and the attitude of their strata were largely conditioned by the severe orogenic disturbance which closed the Mesozoic and initiated the Tertiary era. This movement uplifted, extensively folded, faulted, and overthrust the rocks. Erosion and denudation have since that time removed tremendous volumes of detritus to other areas; and only in one locality in the mountains, the Flathead valley, have rocks other than ephemeral screes and talus slopes or moraines been deposited. These rocks are partially consolidated lake beds of Tertiary age, carrying thin seams of lignite.

As the mountains now stand, they represent the result of the destructive forces of the atmosphere operating on faulted and overthrust blocks composed of bedded sedimentary rocks of variable character.

LOCAL.

The bedrock formations exposed within the limits of the Flathead coal basin range from rocks which are probably Devonian to those of the Eocene epoch. They thus include measures accumulated both in the Palæozoic and Mesozoic eras of sedimentation, and contain most of the known Tertiary rocks in the Rocky mountains of Canada. The transition between these two great eras is represented within the bounds of the area, also the break between the Lower and Upper Cretaceous sedimentation.

The Palæozoic and Mesozoic rocks constitute an aggregate of apparently conformable formations which have been placed in their present attitudes by folding and faulting and have been afterwards bared by erosion. They are exposed in the western two-thirds of the district where they form strips or irregular areas, according to their structure and the topography. Separated from them by a marked unconformity are the less consolidated Tertiary rocks, which occur in the eastern third of the district.

Nearly all of the area, except the higher hill tops, is covered with drift and detritus of various modes of origin. The bottom of the Flathead valley is buried in stream drift, while the higher areas are covered with glacial, slidden, and residual material.

The formations exposed in the Flathead area have been separated and mapped on lithological grounds. The age and correlation of some of them is known with great certainty, and these have been definitely named. Others, however, can only be correlated doubtfully or not at all, and these are designated by general terms, such as "Carboniferous," and "Triassic." This is done because, though important units in this district, they may find a more significant, or typical development elsewhere in the region, and to attach formation names to them from a very localized area might be detrimental to the best interests of science, as well as working an injustice to any who may make a comprehensive study of the whole region.

DESCRIPTIVE GEOLOGY.

Table of Formations.

Quaternary	Pleistocene and Recent		Flood-plain gravels, etc., glacial and other drift.
Tertiary	Eocene (?)	Kishinena formation	Partially consolidated gravels, sands, and clays, with lignite.
Mesozoic	Upper Cretaceous		Siliceous conglomerate at the base; rest probably soft sandstones and shales.
	Lower Cretaceous	Kootenay formation	Grey sandstones, with shales; coal bearing.
	Jurassic	Fernie formation	Grey and brown shales.
	Triassic (?)		White, quartzose sandstone.
Palæozoic	Carboniferous		Grey and black limestones.
	Devono-Carboniferous		Black limy sandstones and shales.

Devono-Carboniferous.

Distribution and Thickness. Diagonally crossing the southwest corner of the map-area is a band of rocks from 1 to 2 miles wide, to which a Devono-Carboniferous age is provisionally assigned. The thickness is unknown, as the base has not been discovered, but it seems to be at least 3,000 feet, though faulting may have caused repetition.

Lithology. These measures consist of black, grey, and brown calcareous shales, black calcareous sandstones, and dark grey limestones. Orthoceras-like forms were found at one locality, but were lost in transit.

Stratigraphy. The shales are thin bedded and are in many places much crumpled and broken. The sandstones and limestones are usually flaggy or thin bedded; beds up to 3 feet thick are not unusual. These thicker members have been considerably deformed, and exposures along Couldrey creek exhibit tight folding, with occasional slight overturns towards the northeast.

The lowest beds exposed are black shales, several hundred feet in thickness, and these are in faulted contact along Burnham creek with the Mesozoic formations of the district. In the extreme southwest corner of the district these rocks are conformably overlain by the next formation to be described, which in part is of upper Mississippian age.

Age and Correlation. The relation described immediately above indicates that these dark sandstones and shales are pre-upper Mississippian in age; and, until their age and relations are better known, it seems best to describe them by the general term Devono-Carboniferous. Provisionally they are correlated with the rocks termed by Daly "Palæozoic limestones of the Macdonald range."[1]

Origin. These rocks bear the aspect of formations of marine origin, and are correlated with formations having that origin.

Carboniferous.

Distribution and Thickness. Rocks classified under this head outcrop on the slopes of the high hills just beyond the north edge of the map-area, and underlie a considerable area in the northeast portion of the district. They are also found flooring the large sink-hole in the northwest corner; in an elliptical patch in the valley of Cabin creek; and forming a narrow strip across the southwest corner of the map-area. At Squaw rock, on the Flathead river, a mile south of Colgate, limestone of this formation is also exposed. Definite data for determining the thickness of these Carboniferous beds have not been observed;

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[1] Geol. Surv., Can., Mem. 38, 1912, p. 113.

but they are thought to be about 2,000 feet thick and have been so delineated on the structure sections.

Lithology. These Carboniferous rocks are wholly limestones of various kinds. They are mostly light grey weathering, grey to black rocks, the latter owing their colour to bituminous matter, which also gives to them a strongly foetid odour when struck. They are found as flaggy, thin-bedded, and massive layers, with platy parting parallel to the stratification. Fossils have been found in two localities, representing different horizons in the formation. These will be referred to later. That more fossils were not discovered is due without doubt to the relatively few exposures studied; for, from the nature of the formation, organic remains are probably present in considerable quantity, especially in certain layers. Many of the rocks are largely composed of fragmentary remains of fossils and a specimen of this type from one of the thick layers was given detailed study.

It is a grey rock, and from its pearl grey weathered surface project numerous fossil fragments up to 2 mm. diameter, embedded in a finer, clastic calcareous matrix. The rock contains a few small crystals of recrystallized calcite, and, in places, fragments of fossils up to a centimetre across can be seen in it. The rock effervesces at once and freely with hydrochloric acid.

The thin section shows that from 75 to 80 per cent of the rock is made up of irregular, angular fragments of various corals, molluscs, etc., averaging 0·25 mm. in size, and embedded in an extremely fine-grained matrix, which appears to be granular calcite, representing a lime mud. About 5 per cent of the rock is composed of individual calcite grains, up to 1·5 mm. diameter, and usually irregular. Some of them have sharp boundaries, others are not so well defined, the edges of the grains grading into the matrix and enclosing small portions of it. Adjacent grains occasionally have parallel orientation, and may be projections from a single individual, or may be analogous to the calcite grains described on page 34. On account of the size, shape, and relations of these grains, they are thought to have recrystallized in place. No trace of organic structure is observed in them, illustrating how that structure may be destroyed by recrystallization.

The rock possesses a faint lamination parallel to the bedding.

Another type of limestone, which forms flaggy massive beds, is grey and extremely dense in hand specimens and effervesces instantly and freely with hydrochloric acid. Many of these beds are extensively replaced along the bedding and joint surfaces by tabular masses of pale, bluish-grey chert, showing a sharp contact with the limestone. Impregnating the limestone are many minute cubes of pyrite.

In thin section the rock is seen to be almost wholly composed of minute granules of calcite, with rare fragments of shells up to 0·05 mm. About 5 per cent of the rock is in the form of sharply outlined, clear, untwinned rhombs, averaging 0·05 mm., and replacing the finer grained calcite. These rhombs contain excessively minute yellowish inclusions, which may possibly be petroleum or limonite scales. They are thought to be dolomite, and the qualitative detection of small amounts of magnesia supports this conclusion. The impregnating cubes of pyrite are from 0·01 to 0·02 mm. across, are well crystallized, and many of them are surrounded by yellowish haloes of limonite.

From the cherty zones, the silicification is progressive, and changes the calcitic groundmass more readily than the dolomite rhombs, which are often left sharply oultined in chert. The silica is in the form of small grains, many of which have undulatory extinction as if fibrous, and is probably chalcedony. A few of the rhombs have been replaced by clear silica without wavy extinction and in this case the silica appears to be quartz.

Stratigraphy. Detailed studies of the stratigraphy of this formation have not been made; but it is known to be composed wholly of limestone and it is apparently all calcitic. It rests conformably on the rocks described above as Devono-Carboniferous, though the contact has not actually been observed. It is overlain by the white sandstone described below, with a sharp break between the two and no indication of transition, though the strata on either side of the contact are conformable, or apparently so. The true relation is thought to be that of a disconformity.

Age and Correlation. Fossils were obtained from this formation at two localities, and have been determined by Dr. G. H. Girty.

On the northern slope of the sharp peak in the southwest corner of the map-area, an 8-foot bed of greyish limestone contains very numerous but poorly preserved fossils embedded in a matrix largely of organic fragments. Stratigraphically this bed is at least 1,000 feet below the top of the formation. The following species have been determined by Doctor Girty who regards them as "upper Mississippian," correlative with the Mountain limestone of Europe and with the formation which in Idaho is called the Brazer limestone.[1]

Triplophyllum ? sp.
Fenestella sp.
Ptilopora sp.
Batostomella sp.
Rhombopora ? sp.
Productus giganteus ?

The species noted below were collected from near the top of the formation, a few hundred feet west of the large sink-hole in the northwest corner of the district. These fossils were found in a 3-inch, cherty band in grey and blackish, dense, flaggy limestone. The shells were very abundant, but poorly preserved, and most of them were obtained from the cherty concretions in which the layer abounded. Doctor Girty recognized the following species:

Derbya aff. *robusta*
Productus cora ?
Spirifer rockymontanus ?

and in regard to them remarks:

"These may be Brazer also, but from my general knowledge of the palæontology and lithology of these beds I am strongly inclined to place them in the early Pennsylvanian, the lower part of the Wells[2] formation of Idaho. Here again I make the

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[1] Richardson, G. B. Am. Jour. Sc., 4th series, vol. 36, 1913, pp. 406–416.
[2] Richards, R. W., and Mansfield, G. P., Jour. Geol., vol. 20, 1912, pp. 689-709.

suggestion subject to stratigraphic evidence. The fauna itself is too small and too poorly represented to be diagnostic."

From the description of the occurrence, it will be seen that the stratigraphical evidence corroborates Doctor Girty's determinations. The fossil content, then, makes it evident that the formation here termed "Carboniferous" ranges from upper Mississippian to lower Pennsylvanian in age. In addition to the correlative formations mentioned by Doctor Girty, these Carboniferous limestones may be correlated with the "Limestone Series" which has been studied to the northward along the line of the Crowsnest branch of the Canadian Pacific railway.[1]

Origin. The fossils indicate marine conditions during the accumulation of these limestones. The clastic nature of some of the beds indicates rather shallow zones of sedimentation, and their purely calcareous composition necessitates their formation in waters free from contamination by detrital sediments. The most reasonable reconstruction of conditions seems to be a shallow, clear sea, bordering low lying land.

Triassic (?).

Distribution and Thickness. The rocks tentatively assigned to the Triassic epoch are the surface formation of a considerable area in the western portion of the district. The shape of the area underlain by them is irregular, and their distribution can best be seen from the accompanying map. The thickness of the formation has been calculated from the traverse made across it on Cabin creek, where the width of the strip underlain by these beds and their attitude calls for a thickness of about 2,500 feet.

Lithology. This formation is strikingly homogeneous wherever it has been observed; and it consists throughout of white or pale grey, very fine, even, compact sandstone. Where unweathered, the rock is pale grey, with a sub-vitreous lustre, simulating a quartzite. Weathering changes the colour to white or whitish-grey, streaked with rusty yellow; and some boulders

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[1] Leach, W. W., Twelfth Inter. Geol. Cong., Guide Book No. 9, pp. 23–24.
McEvoy, J., Geol. Surv., Canada, Ann. Rept., vol. XIII, 1900, pp. 85A-86A.

are stained bright red and brilliant yellow. The rock is extremely hard and tough when fresh; but when weathered is softer, and in places is crumbly and friable, with a pitted surface as if from solution. The fragments observed by the unaided eye, or through a hand lens, are wholly quartz, and the cement is calcite. This is indicated by its manner of weathering and also by its general, slight effervescence in acid. A hand specimen held so that light is reflected from its surface reveals that the calcitic cement, where present, is in the shape of single, irregular crystals up to one-fourth of an inch across, enclosing a great number of clastic quartz grains.

Thin sections cut from two specimens typical of the formation were examined, and found to be so similar that one description suffices for both.

The minerals observed forming the fragments were almost wholly quartz, with very small amounts of chert, tourmaline, zircon, and muscovite; the cement is calcite and small amounts of impregnating pyrite are present.

The quartz, which forms about 98 per cent of the fragments, is mostly subangular, a few grains are rounded, and a very few well rounded. This is to be expected from the sizes of the grains which average 0·123 mm. The quartz is clear, and for the most part extinguishes sharply, though a few grains have shadowy extinction. Much of it contains rows of minute inclusions or cavities about 0·0002 mm. in diameter, the nature of which was not determined. Some grains contain extremely slender rods and needles of some undetermined mineral, possibly apatite. In several instances the quartz was seen to contain embedded zircon, sharply euhedral, and about 0·05 by 0·015 mm. in size. These properties are all diagnostic of granitic quartz, and the separate tourmaline and zircon fragments seen confirm the view that this quartz originally came from some quartzose plutonic rock.

Chert is sparingly present in fine granular fragments.

The tourmaline grains varied in size from 0·02 mm. to 0·17 by 0·12 mm., the largest one being very well rounded, and elliptical in shape with a pale bluish central zone, bordered by brownish zones on each side. Several other tourmaline grains were seen, all much smaller, and pleochroic in brownish and greenish tones. The mineral is in every case unaltered.

Zircon in euhedral individuals up to 0·04 by 0·06 mm. is sparingly present, both as individual grains and embedded in quartz. In the thin sections examined the proportion of minerals occurring as fragments other than quartz and chert is less than one-tenth of one per cent of the total number of grains.

The calcite, which has been observed in amount up to 15 per cent of the volume of the rock, is in somewhat unusual relations for a sandstone. Throughout most of the rock, the quartz grains form a tightly interlocked mosaic, virtually without cement. In certain portions, however, the grains are smaller, more irregular in shape, separated from one another, and embedded in calcite crystal individuals up to 5 mm. diameter, enclosing many hundreds of quartz grains in a manner analogous to the well known "sand calcites." In some of these portions the calcite forms 25 per cent of the rock and not only surrounds but actually replaces much of the quartz. Various stages of corroded quartz crystals can be seen, with the calcite penetrating them in irregular veinlets, or cutting sharply into them with crystalline facets. It may be remarked in passing that overlying this sandstone is a thick mass of fine, dense, shale, and underlying it is a great thickness of limestone. Conditions are thus favourable for the sandstone to become soaked with waters charged with calcium bicarbonate, so that the quartz replacement may be explained.

Sparingly impregnating the rock, and replacing both calcite and quartz, are minute sharply crystallized cubes of pyrite up to 0·03 mm. on an edge. They are found singly, but occur also in swarms or dense clusters. A single grain in some cases replaces parts of two adjacent quartz grains. The pyrite is often partly oxidized, and around it can be seen yellowish zones. The brilliant yellow and red stains found on weathered surfaces of this formation may be ascribed to the decomposition of this pyrite.

The texture of this rock is remarkably uniform. This was observed qualitatively; and, in order to gain some quantitative idea of it, a series of rows of grains selected at random in different portions of the thin section were measured with the following results:

Hundredths of a millimetre..	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
No. of grains, per cent.......	5	2	4	7	13	19	17	11	4	8	3	3	2	2	0	0	0

It will be seen that 60 per cent of the grains are between 0·10 mm. and 0·13 mm. in size. The average size for all is 0·117 mm.

In the other section studied, the grains averaged slightly larger, and the general average for the two specimens studied is 0·123 mm. The largest grain seen was quartz, 0·33 mm. in diameter.

Stratigraphy. It has been remarked that this sandstone is strikingly uniform lithologically throughout its extent. It is finely and evenly laminated, with faint current bedding on a small scale in some places, though, on account of its purity and evenness of grain, such structures are not readily visible. The rock is found in platy layers averaging about 2 feet thick, separated by thinner flags up to 2 inches, and with some beds up to 4 feet thick. It is very hard and tough and forms rough talus slopes and screes on steep slopes. No trace of organic remains was found in this formation. The rock is greatly jointed, in many azimuths, and the joints are nearly all perpendicular to the bedding.

The actual contact of the formation with the lower Pennsylvanian limestone underlying it has not been observed; but the two formations have been seen within a few feet of one another. The change from the fossiliferous limestone to the pure quartzose sandstone is an abrupt one, whenever noted, and there is no sign of gradation. If there be a gradation, it can only exist through a few feet, and must be very rapid. So far as can be ascertained from the attitudes of both formations they are structurally conformable.

The contact with the overlying Fernie shales has not been observed, nor even very closely located. Owing to the nonresistant character of the shale, it does not afford exposures, while the sandstone readily outcrops. The location of the boundary between the formations has been governed, therefore, largely, by observing where the sandstone outcrops or larger boulders ceased. From the structural relations observed, it is thought that the Fernie formation is conformable on the sandstone.

Age and Correlation. This formation, which is barren of fossil remains, has been assigned to the Triassic on deductive grounds, for reasons now to be given.

It is known that marine sedimentation was continuous in this region throughout the later Palæozoic until lower Pennsylvanian time at least; and that at some time after this date an uplift[1] took place, which bared the Palæozoic measures and subjected them to erosion, so that at present we find, in most parts of the region, marine Jurassic beds disconformably overlying the Carboniferous.[2] These Jurassic beds—the Fernie formation—are correlated with the Maude formation (Lower shales of Dawson)[3] of the Queen Charlotte series, which have recently been shown to be lower Jurassic, and probably in part Triassic in age.[4]

With these facts in mind it must be concluded that the white sandstone formation under consideration is younger than lower Pennsylvanian, and older than lower Jurassic. As we have no evidence of more than one oscillation between the Pennsylvanian and the Jurassic, it seems most reasonable to suppose that this formation was deposited during the early stages of the subsidence previous to the lower Jurassic marine sedimentation, and, therefore, may be provisionally assigned to the Triassic, perhaps to the upper Triassic, although possibly it may be lower Triassic or Permian in age.

In the absence of fossil evidence, the correlation of these white sandstones must be wholly conjectural. As noted above, in the Blairmore, Alberta, district the Jurassic Fernie formation

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[1] Daly, R. A., Geol. Surv., Can., Mem. 38, p. 568.
[2] Twelfth Inter. Geol. Cong., Guide Book No. 9, pp. 23–24.
McEvoy, J., Geol. Surv., Can., Ann. Rept., vol. XIII, 1900, pp. 85A, 86A.
[3] Dowling, D. B., Geol. Surv., Can., Mem. 53, 1914, p. 26.
[4] MacKenzie, J. D., Geol. Surv., Can., Sum. Rept., 1913, p. 40.

rests directly on Devono-Carboniferous limestone, and the same is true in the vicinity of Fernie, B.C., so that this white sandstone is a somewhat local intercalation. Should its age prove to be Permian, instead of Triassic, it may be correlated with the Upper Banff shale of the Bow River valley.[1]

Origin. The significant properties of this formation are: its contrast with both underlying and overlying formations; its remarkable purity—quartz being virtually the only mineral present; its general homogeneity; its uniformity of texture; and the nature of the quartz. These properties, all of which have been previously described, must be co-ordinated and explained by any theory bearing on the mode of origin of the rock.

It is virtually certain that the quartz came originally from granitic rocks; but it is not probable that it represents the first accumulated sediment formed by the weathering of such a terrane. The size and uniformity of grain, and the purity of the rock make such a supposition improbable and would seem to indicate æolian conditions of accumulation. Angularity in grains of this size would not be expected in an æolian deposit, but is found in water-worn sands. The even lamination and the faint type of cross-bedding are also diagnostic of aqueous sedimentation.

Until this unusual sandstone is more fully investigated, it may be suggested as a working hypothesis that the quartz was first derived from a rock of the nature of a granite, and was incorporated in a sandstone of somewhat less purity than the present one. This sandstone was later exposed, eroded, and its materials reclassified, in part perhaps by wind, so that virtually only quartz of uniform grain remained. During the marine transgression preceding the deposition of the Fernie measures, this reworked sand was accumulated in its present form, with long continued resorting of its grains.

Fernie Formation.

Distribution, Lithology, and Thickness. The Fernie formation underlies an irregular strip, less than a mile wide and

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[1] Shimer, H. W., Geol. Surv., Can., Sum. Rept., 1910, p. 147.

about 6 miles long, in the west central part of the map-area, with a general trend a few degrees east of north. Well-defined outcrops have not been observed; but, in many places, evenly laminated, brownish, and greyish shales are found near the surface of the ground and debris from them is strewn over many parts of the area. The formation is probably largely composed of such shales.

From its areal and structural relations, the thickness of the Fernie formation is estimated to be about 1,000 feet. It must be remembered, however, that its contacts have not been accurately delimited and that, therefore, the above figure may vary as much as 20 per cent.

Stratigraphy. The Fernie is structurally conformable with the underlying white sandstones, and conformably overlain by the Kootenay formation. While the true nature of the lower contact may be a disconformity, there is every reason to believe from analogies with other districts that it is not only conformable but gradational into the overlying Kootenay.[1]

Age and Correlation. Although no fossils have been found in these shales in this district, their stratigraphical position and lithological character justify their correlation with the Fernie formation of lower Jurassic age.[2]

Origin. The invertebrate fossils of the Fernie formation indicate clearly its marine origin, while the vertebrate remains found in several localities[3] furnish evidence that the sediments were accumulated in shallow water.

Kootenay Formation.

Distribution and Thickness. The coal-bearing Kootenay formation occupies an irregular strip in the west-central part of the map-area, less than a mile wide and about 6 miles long, trending in a direction a few degrees east of north. Northward the formation is not thought to extend appreciably beyond Howell creek, nor beyond Burnham creek to the south. A

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[1] MacKenzie, J. D., Geol. Surv., Can., Sum. Rept., 1912, p. 238.
Cairnes, D. D., Geol. Surv., Can., Mem. 61, 1914, p. 32.
[2] Dowling, D. B., Geol. Surv., Can., Mem. 53, 1914, p. 26.
[3] Allan, J. A., Geol. Surv., Can., Sum. Rept., 1912, p. 174.

measured section of the Kootenay, made on the north side of Cabin Creek valley, gave 1,147 feet of sandstones, shales, and coal. The measures seem to be uniform throughout their extent, and the thickness of the formation may be considered, therefore, to closely approximate 1,100 feet in this district.

Lithology. The Kootenay formation is made up of sandstones, shales, and coal seams. The sandstones are readily recognized for the most part and are grey to dark grey, medium to fine grained, occasionally pebbly, and with a characteristic appearance which may be described as "finely speckled." They are identical in appearance with the Kootenay sandstones of the Blairmore-Coleman, and Southfork coal areas of Alberta.

A single specimen, typical of the finer grained sandstones, was studied in thin section and found to consist of about 30 per cent of quartz grains between 0·15 mm. and 0·30 mm. in size, with some quartz in smaller sizes. The quartz grains are subrounded to subangular, and are mostly clear; some are crowded with microlites; some have wavy extinction, and some are fibrous. Most of the quartz seems to be of granitic origin, but some may be chalcedonic. Chert fragments of about the same sizes as the quartz form about 40 per cent of the rock, and there are a few grains which are apparently of volcanic rocks, and a few of a sericite schist. In parts of the rock very finely granular quartzose material forms a matrix, with shreds of muscovite and a few grains of tourmaline and zircon. The cement is largely limonite, in some cases coating the grains. The rock is uneven in texture.

Stratigraphy. The sandstones of the Kootenay formation are usually thick bedded; in some cases very massive, in layers up to 9 feet thick, and in many cases markedly cross-bedded. The rocks are usually well laminated, this being due to adjacent layers of different sized grains. These strong beds of sandstone form great screes where they outcrop on steep slopes. The shales are usually brown, and vary from fine, dense, to sandy varieties. In the vicinity of the coal seams harder, black bands are found and obscure plant markings and lenticles of coal are common. The coal is described in the chapter on "Economic Geology."

The section of the Kootenay measured north of Cabin creek is given in diagrammatic form as Figure 1 on page 41.

The Kootenay rests conformably on the Fernie shales and is conformably overlain, apparently, by a conglomerate. This conglomerate is described below and, for reasons there given, the contact is thought to be a disconformity.

Age and Correlation. The stratigraphical succession, the fossil contents, plant remains, and coal, and the lithological character form a combination of properties by which a certain correlation may be made with the Kootenay formation of Lower Cretaceous age.

Origin. The composition of the sediments of the Kootenay formation, their uneven grain, their cross-bedding, the thickness of individual layers, and the fossils contained in them, all point to the conclusion that they were accumulated with moderate rapidity in shallow, freshwater lakes, at a time when the region was steadily being depressed. At certain recurrent intervals swamp conditions prevailed over wide areas, owing to the balancing of sinking by sedimentation, or to periods of rest in the sinking; and at these times coal beds were formed. The great length of the area in which the Kootenay formation was deposited —over 350 miles in Canada alone, from the boundary to beyond the Yellowhead pass—its relatively narrow width—probably less than 50 miles— and the varying thickness of the formation in different parts of the area[1], indicate that the Kootenay was accumulated in a long lake of varying depth, or, more probably, in a chain of lakes and swamps extending along what is now the axis of the Rocky mountains. Minor variations in the rate of sinking, or slight changes in the rate of sedimentation caused alternate lacustrine and swamp conditions to prevail; and during the prevalence of swamp conditions coal seams were accumulated.

Upper Cretaceous.

Distribution and Thickness. East of the territory occupied by the Kootenay formation, and lying on the flanks of the hills facing the flood-plain of the Flathead river, an irregular area

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[1] Dowling, D. B., Geol. Surv., Can., Mem. 53, 1914, p. 27.

of about 5 square miles is underlain by beds assigned to the Upper Cretaceous. A persistent bed of conglomerate, 85 feet thick, at the base of these measures, forms the only rock exposures of the formation seen. It is estimated on structural evidence that more than 2,000 feet of measures are probably present, though undetected faulting may modify this estimate.

Lithology. The basal conglomerate is of a grey colour generally, weathering bright red and yellow in some places, owing to small amounts of evenly distributed iron oxide. The pebbles range from one-eighth of an inch to 3 inches in diameter, the larger number being three-eighths of an inch to one-half inch in diameter. They are very well rounded, and form about 60 per cent of the rock. For the most part, as shown by blowpipe and optical tests, the pebbles are black, grey, and faintly pink chert and clear, white and pinkish, vitreous quartzites. The matrix is white, clean, coarse, siliceous sand and the cement is in large part siliceous. The resistant nature of this conglomerate to processes of weathering and erosion make it an extremely valuable horizon marker wherever it occurs.

The lithology of the beds above the conglomerate is unknown. Reasoning from the fact that they form no outcrops, and from analogy with the rocks of southwest Alberta, they are probably soft sandstones and shales.

Stratigraphy. The conglomerate abruptly overlies the soft shales and finer sandstones of the Kootenay without a sign of transition. So far as could be discerned the conglomerate is structurally conformable on the Kootenay beds; nevertheless the relation is thought to be that of disconformity. It may be stated that this conglomerate is correlated with a formation found in southwest Alberta that lithologically is virtually identical. This Alberta conglomerate overlies the Kootenay apparently conformably, but in reality disconformably. This is well shown in the Blairmore-Coleman district, where the uppermost coal seam of that district—one of the best occurring there—has this conglomerate for a roof, wherever the seam is found. The seam is, however, frequently absent for no apparent reason. In the Southfork coal area, the writer has seen this conglomerate in contact with the fresh, hard coal; the pebbles lie on the coal, indenting it slightly but with no sign of transition between the two sediments. The consolidation of the coal to such a degree so that the pebbles would scarcely indent it must have required a long time and probably a great load of sediments. The time interval is not represented in the stratigraphical record, and the sediments, which may reasonably be supposed to have existed, have been removed. This example of marked discontinuity of sedimentation virtually proves that the conglomerate is in disconformable relation to the underlying beds.

Age and Correlation. On account of its distinctive lithological characters and stratigraphical position this conglomerate is correlated with assurance with a very similar formation occurring at the base of the beds assigned to the Dakota in southwest Alberta, with which the writer is familiar.[1] The latter conglomerate is of very widespread occurrence in southwest Alberta, and is described by Cairnes from the Moose Mountain district, 140 miles north of the Flathead map-area.[2] The conglomerate in the Flathead area is also correlated with those occurring above the Kootenay formation in the Elk river escarpment,[3] which are cherty conglomerates interbedded with grey nodular limestone, and sandstone and brown shale. Wherever it has been observed, the cherty character of this conglomerate has attracted attention, and has been commented on by the writers referred to above. Its peculiar nature furnishes a clue to its origin and to the physiographical conditions of the region at the time of its accumulation.

Origin. The special and uniform character of the conglomerate over wide areas calls for some explanation. The source of the pebbles may be assigned with confidence to the cherty bands of the Devono-Carboniferous limestones which were subjected to erosion in pre-Jurassic time; and it is quite possible that parts of the district were undergoing erosion well up through the Lower Cretaceous. This erosion would inevitably concentrate the silicified layers as a fragmental veneer of

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[1] MacKenzie, J. D., Geol. Surv., Can., Sum. Rept., 1912, p. 238.
Leach, W. W., Geol. Surv., Can., Sum. Rept., 1911, p. 194.

[2] Cairnes, D. D., Geol. Surv., Can., Mem. 61, 1914, p. 30.

[3] McEvoy, J., Geol. Surv., Can., Ann. Rept., 1900, p. 87A.

chert on the surface of the limestone terrane, from which they could be readily concentrated when suitable conditions supervened. These conditions arrived at the end of Kootenay time, but their exact mode of action is not wholly clear. The occurrence of this conglomerate in the midst of a great freshwater series—for probably the rocks from the base of the Kootenay to the top of the so-called Dakota represent freshwater accumulation[1]—is strong evidence that it, too, is a freshwater sediment. Its freshwater origin, its very wide distribution, and its deposition after a period of general but relatively slight erosion, indicate that it was collected by rivers and streams into shallow, extensive, and probably shifting lakes, and there re-sorted and evenly spread out.

Kishinena Formation.

Distribution and Thickness. Outcrops of the Kishinena formation are found at various cut banks on the Flathead river, on Couldrey creek, and on Burnham creek a few hundred feet above its junction with Couldrey creek. Outcrops are reported to occur on Cabin creek also, a short distance below where it debouches from the hills to the flood-plain of the Flathead. The formation underlies, therefore, the larger part of the eastern half of the map-area and is the most extensive, areally, of the formations found in the district. Little information, and that largely inferential, is available in regard to the thickness of these beds. They are so poorly exposed, and their structures so uncertain that it can only be said that they apparently reach a thickness of 1,500 feet, but may be much thicker.

"Ten miles south of the International boundary, near the mouth of Kintla creek, the Kintla Lake Oil Company has drilled through 700 feet of soft 'shales' and sandstones bearing at intervals thin seams of coal"[2] which undoubtedly belong to this formation. Daly found "not more than 250 feet of beds" exposed at the boundary, though probably over 500 feet were represented.

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[1] Dowling, D. B., Geol. Surv., Can., Mem. 53, 1914, p. 27.
[2] Daly, R. A., Geol. Surv., Can., Mem. 38, 1912, p. 87.

Lithology and Stratigraphy. These sediments may be divided into two facies. The first consists of coarse gravels and sands with some clay, is cross-bedded and lenticular in character and contains many thin seams of lignite. The second facies is made up of partially consolidated, very fine-grained, evenly laminated, fossiliferous, freshwater limestones, alternating with fine clay beds and very thin seams of lignite.

A typical section of the coarser facies was measured on the east bank of Flathead river within a mile of the northern boundary of the map-area, and is given here:

	Feet	Inches
River drift and coarse gravel, unconformable on:		
Brownish-grey, well stratified clayey sand, not consolidated	3	....
Partially consolidated gravel, well rounded slightly flattish pebbles up to 6 inches, mostly quartzites; a very few of a soft weathered limestone, all set in a sandy matrix...	10	....
Lignite; black to brownish, hard, bent in minor crinkles....	..	1½
Yellowish-brown clayey sand with lignite streaks..........	..	5
Lignite, a dirty seam..............................	..	6
Rusty grey clayey sand..............................	..	2–4
Lignite..	..	1
Yellowish rusty sand................................	..	3
Grey plastic clay......................................	1	..
Grey, moderately hard shale..........................	1	8
Lignite, dirty..	..	6
Grey, soft clay shale..................................	1	..
Lignite, a well marked and extensive seam..............	1	4
Dark grey soft shale, carbonaceous at base...............	4	..
Lignite..	..	8
Greyish clay shale....................................	4	..
Lignite..	..	6
Shale..	2	..
Lignite..	..	4
Shale..	3	..
Lignite..	..	3
Total thickness exposed here..........................	34	11½

Several feet of similar conformable measures are exposed below these in the section.

A section of the finer facies was measured on the north bank of Couldrey creek, less than a mile above its junction with Flathead river, and is given below:

	Feet	Inches
Whitish weathering clay shale	..	2
Lead grey, very fine, plastic, clay shale, rusty on joints	..	5
Light brown, plastic clay shale, crowded with shells and fragments of shells	..	1½
Greyish, white, and buff, soft, light weight, calcareous rocks fully described below and which for brevity will be termed marl here	..	10
Brownish, grey, soft, plastic, clay shale	..	11½
Light brownish-white, finely laminated marl, similar to above, but less fossiliferous	..	2
Brownish-white bituminous marl like 10-inch band above ..	..	4
Lignite, black, dense, and lustreless, containing some fossils	..	1½
Brownish, paper thin shale, argillaceous at top, grading into the underlying marl	..	1
White and brownish-white, bituminous marl, weathering into paper thin sheets	2	4
Brownish, non-bituminous clay shale	..	¾–1
Brown, bituminous laminated marl	..	3
White, massive, firm and tough marl, virtually without fossils, recrystallized as described below	1	6
Brown and black, grey, soft shale	1	9
Similar rocks with fossils, and less plastic	..	6
Massive whitish marl as before	1	6
Soft, rusty weathering, laminated fossiliferous marl	1	..
Greyish-brown, soft shale	2	3
White marl as before, but fossils largely fragmental	1	6
Bluish-grey, extremely fine, clay shale	..	4
Brown, soft, concentric weathering, clay shale	4	..
Total thickness exposed here	20	2½

The buff, soft, fossiliferous, calcareous rocks referred to as marl, which form such a large proportion of the section given above, exhibit minor differences in different bands, but on the whole are of the same nature and origin. The somewhat ambiguous name "marl"[1] is used for lack of a better term; it is not employed here with any genetic significance.

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[1] Stewart, C. A., Econ. Geol. vol., 4, 1909, p. 485.

These rocks are greyish-white to light buff, and very soft, so that they may be cut with a knife, yet they are firm, and harden slightly on exposure. They are coherent, break with an uneven fracture, and have a rough feel. On drying, the specimens become dusty on the surface, indicating that the grains are only slightly cemented.

A marked characteristic of these rocks is their bituminous odour when struck or rubbed, and on joint planes brownish stains are frequently seen which give a strong bituminous smell when heated, The rock itself, heated in a closed tube, gives off hydrocarbon gases. Hydrochloric acid causes instant and strong effervescence, accompanied by a bituminous smell. Some bands are impregnated more than others with the bitumen which serves to darken them.

In places joint planes are stained bright yellow, and portions of the rocks are very soft and ochreous. Qualitative chemical tests show that the rocks are largely composed of calcite, with varying amounts of clayey substance and bitumen and contain traces or very small amounts of magnesia.

The fossils, with which many layers are crowded (even the lignite seam contains them) are in most cases crushed and fragmental. The shells are virtually unchanged, and are pearly white and hard. A list of the species found is given later.

In thin section the calcite composing the rocks is seen to be in minute, irregular grains of widely varying size but all under 0·01 mm. The grains are closely packed together in thin layers in some cases with a crinkly lamination. Many elongate, rod-like grains, about 0·1 mm. by 0·005 mm. in size, and perhaps of organic origin, have been noted. Embedded in the dense matrix are numerous small thin shells and fragments of shells, usually lying parallel to the bedding lamination, but in places irregularly disposed as if accumulated under slight movement. The shells are clear, and are formed of platy and fibrous layers of calcite (aragonite ?).

Recrystallization of the rocks has begun in some instances, and consists of a rearrangement of the minute irregular grains into larger calcite grains disposed in flat lenticular aggregates along the bedding lamination. In cases where this process has progressed appreciably the rocks are firmer and harder than they are elsewhere.

Throughout all of these rocks and with varying concentrations in different specimens are found impregnations of yellowish, brownish, and black material which is thought to be a residue from the evaporation of petroleum. These impregnations occur, in part, as a faint brownish coloration throughout the rock, which disappears on heating and is absent in the recrystallized parts. The colour is much more intense in some layers, and even in different parts of the same layer, and grades into yellow to deep brown or almost black irregular spots. The lighter coloured spots are transparent, and even the deeper coloured ones in strong transmitted light give a reddish tinge suggestive of petroleum.

In many cases the bitumen takes the form of spheres, from sub-microscopic in size to 0·04 mm. in diameter, and arranged in "swarms" of a few dozens of the larger spheres, or several scores of the most minute ones. Spheres over 0·03 mm. in diameter are brown and opaque; and in those of less diameter a golden reddish tinge is common in transmitted light. The spherical shape can be well seen by slightly changing the focus of the microscope. All of the impregnations, when segregated in individual areas, are isotropic.

The spheres are thought to represent drops of petroleum that have segregated under the influence of surface tension in the water saturated rocks, yet were unable to migrate to any considerable distance owing to the very dense character of the enclosing material. They are so small that their present degree of fluidity can not be determined, but they exhibit no migratory tendency in their present condition and environment.

A feature of the stratigraphy of the Kishinena formation which may be of considerable significance is the marked local unconformable relation observed at the locality where the section given on page 32 was measured. Two similar series of clays, sands, and gravels occur there, both containing lignite; the lower series strikes north 20 degrees east and dips 50 degrees southeast, while the upper, clearly truncating the edges of the lower layers, has a strike of north 30 degrees east and dips 20 degrees southeast. This large angular divergence seems too great to be accounted for by contemporaneous erosion and deposition; and must be explained by a tipping of the lower series by faulting, and the deposition on them of the upper series, the whole being again tipped by recurrent slipping. That both series were deposited in a horizontal attitude or nearly so, is indicated by the beds of fine clay and lignite which they contain.

As a whole, the Kishinena formation is unconformable on the underlying Mesozoic and Palæozoic rocks, though the exact contact is everywhere concealed by surface detritus. It is unconformably overlain by surface gravels, and this contact has been observed in several places.

Age and Correlation. Fossils collected by the writer have been determined by Dr. W. H. Dall, who reports finding "Two species of *Planorbis*, crushed flat...... and the remains of a species of *Physa.* The shells are specifically indeterminable owing to their bad state of preservation, but the larger one recalls *Planorbis utahensis* White, and the smaller multispiral one *Planorbis cirratus* White, the former from the Bridger group, and the latter from the Green River beds of Wyoming. Only a guess is permissible, yet a probability of Eocene age is existent so far as I dare express an opinion."

Fossils collected by Daly[1] were examined by Dr. T. W. Stanton, who reported the collection to "consist entirely of freshwater shells belonging to the genera Sphaerium, Valvata(?) Physa, Planorbis, and Limnæa. Similar forms occur as early as Fort Union, now regarded as earliest Eocene, but there is nothing in the fossils themselves to prevent their reference to a much later horizon in the Tertiary, because they all belong to modern types that have persisted to the present day, though it should be stated that their nearest known relatives among the western fossil species are in the Eocene."

[1] Geol. Surv., Can., Mem. 38, 1912, p. 87.

Doctor Stanton lists the species as follows:

Sphaerium sp., related to *Sphaerium subellipticum* M. and H.
Valvata (?) sp., resembles *Valvata subumbilicata* M. and H.
Physa sp.
Planorbis sp., related to *Planorbis convolutus* M. and H.
Limnæa sp.

This fossil evidence, though not absolute, at least strongly supports the conclusion that the Kishinena formation is of Eocene age.

Origin. The character of the sediments as described above and their fossil content, both plant and animal, determine these rocks to be of freshwater origin. The conditions of the accumulation of the Tertiary lake beds farther down the Flathead valley, in Montana, have been given by Willis and his description applies so well to the northward extension of these beds, in the Flathead map-area, that it may be repeated here.[1]

"......These deposits are called lake beds because they are very distinctly and evenly stratified. They consist of fine sediment, such as would settle from quiet water only, and they occur in a valley of such moderate width between mountains of such height that no simple condition of alluvial accumulation seems appropriate. It is possible that the lake was at times shallow like a flooded river. It is probable that it was some time reduced to the proportions of a river. It is certain that during considerable intervals some areas were marshes; but, admitting that a lake may pass through various phases of depth and extent, the term lake beds best describes these deposits."

In addition it may be repeated here that the local unconformity noted in these beds in one locality and described above, seems too great to be assigned an origin in the vagaries of delta structure alone; rather it is supposed that tipping disturbed these beds once or more during their accumulation, giving rise to their present discordant attitudes.

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[1] Bull. Geol. Soc. Am., vol. 13, 1902, pp. 327–328.

Quaternary Deposits.

The river gravel which is so widespread in the eastern half of the map-area is largely composed of rounded pebbles and boulders of red argillite, quartzite, and basaltic rock from the Clarke range to the east.

Glacial deposits have not been certainly recognized in the area, but the lower slopes of some of the hills may in part be covered with till.

STRUCTURAL GEOLOGY.

The structure of the Flathead map-area may be succinctly described as that of a downfolded, warped, monoclinal fault block, with northeast strikes and, for the most part, southeast dips; bounded on the northeast and southwest by normal faults with a northwest strike, the upthrown sides being on the north-east, and southwest respectively.

The upthrown blocks form the limestone mountains in the southwestern part, and those just north of the map-area, and with their southwestward dipping strata partake of the structure of the Macdonald range to the west. Between these older rocks is a downthrown block of younger beds which, in the western portion of the district, lie with moderate dips diverging from a low north-south anticlinal axis, less pronounced toward the south, which is located a mile or so east of the western edge of the map-area.

To the east of this axis for a short distance the strata lie in low, undulating, minor folds, then dip more sharply to the eastward, giving this fault block its essentially monoclinal character.

Apart from the major breaks mentioned, faulting is not pronounced and no other breaks have been certainly observed. It is probable, however, that strike faults of relatively small displacement will be found during the development of the coal seams, and may prove a factor of some consequence in mining operations.

The structure of the Tertiary Kishinena formation is only imperfectly known. Dips up to 50 degrees have been observed, also local unconformities, so that it is plain that these beds have been strongly deformed, and probably more than once. As all the dips are towards the east or southeast, a tilting in that direction is apparent. The inference seems clear that the beds were formed in part before the slipping along the great fault on the east of the Flathead valley was completed and that slipping occurred during their period of accumulation. This interpretation places the date of the beginning of normal faulting as early Eocene, which is earlier than the Miocene date assigned to it by Willis.[1] The major part of the normal faulting may best be assigned to a period immediately succeeding the Laramide revolution, as it occurred as soon as the compression of that orogenic disturbance ceased. Later, lesser slipping continued into the Eocene, and perhaps for a longer time.

[1] Bull. Geol. Soc. Am., vol. 13, 1902, p. 344.

CHAPTER VI.

ECONOMIC GEOLOGY.

COAL.

Coal is the only mineral product of the Flathead map-area that is likely to have commercial value. The seams, although they underlie a relatively limited area and are not numerous, are thick and contain a good quality of bituminous coal. Their attitude is such that a considerable amount of coal may be mined under the economic conditions at present prevailing in the mountain coal regions as soon as railway transport becomes available.

Owing to the poor natural exposures, and the limited amount of prospecting that had been done, the writer was able to obtain very little detailed information in regard to the seams, and such as has been gathered is largely from surface exposures and shallow open-cuts. The following information and opinions, therefore, are of necessity qualitative except where otherwise stated, and this is all that can be expected of a report of this nature on a field in such an early state of development.

STRATIGRAPHY AND COMPOSITION OF THE COAL.

The best exposed section of the Kootenay formation occurs about half a mile north of Cabin creek, on the steep hillside facing south, where, besides natural exposures, a number of shallow prospect trenches have bared the coal seams. The general relations of the seams and the stratigraphy of the formation as determined at this place are given in diagrammatic form in Figure 1 and may be taken as representative of the formation throughout the district. It will be noted that all the seams of commercial size are found in about 400 feet of measures, in the lower part of the formation, which is the opposite relation to that obtaining in southwest Alberta.[1]

[1] MacKenzie, J. D., Geol. Surv., Can., Sum. Rept., 1912, p. 241.

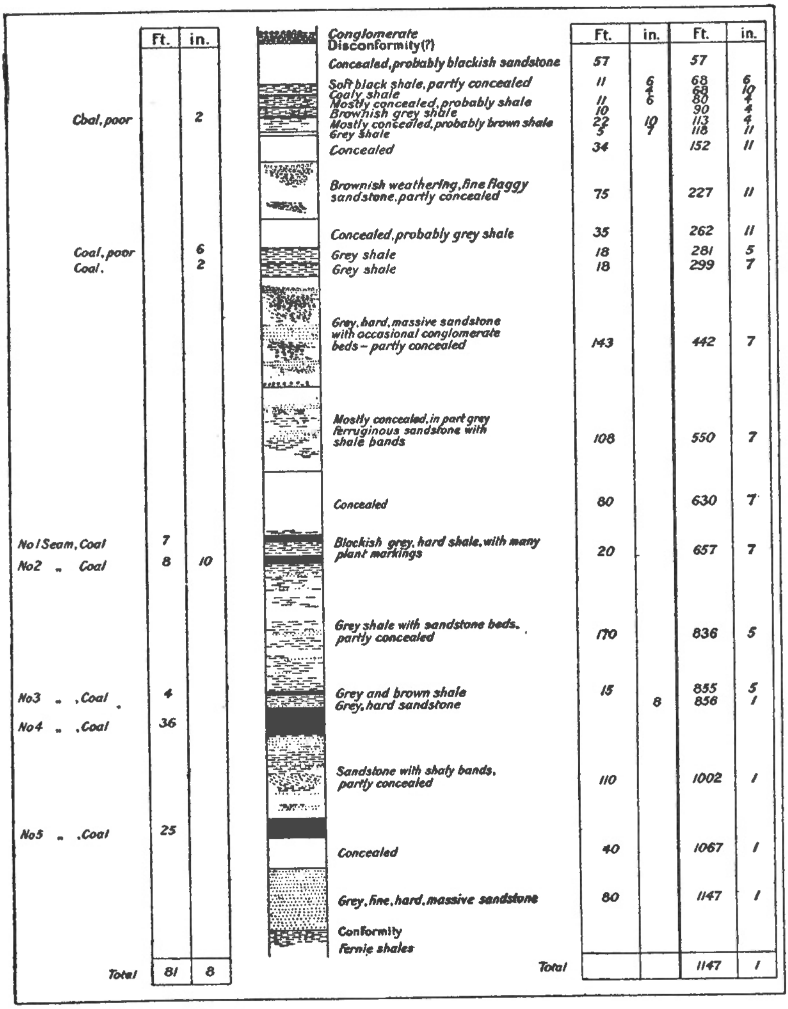

Figure 1. Columnar section of the Kootenay formation, one mile north of Cabin creek.

Detailed sections of the five seams of workable size are given below:

Top (No. 1) Seam.

	Feet	Inches
Roof is hard, firm, medium grained grey sandstone.		
Coal	3	..
Brown coaly shale	1	..
Coal	..	6
Soft brown bone	..	0¾
Coal ... about	1	8
Shale ... about	..	4
Coal ... about	..	6
Total	7	0¾
Total coal	5	8
Floor is of hard grey shale, 20 feet thick.		

No. 2 Seam.

	Feet	Inches
Roof is greyish-brown shale.		
Coaly shale	..	6
Hard grey shale with coaly streaks	..	9
Coal, soft but clean	2	2
Grey shale	..	1
Coal	..	1½
Shale	..	1
Coal	..	3
Shale	..	1
Coal	..	4
Shale	..	1
Coal, clean and soft	1	3
Grey shale	..	4
Coal, clean and soft	2	2
Shale	..	2
Coal	..	6
Total	8	10½
Total coal	6	9½
Floor is hard grey shale, full of plant markings but containing no rootlets.		

No. 3 Seam.

	Feet	Inches
Roof is hard grey shale..		
Coal, soft but clean	4	..
Floor is hard greyish-black shale.		

No. 4 Seam.

	Feet	Inches
Roof is cracked grey sandstone, 8 inches thick. The upper 12 feet of this seam is shaly, dirty, and probably valueless as fuel. The next 12 feet is soft, good coal, apparently in place and clean. Below this is 5 feet of dirty valueless coaly shale, and the lower 7 feet is soft, good clean coal. The seam is apparently undisturbed, and shows no evidence of local thickening, although only moderately well exposed.		
Total thickness....about	..	36
Total good coal....about	..	19

Bottom (No. 5) Seam.

This seam is poorly exposed, but is apparently 25 feet thick.

South of Cabin creek, on the eastern slopes of the 6,300-foot hill, known as Dally mountain, a considerable amount of prospecting has been done, exposing several seams; but the various exposures have not yet been correlated with each other, nor with the seams north of Cabin creek. The following section of a seam was measured in a trench on the trail over the top of the hill at the 5,250-foot contour.

	Feet	Inches
Roof is lenticularly slickensided soft greyish-brown clay shale.		
Coaly shale with streaks of coal....	..	2
Black carbonaceous shale....	..	2
Coal, soft and of questionable value, but which will probably improve with depth. Contains a few lenticular bone concretions up to 2 inches thick....	2	4
Hard, greyish-brown clay shale....	..	5
Coal, much like upper bench....	5	6
Black, soft, coaly shale, probably valueless, though containing thin streaks of coal....	5	..
Coal, as before, but softer....about	5	..
Total....	18	7
Total coal....	12	10

This seam will probably improve considerably with depth. The floor is brownish-grey shale, full of plant stems, but shows no rootlets so far as can be observed. The coal rests directly on the floor without any underclay.

The prospect openings, one-fourth of a mile south of Cabin creek, which are marked on the map, have exposed two coal seams which can be correlated with those found on the north side of the creek and described above. In the middle tunnel shown, an 8-foot 8-inch seam of fairly clean coal is visible, striking north 30 degrees east and dipping 45 degrees southeast, doubtless the No. 2 seam above. In the crosscut and tunnel of the uppermost opening a seam over 35 feet thick is exposed, which represents the No. 4 seam above. In the tunnel the coal is greatly crushed and soft, evidently from the effect of surface creep, and it will unquestionably improve in coherence and quality with depth. A sample of the coal from this opening was taken from the dump, and its analysis is No. 1 on page 46. Parts of the seam will average better than this analysis of material from near the surface and it is probable that the seam as a whole will average better.

In a small draw opposite the end of the wagon road leading west from the ranch of E. W. Butts, at Colgate, a number of prospect openings have been made on the outcropping seams. There appears to be considerable surface creep and local disturbance at this place and most of the openings are caved or slumped, so that accurate information is difficult to obtain. The general strike of the measure is about north 30 degrees east, though locally it varies from north 15 degrees east to north 60 degrees east. The dip is about 30 degrees southeast. All the coal seams exposed appear to be within a stratigraphical thickness of 300 feet. The uppermost seam stratigraphically—the lowest exposed in the draw—is about 10 feet thick and, although soft and crushed at the surface, appears clean and should improve with depth. Both roof and floor of this seam are of grey shale. Farther up the draw and, stratigraphically, 20 feet below this 10-foot seam, there is a 15-foot seam with shale roof and floor; the seam is much disturbed at the surface and contains a few shaly partings up to one inch thick. A sample of the lower 9 feet of this seam was taken about 4 feet from the surface. Its analysis is No. 4 on page 46. Above this seam in the draw, and stratigraphically more than 100 feet below it, an excellent seam of coal of good quality is exposed. It lies in shale, is only slightly disturbed at the surface, and contains at least 30 feet of good looking coal with very few and thin shaly partings. Much of the coal is in firm, hard layers, not greatly broken, even at the surface. Analysis No. 2 is from a 4-foot bench of the best looking coal in the lower part of the seam, and analysis No. 3 is from a 4-foot bench of soft, poor looking coal just below the roof and near the surface. The whole seam as exposed will average between these two samples. It may be confidently expected that the quality of the seam will improve somewhat with depth.

Openings other than those mentioned above expose coal seams at this locality; but the writer could not make sure of more than the three seams mentioned, though others are probably present and not yet exposed.

Not enough data are at hand to safely correlate the seams at this locality with those near Cabin creek. It may be suggested, however, that the 10, 15, and 30-foot seams represent the 7, 8, and 36-foot seams found farther south. The stratigraphical thickness between them is identical in the case of the first two, and of the same order of magnitude between the second and third. If this correlation be correct a 25-foot seam may be expected to occur farther up the draw. There is a local, small anticline just above, on the hill, which may be the cause of the non-appearance of the 25-foot seam at this point.

Coal and Lignite Analyses.[1]

	1	2	3	4	5	6
Moisture	1·4	2·0	4·7	9·2	1·6	23·9
Ash	15·2	9·4	12·0	10·7	20·0	17·3
Volatile matter	21·9	22·6	24·1	24·4	24·2	39·6
Fixed carbon (by difference)	61·5	66·0	59·2	55·7	54·2	19·2
Total	100·0	100·0	100·0	100·0	100·0	100·0
Fuel ratio $\frac{\text{Fixed carbon}}{\text{Vol. matter}}$	2·8	2·9	2·5	2·3	2·2	0·5

1. No. 4 seam. Sample taken from the dump at the mouth of the prospect tunnel, south of Cabin creek. The seam as a whole will probably average better than this sample.
2. No. 4 seam (?). Sample of a 4-foot bench of the best looking coal exposed near the end of the wagon road leading west from E. W. Butt's ranch at Colgate.
3. No. 4 seam (?). Same locality as for No. 2. Sample of a 4-foot bench in the upper part of the seam.
4. No. 2 seam (?). Same locality as No. 2. Sample of a 9-foot bench in the lower part of a 15-foot seam, thought to be the No. 2 seam.
5. A grab sample taken from a bin at the "Townsite," where there are said to be 14 or 15 seams ranging up to 10 feet thick.
6. Lignite from the 1½-inch seam occurring in the section of No. 2 seam given on p. 42.

The coking qualities of these coals are good, as indicated by rough tests made in the field. Tests made with some degree of care, on the coals found at the Townsite, show that their coking quality is good, furnishing a hard, coherent, bright coke.

[1] All samples collected by J. D. MacKenzie and analysed by Edgar Stansfield, Mines Branch, Department of Mines.

STRUCTURE OF THE COAL MEASURES AND NOTES ON MINING.

The Kootenay formation, which is coal-bearing in its lower portion, occupies an irregular strip less than a mile wide and about 6 miles long, the measures in general striking a few degrees east of north and dipping southeast at various angles up to 60 degrees, though flatter dips prevail. Northward the formation is cut off by a fault along the valley of Howell creek; but it is possible that this fault is not as far south as it is represented to be on the map, though its position as given is thought to be nearly correct. Southward the formation terminates along Burnham creek at another fault, and the position of this fault is mapped with considerable confidence.

The cap of coal measures on the top of Dally mountain has the form of a shallow syncline which folds over into a low anticline on the east slope of the hill. On this east slope the numerous ridges parallel to the strike of the rocks are possibly due to minor strike faulting, but most of them are probably hog backs caused by the alternation of soft shales with the massive more resistant sandstone layers. Nevertheless it would be well to investigate this point thoroughly before beginning mining operations as it is possible that small faults occur that are not evident on the surface, but which might seriously interfere with mining.

The valley of Cabin creek naturally offers the most advantageous location for the beginning of mining operations, yet it is possible that adjacent to the valley the coal measures will be found to be somewhat broken, and the maximum minor deformation of the measures may be looked for there. The valley of Cabin creek is a transverse one with relation to the structure of the district and in southwest Alberta several of these transverse valleys are located on zones of accentuated structural disturbance;[1] so it is possible that the coal measures are more disturbed near Cabin creek than elsewhere in the district. The thick surface covering of detritus and stream drift in the valley renders the certain elucidation of the structure very difficult without recourse to stripping or underground operations. Never-

[1] MacKenzie, J. D., Geol. Surv., Can., Sum. Rept., 1912, p. 237.
Dawson, G. M., Geol. and Nat. Hist. Surv., Can., Ann. Rept., pt. B, 1885, p. 67.

theless, so far as can be said at present, this valley offers the best facilities for the extraction of the largest amount of coal. The measures here are topographically at their lowest, so gangways north and south from this point would make available the largest amount of gravity coal. The adjacent gravelly flats are well suited for the location of the surface plant of a coal mine, and a good grade may be readily obtained down the valley.

LIGNITE.

Thin seams of lignite occur in the Kishinena formation, as may be seen from the sections on pages 32 and 33. The lignite is brownish black in colour and gives a brown streak. It is composed largely of flattened woody stems, in which the grain of the wood is often visible and differences between bark and wood can in some cases be made out. The lignite checks badly on exposure to the air and will not stand transportation. This property, taken in connexion with the smallness of the seams both individually and in the aggregate, makes the lignite an economic factor of negligible importance. An analysis of the seam found in the exposure of which a section is given on page 42 is No. 6 on page 46.

PETROLEUM.

In the description of the finer grained calcareous beds of the Kishinena formation it was brought out that many bands are bituminous and contain globules of what appears to be petroleum or some residue of petroleum. Occurrences of this nature have caused some preliminary prospecting for oil in these beds. The following facts bearing on the possibility of finding petroleum reservoirs and the conclusions drawn from them should be borne in mind by those interested in the oil question in the district mapped in connexion with this report.

That bituminous material exists in the Kishinena rocks is without question, and its source may be with confidence assigned to the soft parts of the numerous molluscs with whose shells it is now so closely associated. Whether or not petroleum as such exists in these beds is not yet proved, and chloroform tests of some of them furnished only negative results. However, the seepages of a kerosene-like oil on Sage creek, east of Flathead valley, suggests the rather unlikely possibility that the oil may have been derived by migration from these bituminous Tertiary sediments.

The porous, coarse nature of many of the sands of the Kishinena formation would render them suitable for petroleum reservoirs; and, although little is known of their structure in detail, it is probable that local conditions of porosity or succession of strata might afford a gathering place for bodies of oil, though these assuredly would not be large.

The small possible thickness of oil-bearing strata and their position near the surface render the finding of any considerable body of oil improbable; for, if any had been present, it would have readily escaped by natural channels and, furthermore, a sufficient gas pressure to make a field workable is unlikely at such shallow depths.

To sum up: while a possible source for petroleum is present, the presence of the oil itself is yet to be proved; and under the most favourable conditions of structure, reservoirs other than small ones under low pressure are very unlikely. It is apparent that the chances of the occurrence of commercial deposits of petroleum in the Flathead map-area are very slight.

INDEX.

P.

Q.

R.

S.

T.

U.

V.

W.

PUBLICATIONS OF THE GEOLOGICAL SURVEY.

The Geological Survey was established in 1842 and "Reports of Progress" were issued, generally in annual volumes, from that date to 1885, the first report being that for the year 1843 published in 1845. Beginning with the year 1885, "Annual Reports" (new series) were published in volumes until 1905, the last being Vol. XVI, 1904. Many of the individual reports and maps published before 1905 were issued separately and from 1905 to the present, all have been published as separates and no annual volume has been issued. Since 1910, the reports have been issued as Memoirs and Museum Bulletins, each subdivided into series, thus:—

Memoir 41, *Geological Series 38.*
Memoir 54, *Biological Series 2.*
Museum Bulletin 5, *Geological Series 21.*
Museum Bulletin 6, *Anthropological Series 3.*

In addition to the publications specified above, a Summary Report is issued annually; and miscellaneous publications of various kinds including Reports of Explorations, Guide Books, etc., have been issued from time to time.

Publications Issued 1910-1915 Inclusive.

MEMOIRS.

MEMOIR 1. *Geological Series 1.* Geology of the Nipigon basin, Ontario, 1910—by Alfred W. G. Wilson.

MEMOIR 2. *Geological Series 2.* Geology and ore deposits of Hedley mining district, British Columbia, 1910—by Charles Camsell.

MEMOIR 3. *Geological Series 3.* Palæoniscid fishes from the Albert shales of New Brunswick, 1910—by Lawrence M. Lambe.

MEMOIR 4. *Geological Series 7.* Geological reconnaissance along the line of the National Transcontinental railway in western Quebec, 1911—by W. J. Wilson.

MEMOIR 5. *Geological Series 4.* Preliminary memoir on the Lewes and Nordenskiöld Rivers coal district, Yukon Territory, 1910—by D. D. Cairnes.

MEMOIR 6. *Geological Series 5* Geology of the Haliburton and Bancroft areas, Province of Ontario, 1910—by Frank D. Adams and Alfred E. Barlow.

MEMOIR 7. *Geological Series 6.* Geology of St. Bruno mountain, Province of Quebec, 1910—by John A. Dresser.

MEMOIR 8. *Geological Series 8.* The Edmonton coal field, Alberta, 1911—by D. B. Dowling.

MEMOIR 9. *Geological Series 9.* Bighorn coal basin, Alberta, 1911—by G. S. Malloch.

MEMOIR 10. *Geological Series 10.* An instrumental survey of the shore-lines of the extinct lakes Algonquin and Nipissing in south-western Ontario, 1911—by J. W. Goldthwait.

MEMOIR 11. *Topographical Series 1.* Triangulation and spirit levelling of Vancouver island, B.C., 1909, issued 1910—by R. H. Chapman.

MEMOIR 12. *Geological Series 11.* Insects from the Tertiary lake deposits of the southern interior of British Columbia, collected by Mr. Lawrence M. Lambe, in 1906, issued 1911—by Anton Handlirsch.

MEMOIR 13. *Geological Series 14.* Southern Vancouver island, 1912—by Charles H. Clapp.

MEMOIR 14. *Biological Series 1.* New species of shells collected by Mr. John Macoun at Barkley sound, Vancouver island, British Columbia, 1911—by William H. Dall and Paul Bartsch.

MEMOIR 15. *Geological Series 12.* On a Trenton Echinoderm fauna at Kirkfield, Ontario, 1911—by Frank Springer.

MEMOIR 16. *Geological Series 13.* The clay and shale deposits of Nova Scotia and portions of New Brunswick, 1911—by Heinrich Ries assisted by Joseph Keele.

MEMOIR 17. *Geological Series 28.* Geology and economic resources of the Larder Lake district, Ont., and adjoining portions of Pontiac county, Que., 1913—by Morley E. Wilson.

MEMOIR 18. *Geological Series 19.* Bathurst district, New Brunswick, 1913—by G. A. Young.

MEMOIR 19. *Geological Series 26.* Geology of Mother Lode and Sunset mines, Boundary district, B.C., 1914—by O. E. LeRoy.

MEMOIR 20. *Geological Series 41.* Gold fields of Nova Scotia, 1914—by W. Malcolm.

MEMOIR 21. *Geological Series 15.* The geology and ore deposits of Phoenix Boundary district, British Columbia, 1912—by O. E. LeRoy.

MEMOIR 22. *Geological Series 27.* Preliminary report on the serpentines and associated rocks in southern Quebec,, 1914—by J. A. Dresser.

MEMOIR 23. *Geological Series 23.* Geology of the coast and islands between the Strait of Georgia and Queen Charlotte sound, B.C., 1914—by J. Austen Bancroft.

MEMOIR 24. *Geological Series 16.* Preliminary report on the clay and shale. deposits of the western provinces, 1912—by Heinrich Ries and Joseph Keele.

MEMOIR 25. *Geological Series 21.* Report on the clay and shale deposits of the western provinces, Part II, 1914—by Heinrich Ries and Joseph Keele.

MEMOIR 26. *Geological Series 34.* Geology and mineral deposits of the Tulameen district, B.C., 1913—by C. Camsell.

MEMOIR 27. *Geological Series 17.* Report of the Commission appointed to investigate Turtle mountain, Frank, Alberta, 1911, issued 1912.

MEMOIR 28. *Geological Series 18.* The Geology of Steeprock lake, Ontario—by Andrew C. Lawson. Notes on fossils from limestone of Steeprock lake, Ontario, 1912—by Charles D. Walcott.

MEMOIR 29. *Geological Series 32.* Oil and gas prospects of the northwest provinces of Canada, 1913—by W. Malcolm.

MEMOIR 30. *Geological Series 40.* The basins of Nelson and Churchill rivers, 1914—by William McInnes.

MEMOIR 31. *Geological Series 20.* Wheaton district, Yukon Territory, 1913—by D. D. Cairnes.

MEMOIR 32. *Geological Series 25.* Portions of Portland Canal and Skeena Mining divisions, Skeena district, B.C., 1914—by R. G. McConnell.

MEMOIR 33. *Geological Series 30.* The geology of Gowganda Mining Division, 1913—by W. H. Collins.

MEMOIR 34. *Geological Series 63.* The Devonian of southwestern Ontario, 1915—by C. R. Stauffer.

MEMOIR 35. *Geological Series 29.* Reconnaissance along the National Transcontinental railway in southern Quebec, 1913—John A. Dresser.

MEMOIR 36. *Geological Series 33.* Geology of the Victoria and Saanich map-areas, Vancouver island, B.C., 1914—by C. H. Clapp.

MEMOIR 37. *Geological Series 22.* Portions of Atlin district, B.C., 1913—by D. D. Cairnes.

MEMOIR 38. *Geological Series 31.* Geology of the North American Cordillera at the forty-ninth parallel, Parts 1 and II, 1913—by Reginald Aldworth Daly.

MEMOIR 39. *Geological Series 35.* Kewagama Lake map-area, Quebec, 1914—by M. E. Wilson.

MEMOIR 40. *Geological Series 24.* The Archæan geology of Rainy Lake, 1914—by Andrew C. Lawson.

MEMOIR 41. *Geological Series 38.* The "Fern Ledges" Carboniferous flora of St. John, New Brunswick, 1914—by Marie C. Stopes.

MEMOIR 42. *Anthropoligical Series 1.* The double-curve motive in north-eastern Algonkian art, 1914—by Frank G. Speck.

MEMOIR 43. *Geological Series 36.* St. Hilaire (Beloeil) and Rougemont mountains, Quebec, 1914—by J. J. O'Neill.

MEMOIR 44. *Geological Series 37.* Clay and shale deposits of New Brunswick, 1914—by J. Keele.

MEMOIR 45. *Anthropoligical Series 3.* The inviting-in feast of the Alaska Eskimo, 1914—by E. W. Hawkes.

MEMOIR 46. *Anthropoligical Series 7*. Classification of Iroquoian radicals and subjective pronominal prefixes, 1915—by C. M. Barbeau.

MEMOIR 47. *Geological Series 39*. Clay and shale deposits of the western provinces, Part III, 1914—by Heinrich Ries.

MEMOIR 48. *Anthropological Series 2*. Some myths and tales of the Ojibwa of southeastern Ontario, 1914—by Paul Radin.

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