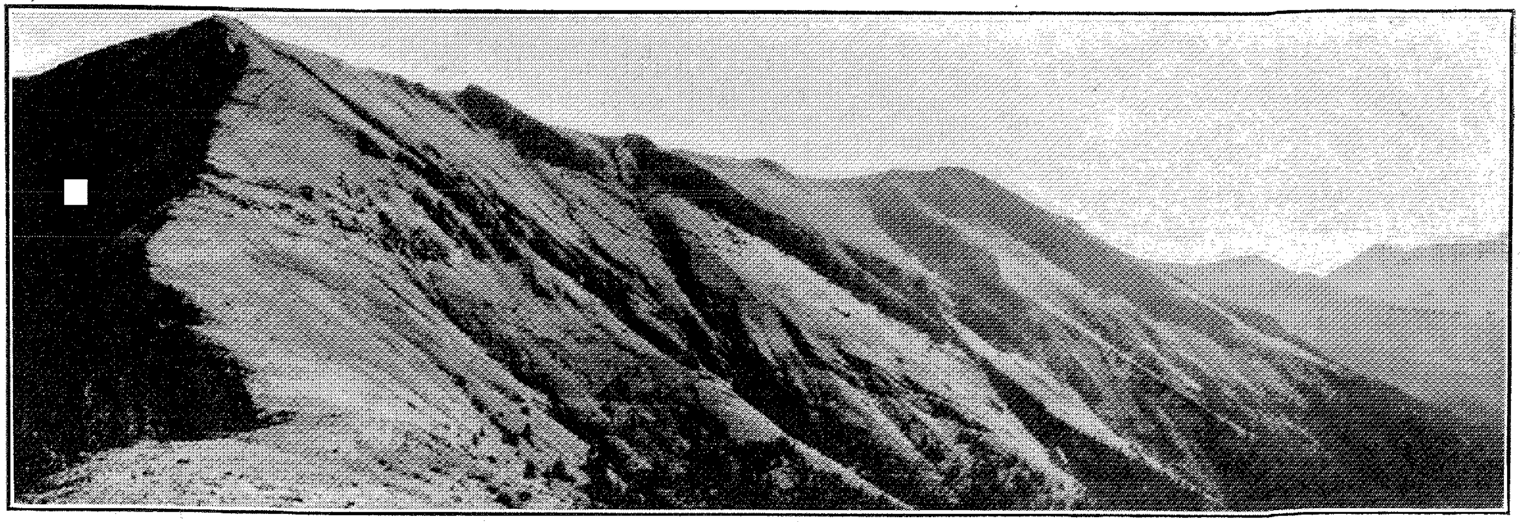

Top of Folding mountain, elevation 6,900 feet, showing folded Kootenay beds that cap the mountain. The hard member shown by the crenellations is the Kootenay conglomerate.—(Frontispiece.)

PROVINCE OF ALBERTA

Scientific and Industrial Research Council.—Report No. 11.
University of Alberta, Edmonton, Alberta.

GEOLOGICAL SURVEY DIVISION

JOHN A. ALLAN, Director

Geology of the Foothills Belt

BETWEEN

McLeod and Athabaska Rivers

Alberta

BY

RALPH L. RUTHERFORD

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ORGANIZATION

The Scientific and Industrial Research Council of Alberta, formed in January, 1921, carries on its work in co-operation with the University of Alberta. The Geological reports are prepared under the direction of J. A. Allan, Professor of Geology, University of Alberta.

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Requests for geological information and reports should be addressed to Department of Geology, University of Alberta, Edmonton, Alberta.

LETTER OF TRANSMITTAL

HONOURABLE HERBERT GREENFIELD,
Premier of Alberta,
Edmonton, Alberta.

SIR:—I have the honour to transmit herewith a report entitled, "*Geology of the Foothills Belt between McLeod and Athabaska Rivers, Alberta,*" prepared from field observations by Dr. Ralph L. Rutherford. This is Report No. 11 of the publications of the Scientific and Industrial Research Council of Alberta.

This report deals with the geology and physiography of a part of the foothills belt, and is a continuation to the northwest of the area discussed in Report No. 9, which was published in 1924. This geological survey of the foothills was started in 1922 at North Saskatchewan river and is now completed to Athabaska river. The total area, surveyed geologically in the foothills to date, comprises about 3,000 square miles, of which this report deals with approximately 600 square miles. This report is accompanied by a geological map in eight colours on a scale of one inch to two miles. The topography of the area is shown by sketched contours, and a series of structure sections is included with the map.

In this report (No. 11) and in the two previous geological reports (Nos. 6 and 9) it has been possible to trace and map the upper Cretaceous formations between North Saskatchewan and Athabaska rivers, and to determine the various coal horizons throughout the Saunders Creek and Coalspur coal areas, and that part of Prairie Creek coal area south of Athabaska river.

The field survey is now being extended eastwards to connect the coal horizons in the foothills with the coal in the Edmonton formation mined at Evansburg and Wabamun.

All of which is respectfully submitted.

Yours truly,

JOHN A. ALLAN.

Department of Geology,
University of Alberta,
Edmonton, Alberta, June 4th, 1925.

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Geology of the Foothills Belt Between McLeod and Athabaska Rivers, Alberta

By

RALPH L. RUTHERFORD

CHAPTER I.

INTRODUCTION.

General Statement.—The coal resources of Alberta constitute the outstanding known mineral reserve, and the industry based upon this resource is one of the most valuable assets in the Province. In view of these facts it is apparent that field investigations of the coal deposits should receive first consideration in a programme of geological work. A geological survey of a part of the foothills belt was carried on in 1922 and 1923. In 1924 this survey was continued and the following report is based largely on the last season's work. It forms a part of the Sixth Annual Report on the Mineral Resources of Alberta.

Object of Investigation.—The chief purpose of the field work of 1924 was to continue to the northwest the geological mapping and study of the foothills belt, which was started in 1922 in the Saunders creek and Nordegg areas,[1] and was continued northwards to Coalspur in 1923.[2]

The objective in this work was to complete a field investigation and geological mapping of the foothills belt from the North Saskatchewan river to Athabaska river.

Geographical Position and Accessibility.—The area discussed in this report and shown on the accompanying map (No. 7) is situated in the foothills of Alberta, between 117 degrees and 118 degrees west longitude. It includes all or portions of township 46 to 51, ranges 21 to 27, west of the fifth meridian. The thirteenth base line passes approximately through the centre of this area. The southern part lies within the Brazeau Forest Reserve and a narrow strip along the north is included in the Athabaska Forest Reserve. Some of the western part lies within Jasper National Park. In addition this map includes an area lying along the south side of the

1Allan, J. A., and Rutherford, R. L., "Saunders Creek and Nordegg Coal Basins," Rept. No. 6, Sci. and Ind. Res. Council of Alta., Fourth Ann. Rept. Min. Res. Alta., Edmonton, 1923. (Note: Hereafter referred to as Rept. No. 6.)

2Allan, J. A., and Rutherford, R. L., "Geology Along the Blackstone, Brazeau and Pembina Rivers, in the Foothills Belt, Alberta," Rept. No. 9, Sci. and Ind. Res. Council of Alta., University of Alberta, Edmonton, 1924. (Note: Hereafter referred to as Rept. No. 9.)

Athabaska which is not included in the Athabaska Forest Reserve. It includes parts of the "Prairie Creek", "Coalspur", "Brule" and Mountain Park" coal areas, as shown on the "Coal Areas Map of Alberta"[3], by J. A. Allan.

The northern limit of this map-area is the Athabaska river, which here has a northeast trend. The southeastern boundary is somewhat irregular, being made to tie on with the area mapped and reported on in 1923[4].

The southwestern boundary is formed by the Paleozoic and early Mesozoic strata which form the most easterly ranges or outliers of the Rocky Mountains in this district.

The northeastern limit of the area mapped is not marked by any physiographical or geological boundary. The position of the northeastern limit roughly separates the well defined foothills on the west from the area to the east which does not, in general, show pronounced uplands. This area mapped constitutes a belt approximately forty miles long and fifteen miles wide, or 600 square miles.

The Alberta Coal Branch of the Canadian National Railway crosses the southern part of the area. This branch line leaves the main transcontinental line at Bickerdike, 138 miles west of Edmonton. The main line of the Canadian National Railway to the Pacific coast follows along the northern boundary. The area lying between these two railways is accessible by means of pack trails, maintained by the Forestry Branch.

The proposed Jasper Highway crosses the north end of this map-area. It parallels the railway through the eastern part, but turns more to the south at Hinton station and follows up Prairie creek into Jasper Park. To date this is not used much as an automobile highway, more on account of unfavourable road conditions east of this area than within it. The portion of the proposed highway lying within this map-area can be put into excellent condition for a relatively small expenditure, and the maintenance costs should be as low as that of any public highway within the province. No expensive or large bridges are necessary and the average grade is not any larger than that of almost any highway on the plains. The highest point on this part of the proposed highway is about 3,850 feet, near the headwaters of Prairie creek. It crosses Prairie creek at about 3,350 feet in section 31, township 50, range 25, about 8 miles east of the highest point, which indicates a very favourable grade. The grade west from the highest point at the headwaters of Prairie creek to the Athabaska valley is about the same as that to the east. Plate 3,A shows the pack train on Jasper Highway at the north end of Folding Mountain.

Culture.—Coal mining is the chief industry carried on at several places indicated on the map. The Burnt Mountain Lumber Company operates a small mill at Mercoal and obtains its raw material from the adjacent territory. The McPherson and Quigley Lumber

3Map No. 6, Rept. No. 10, Sci. and Ind. Res. Council of Alta., Edmonton, 1924.
4Rept. No. 9 (Map No. 5).

Company carry on lumbering operations on McLeod river just east of the area mapped geologically. The location of the sawmill is shown in township 51, range 22. This plant is connected with the main line of the Canadian National Railway by an eleven mile spur line from Hargwen station in township 52, range 22.

There are no towns or settlements within the area other than those built up around the mines. A large strip of country extending from Bliss station up Prairie creek to the Jasper Park boundary is suitable for ranching purposes. Most of this parcel of land is owned or leased by Mr. F. Seabolt, who operates a ranch just at the boundary of Jasper Park on the proposed Jasper Highway.

Mention should be made of the abandoned portion of the railway, formerly known as the Grand Trunk Pacific, which is shown at the northern end of the map. This was abandoned during the war when there was a consolidation of western routes to the Pacific. Most of the abandoned grade is much better than the one at present in use by the Canadian National Railway. The old grade follows a less sinuous course and with much less adverse grade than that of the Canadian National. Starting from Obed (elevation 3,562 feet), in township 53, range 22, the present Canadian National line drops all the way to the crossing of Prairie creek (elevation 3,173 feet), then rises to cross the Athabaska (elevation 3,216 feet), and continues to rise up to Brule lake. The Grand Trunk grade, starting at Obed (elevation 3,560 feet), crosses Prairie creek at an elevation of 3,272 feet, or 99 feet higher than the Canadian National grade. It then rises to Brule lake, and at the south end of the lake the two grades are at about the same elevation. The chief trouble with the old Grand Trunk Pacific grade is along the east shore of Brule lake where the grade cuts through the old lake deposits of sand. (Plate VII.) The prevailing easterly winds through the Athabaska gap in the front ranges blow this sand across the grade and during the time the railroad was in operation it was difficult to keep the track clear.

The best route to have followed appears to be the one selected many years ago by the Canadian Pacific Railway,[5] which was to follow approximately the route later chosen for the Grand Trunk Pacific railway to the north end of Brule lake and then to cross Athabaska river to the approximate position of the present Canadian National railway grade. The remarkable state of repair of the Grand Trunk grade, after seven years of abandonment, shows it to be well selected.

Field Work and Preparation of Map.—This report is based on information obtained in the field between May 28th and September 13th, 1924. The country was traversed by means of pack horses. Leonard Telfer, a graduate in Mining Geology, rendered efficient service as assistant and draftsman. Geo. C. Haworth, assisted by H. Scott, had charge of the pack train and cooking, and gave very capable and satisfactory service.

[5] Geol. Surv. Can., Ann. Rept. 1898, Vol. XI, map accompanying Pt. D.

During the close of the season Dr. J. A. Allan spent some time in the field assisting the writer in checking up some of the summer's work.

Most of the geological information was obtained by traversing the major stream channels and their larger tributaries where continuous exposures are more abundant. Considerable time, however, was spent on traversing the inter-stream uplands, in order to sketch a lot of country that is, as yet, unsurveyed.

The abnormally wet season of 1924 in the foothills belt curtailed these activities of the party to a considerable degree.

Precipitation at	*Coalspur*[6]	*Luscar*[7]
For year 1924	27.91 inches	40.85 inches
For June, July and August.....	8.91 inches	14.95 inches

The base for the accompanying map has been compiled from several sources and an attempt has been made to incorporate all available correct data. A part of this area has been mapped topographically, namely, the Cadomin sheet,[8] which covers an area 15 minutes square, lying between 53 degrees and 53 degrees 15 minutes, north latitude, and between 117 degrees 15 minutes and 117 degrees 30 minutes, west longitude.

The topography has been traced from the Cadomin sheet for the area that it covers on the accompanying map. One appreciable change has been made in the position of Berrys creek in township 47, range 24. This is shown on the Cadomin sheet, as entering Gregg river about a mile further downstream than is actually the case. A survey in 1923 of part of township 47, range 24, by the Topographical Survey of Canada, also substantiates this change.

While many of the smaller creeks and hills are inaccurately mapped on the Cadomin sheet it is a very valuable asset to those working in this area, which is heavily wooded in many places, and where one frequently has great difficulty in determining his location. A land survey has been made of some parts of the area by the Dominion Land Survey Branch. These surveyed areas are indicated on the map. Railway surveys at the north and south ends of the area also furnished further geographical data.

Considerable of the above mentioned data have been compiled by the Forestry Branch and issued as whiteprint maps of the forest reserves, scale one inch to three miles. These maps show the approximate position of the major streams and trails in the unsurveyed areas. There are many townships, however, within this map-area in which no government surveying of any kind has been done, and which contain reasonably large streams not shown on any map. While in the field an attempt was made to sketch in the drainage system and general topography within these unsurveyed

[6]Data kindly supplied by Mr. D. M. MacKenzie, Forestry Supervisor at Coalspur.
[7]Data kindly supplied by Mr. W. B. Hetherington, Manager, Luscar Collieries.
[8]Geol. Survey Can., Publication No. 1993 (1924).

areas. *It must be emphasized that the positions of these streams are only approximate, as well as the elevation of the ridges and uplands, since the only control used was compass and barometer.* This emphasis seems necessary since prospectors and others, looking for coal, have, in other areas mapped by the writer, depended too largely on the map in unsurveyed areas and staked claims accordingly. Those staking claims must bear in mind that in order to insure accuracy of position they should survey the claim and tie it on to some point already accurately located.

The data secured from all the above mentioned sources have been plotted on a scale of one inch to the mile and reduced to one inch to two miles for publication purposes. In view of the fact that the information compiled on the accompanying map is from several sources, it follows that the geographical precision is not uniform for the whole map. Several of the more pronounced streams, not indicated on any map, have been given names that seem appropriate to the writer. These names cannot be accepted as final unless at some future date they are all, or in part, adopted by the Geographic Board of Canada.

There has been duplication of geological surveying in that part of the Cadomin sheet shown on the map accompanying this report. This is due to the fact that the Federal Geological Survey were doing the Cadomin sheet and the Provincial Geological Survey were continuing the mapping of the foothills belt between the North Saskatchewan and Athabaska rivers.

Previous Work.—In 1898 McEvoy[9] made a reconnaissance survey of the "Yellowhead Pass Route". This was considerably previous to the opening up of the country by railroads, and his descriptions of the geography of the route travelled are excellent, that is, in so far as it traverses the area discussed in this report, which the author has seen. The geology at various points along the route traversed by McEvoy is discussed in some detail. Further reference will be made to his work in various chapters of the report.

Previous to the construction of the branch lines of the railway into Coalspur and Cadomin districts, Dowling[10] made traverses over the southern portion of this area, and reported on the general characteristics of the coal field south of the Grand Trunk Railway (now part of the Canadian National Railway). He revisited this portion of the area in 1922, and reported[11] some further observations on the general structure and coal seams.

In 1916 J. S. Stewart[12] visited some of the mines in the southern part of this area and made a brief report on the structure of the rocks in the vicinity of Coalspur.

9McEvoy, J., Geol. Surv. Can. Ann. Rept., 1898, Part D., p. 1-44.
10Dowling, D. B., Geol. Surv. Can., Sum. Rept., 1909, p. 139.
11Geol. Surv. Can. Sum. Rept. 1922, Pt. B, p. 102.
12Geol. Surv. Can. Sum. Rept., 1916, p. 94.

Dowling also did considerable early geological work in areas[13] adjacent to and overlapping the northwest portion of this map-area. Further reference to these reports is made in several places in this report.

The areas extending northwest from Athabaska river and Brule lake have been examined and reported on by J. MacVicar.[14] This area and an adjacent district have been further described in a more recent report.[15] There is considerable similarity in the geology of the area reported on by MacVicar with that discussed in this report.

In addition to this previous work the Geological Survey of Canada had a party under Dr. B. R. McKay, mapping the geology on the Cadomin sheet during the field season of 1924. The results of this work have not yet been published.

A large part of the area here mapped had not yet been traversed by government parties prior to 1924, and the reports referred to above deal more with areas that border or somewhat overlap it.

Acknowledgements.—The writer wishes to acknowledge the many assistances and favours given the party during the summer season by various persons. The managers and other officials of the mines at Cadomin, Luscar and Mercoal willingly assisted with information and private maps of their properties.

Considerable information regarding the trails throughout the area, map information, and storage privileges were given by the Forestry officials. In this connection thanks are due to Mr. D. M. MacKenzie, forest supervisor at Coalspur, Mr. Chas. White of the same station, and Mr. T. C. Burrows, forest supervisor at Entrance. The various forest rangers and park wardens with whom the writer came in contact rendered assistance whenever possible.

The writer wishes also to express appreciation for the co-operation and willing exchange of ideas regarding the geology of a part of the area from Dr. B. R. McKay and his associate, Dr. P. S. Warren, who were doing the geology of the Cadomin sheet area for the federal government during the past field season.

In the preparation of the accompanying map the writer has had the co-operation of Dr. J. A. Allan, who has also given considerable of his time to revision of the manuscript for this report. Dr. P. S. Warren has kindly identified the fossils collected by the writer during the summer, and the results of his examinations are included in this report.

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13 "Coal Fields of Jasper Park," Geol. Surv. Can., Sum. Rept., 1910, p. 150; "Geology of Roche Miette Map Area," Geol. Surv. Can., Sum. Rept., 1911, p. 201.

14 "Foothill Coal Areas North of the Grand Trunk Pacific Railway, Alta.", Geol. Surv. Can., Sum. Rept., 1916, p. 85.

15 Geol. Surv. Can., Sum. Rept. 1923, Pt. B, p. 21.

CHAPTER II.

GENERAL GEOLOGY.

An outline of the geological succession is given here as a basis for the following discussion on structure and physiography.

Rocks of Mesozoic age, belonging chiefly to the Cretaceous, occupy the area discussed in the report. Paleozoic rocks border this area on the west, but these have not received any special attention by the writer. Beds of Jurassic age outcrop in a few places, but do not occupy a very large portion of the map-area.

The Cretaceous rocks are represented by three groups. This division is based primarily on lithological differences. The lowest group consists of sandstones, shales, conglomerates, and coal seams. These are of continental or fresh water deposition. These are overlain by a group of strata that are largely dark shales of marine deposition. The uppermost group consists of a series of sandstones, shales, conglomerates, and coal seams of continental deposition representing a return to conditions very similar to those that prevailed during the deposition of the lower Cretaceous group.

A correlation table of formations in the foothills belt of Alberta is given below:

CORRELATION TABLE OF FORMATIONS IN THE FOOTHILLS BELT, ALBERTA

		Group	McLeod to Athabaska rivers; foothills belt	1 Smoky, Hay, and Berland rivers	2 Bighorn Coal Basin	3 Moose Mountain	4 S. W. Alberta	5 Highwood Coal Area	6 Crowsnest Coal Field
CENOZOIC	Quaternary		Fluviatile and glacial	Recent and Pleistocene	River drift Glacial drift		Alluvium and glacial drift	Superficial deposits	Superficial deposits
	Tertiary						Porcupine Hills fmt. Willow Creek fmt.		
MESOZOIC	Cretaceous	Montana	Saunders fmt.	Upper sandstone and shale	Brazeau ss.	Edmonton fmt. Bearpaw shales Belly River beds	St. Mary River fmt. Bearpaw fmt. Belly River fmt.	St. Mary River fmt. (?) Allison fmt.	Allison fmt.
		Colorado	Wapiabi fmt. Bighorn fmt. Blackstone fmt.	Berland shale	Wapiabi sh. Bighorn ss. Blackstone sh.	Claggett shales Niobrara-Benton	Benton fmt.	Benton fmt.	Benton fmt. Crowsnest volcanics
				Sunset sandstone	Dakota ss. and sh.	Dakota beds	Blairmore fmt. (Dakota)	Blairmore fmt.	Blairmore fmt.
		Kootenay	Kootenay	Kootenay fmt.	Kootenay	Kootenay fmt.	Kootenay fmt.	Kootenay fmt.	Kootenay fmt.
	Jurassic	Jurassic	Fernie fmt.		Fernie sh.	Fernie sh.		Fernie fmt.	Fernie fmt.
	Triassic				Upper Banff sh.			Upper Banff fmt.	
PALEOZOIC			Not subdivided.						

1. MacVicar, J., Geol. Surv. Can., Sum. Rept., 1923, Pt. B, p. 21.
2. Malloch, G. S., Geol. Surv. Can., Mem. 9E, 1911.
3. Cairns, D. D., Geol. Surv. Can., Mem. 61, 1914
4. Stewart, J. S., Geol. Surv. Can., Mem. 112, 1919.
6. Rose, B., Geol. Surv. Can., Sum. Rept., 1916, p. 108.
5. Rose, B., Geol. Surv. Can., Sum. Rept., 1919, Pt. C, p. 15c.

Since there is no well defined break in the lowest division of the Cretaceous it has all been mapped together as Kootenay. While there is some lithological difference between the lower and upper beds of this lower Cretaceous series of continental deposits there is no boundary between these types of sediments that can be traced regionally even through this map area, and such changes that did occur during the deposition of this series were gradational. A fuller discussion of these relations is given in a later chapter.

The Colorado marine strata overlying the lower non-marine series were divided by Malloch[16] in the Bighorn area into the Blackstone shales, Bighorn sandstones, and Wapiabi shales. Malloch's division has been adopted for this area, although in the mapping all the Colorado group is shown in one colour.

The Bighorn formation is a thin member, and because most of the Colorado strata are soft shales they are concealed, and it is not possible from surface outcrops to map the divisions separately except at local points.

The upper Cretaceous series of continental deposits is mapped as the *Saunders* formation. This name was given to the corresponding series in the areas to the southeast.[17] Similar to the lower Cretaceous series there is a difference in lithological character between the basal and upper strata, but any changes are gradational, so it has all been mapped as one formation. There is, however, a possibility of the youngest beds of this series being younger than Cretaceous age, but definite evidence of this has not yet been obtained.

16Bighorn Coal Basin, Mem. 9E, Geol. Surv. Can., 1911.
17Repts. Nos. 6 and 9.

CHAPTER III.

STRUCTURAL GEOLOGY.

General Statement.—The structural relations in this area are similar to those in the foothills areas to the southeast, described in Reports No. 6 and 9. The rocks have been deformed by mountain building forces and occur as a series of folds and faults with a general trend of north 60 to 70 degrees west.

Characteristic of the foothills belt, increased deformation is shown from east to west across the strike of the formation. On the eastern side of the area relatively open folds prevail, while to the west the folds are more closed and a greater amount of faulting has taken place, which has brought the lower strata to the surface. This increased deformation to the west has raised the Paleozoic beds to the surface, and these form the front ranges of the Rocky Mountain or outliers of Paleozoic rocks as pronounced uplands.

Major Structural Features of the Area.—This map-area is bordered on the west mostly by Paleozoic rocks which have a very irregular eastern boundary. This irregular boundary is due largely to different structural relations prevailing at different points along the eastern front of the Paleozoic rocks. The southwestern contact with the Paleozoics is a well defined thrust fault, showing the Paleozoic rocks thrust from the southwest on to Colorado rocks, as exposed at the headwaters of Pembina River in township 46, range 21, and on MacKenzie creek, in township 46, range 22.

Tracing this boundary northwest to Cadomin the Paleozoics are found to be over-riding the basal Kootenay and Jurassic beds, and still further to the northwest the structural boundary between the Paleozoic and Mesozoic rocks is more difficult to locate. In general the boundary is a thrust faulting, but this fault is associated with considerable folding, and the breaks lie more within the Paleozoic rocks causing the Paleozoics to be thrust over Lower Cretaceous, Jurassic and at some places the Triassic. These conditions prevail at the head of Gregg river, Berrys creek and Drinnan creek.

At the northwest end of this structure line, geological relations are considerably different from those existing to the southeast, due to the forces which formed a fold of Paleozoic rock underlying Folding mountain east of the front range. (Plate IIIA.) This fold carried up with it Triassic, Jurassic and Cretaceous rocks, and formed a somewhat detached outlier from the main range to the west. (Plate II.) Thus the structural relations between Cadomin and the Athabaska are represented in general by a thrust fault at Cadomin, passing into less pronounced faults and into folds at the northwest end.

In mapping, the Triassic and Paleozoic rocks have been shown by one colour along the southwest boundary. These form the Nikanassin range which is in reality a spur or branch from the main range to the west. Nikanassin range terminates to the southeast before reaching Cardinal[18] river, in township 45, range 21.

Cretaceous beds extend northwest along the south side of the Nikanassin range, and Mountain Park is situated on this belt of Cretaceous rocks. The Nikanassin range joins the main range northwest of Cadomin and at the junction of these two ranges the eastern boundary exhibits the very irregular structural relations that are present in township 48, range 25 and 26. The northern end of the range at the Athabaska valley is known as Fiddle range.

In discussing the structure within this map-area an attempt has been made to select and describe the major structural features that have significance with respect to an appreciable part of the area. Most of the exposures from which information can be obtained occur along the major stream channels, while in the inter-stream areas the rocks are largely concealed by vegetation or recent deposits from erosion. For this reason it is impossible to trace minor structures for any appreciable distance from the stream exposures.

The structure is described from northeast to southwest across the strike of the formations.

Along the northeast side of the area the beds have a dip to the northeast. This dip decreases to the east and the beds are flat-lying a few miles northeast of the boundary of this map. These northeast dipping beds form the east limb of a faulted anticline. This fault was named the "Lovett" fault in Report No. 9, and was traced from the Blackstone river in township 43, range 16, northwest to the vicinity of Coalspur. This break crosses the railway in section 3, township 49, range 21, and from the dips in separated outcrops of strata it can be traced northwest for about seven miles. Northwest of this the beds are too much concealed to follow any major structural lines until McLeod and Gregg rivers are reached. On Gregg river there is a well defined break about a mile above its confluence with McLeod river. Since all the beds to the northeast of this break have a northeast dip, this is believed to represent the major break to the southeast.

On the Athabaska there is a well defined break occurring in section 8 and 9, township 51, range 25. This is believed to be the northwest continuation of the fault described above, although it cannot be traced definitely through the area between the McLeod and Athabaska rivers, other than by the dips of the beds on either side of the position of the fault line as indicated on the map.

There appears to be much more relative displacement of the beds at the north end of this break on Athabaska river than is apparent near Coalspur. At the Athabaska basal Saunders beds occur on the west side, whereas Saunders beds at least 3,000 feet above the base lie on the east side of the fault. From the ex-

18This stream is more commonly known as the North Brazeau River.

posures near Coalspur the displacement appears to be less since the beds on the west side of the break are younger than those at Athabaska river on the same side.

In 1923 a well defined break termed the "Chungo" fault (Map No. 5, Rept. No. 9) was traced from Blackstone river northwest to where it crossed Pembina river in township 46, range 20. This fault has expression to the northwest of Pembina river as an anticline through township 47, range 21, and as a monocline to the northwest of this across McLeod and Gregg rivers.

On Pembina river this fault separates Colorado beds on the west from Saunders on the east, but in rising out of the valley of the Pembina to the northwest, Saunders beds occur on both sides of this break, and the displacement apparently has decreased to such a point that the fault becomes the axis of an anticline. This anticlinal structure is well defined to the east of the Forestry cabin on Beaverdam creek, in township 47, range 21. At McLeod river only the east limb shows beds dipping to the northeast, while those of the western limb to the south are flat-lying. Apparently this structural features causes McLeod river to change its course in township 48, range 22, from a northeasterly to a northwesterly direction.

This monoclinal structure is also exposed on McLeod river in the northeast quarter of section 5, township 49, range 23, where the beds show a sharp change in dip. Those to the east of the axis dip steeply to the northeast (85 degrees), while those to the west dip more gently (15 degrees) to the northeast. The break here has not the significance of a fault or anticlinal axis, but only a point where the dip changes rapidly. The same structural relations occur on Gregg river about four miles to the northwest in sections 22 and 23, township 49, range 24. This structural feature could not be traced to the northwest beyond the Gregg river, as rock exposures are few, and apparently it does not express itself in the physiography. From Pembina river northwest this structural feature is represented by a fault passing into an anticline, then to a monocline, and finally disappearing northwest of Gregg river.

Between this structural line and the fault to the east the area is underlain by Saunders bed with synclinal structure.

On Gregg river, in section 16, township 49, range 24, another fault occurs that is locally of special significance, since the displacement has been sufficient to bring Colorado beds to the surface on the west side of the break. This is the most easterly exposure of Colorado beds in the area, considering the strike of the formations. This structure appears to be a broken anticline and does not extend southeast to McLeod river. The only evidence of it to the southeast is seen in the anticlinal structure of lower Saunders beds on Antler creek in section 5, township 49, range 23. Northwest of Gregg river it cannot be traced beyond Teepee creek in section 20, township 49, range 24, and this does not have a regional significance in this map-area.

The next major break to the west is mapped as separating Saunders and Colorado beds on McLeod and Gregg rivers and separating two belts of Saunders strata north of Gregg river towards the Athabaska. On Pembina river to the southeast it is hard to place this fault at any precise point since it passes through Colorado shales, which do not, as a rule, show well defined breaks, but show instead a series of minor folds and faults.

This fault crosses McLeod river in the southwest quarter of section 29, township 47, range 23. In the work of 1923 (Map No. 5) this fault was shown to the east of its present position or on the eastern side of the small outcrop of Colorado beds as shown on Map No. 7. In the work of 1924 it was found that this outcrop of Colorado beds in section 29 is due to the fact that basal Saunders beds form a sharp anticline east of the fault, and some of the uppermost Colorado beds in the centre of this anticline have been exposed in the channels of McLeod river and MacKenzie creek.

On Mary Gregg creek, in township 48, range 23, and on Gregg river in section 6, township 49, range 24, the exact position of the fault is concealed, but from the attitude of the beds the approximate position has been mapped. Similarly to the northwest the dip of the beds on branches of Prairie creek in township 50, range 26, indicates that a fault must pass through the area to Athabaska river, approximately as mapped.

The beds lying to the east of the fault in the southeastern part of the area form a syncline, the eastern limb being defined by the anticlinal axis east of Beaverdam creek. This syncline is very broad to the northwest, and on McLeod river only the western limb is well defined.

In the area between McLeod and Gregg rivers the beds adjacent to the east side of the fault dip to the northeast but flatten out to the east and are flat-lying on McLeod river in section 3, township 48, range 22, and section 34, township 47, range 22, on Mary Gregg creek about a mile up from the mouth, and on Gregg river in section 8, township 49, range 24. On Athabaska river and Prairie creek, Saunders beds as a broad syncline occupy the entire area from this fault east to the first fault described above. This syncline is assymetrical, having a more steeply dipping east limb.

West of this last described fault a belt of Colorado beds extends from the Pembina northwest across McLeod and Gregg rivers. There are many faults and folds within these beds, but such cannot be traced regionally in soft shales. These Colorado beds grade into Saunders on the west side and dip to the southwest, forming the eastern limb of a syncline of Saunders beds. This syncline extends all the way from the Pembina to the Athabaska. North of Gregg river it is separated from the Saunders to the east by the fault described above.

On Prairie creek in township 50, range 26, the western limb of this syncline is pronounced, but the eastern limb is not well defined in the hills. However, the exposures in some of the branch creeks show the presence of an eastern limb.

On Drinnan creek in township 48, range 25, this syncline is almost symmetrical and has gradational contacts with the Colorado beds on both sides.

On McLeod river the east limb of this syncline dips steeply (70 degrees) to the southwest, and the west limb is overturned about 15 degrees and dips 85 degrees also to the southwest. (Plate V,A.) Similar relations exist on MacKenzie creek. On Pembina river the west limb shows faulted relations with the Colorado beds, while the east limb has about the same dip as it has on McLeod river.

This syncline of Saunders beds is known to extend south of the Pembina for a considerable distance (see Map No. 5) across Blackstone river into township 41, range 17. It appears to be narrowest where it crosses Pembina river.

The above syncline of Saunders is bordered to the west by a belt of Colorado beds that extends from Pembina river across the map area to the Athabaska. Undoubtedly there are many faults and folds within these beds of shale, but these cannot be traced for any appreciable distance beyond the exposures in stream valleys. This belt of Colorado is bordered on the west by a fault that separates it from Kootenay beds. This fault extends from near McLeod river in sections 17 and 18, township 47, range 23, northwest to the headwaters of Prairie creek and probably through beneath Brule lake. The heavy cover of lake deposits render it impossible to locate its position north of Prairie creek.

In the vicinity of Cadomin, the Colorado and Kootenay strata are separated by another fault. This extends northwest into Kootenay beds and to the southeast is either cut off by the thrust fault along the front of Nikanassin range or runs into the Colorado beds. A large syncline of Colorado beds lies to the northeast of this fault, and the basin of this syncline is occupied by Saunders beds, as shown on MacKenzie creek in township 46, range 22.

The above described structure with the break along the eastern front of the Paleozoic ranges constitute the major structural features of this area.

Since the Cretaceous rocks have been rather intensely deformed in the western part of the area, there are undoubtedly numerous other faults and folds not described above. This is especially the condition present in the beds adjacent to Nikanassin range, and the belt of Kootenay rocks extending from southeast of Cadomin, northwest to Prairie creek, shows many minor folds and faults.

The belt of Colorado beds lying east of the Kootenay and extending all the way across the map-area has taken up a lot of the deformation which has resulted in many minor folds with some faults. The soft shales which predominate in this formation are more subject to folding than faulting. East of this belt of Colorado rocks the structure is more regular and continuous, so that folds and faults have a more regional significance.

Structure Along the Major Streams.—Since the best exposures are found along the major stream channels a description of the structure along these will be most valuable to those working in the area.

The structure along Pembina river at the southern boundary of this map-area was described in Report No. 9, page 15, and will not be repeated here.

McLeod river from the gap through Nikanassin range, near Cadomin, to the mouth of Beaverdam creek in section 11, township 48, range 22, flows approximately across the strike of the formations. Its main tributary in this part of the area is MacKenzie creek, which also has a course across the strike, and exposes the structure quite distinctly.

Beaverdam creek is flowing subsequent to the structure in township 47, range 21, and the valley of the stream lies in a syncline of Saunders beds. The sinuous course it follows in townships 47 and 48, range 22, shows exposures of flat-lying beds along its channel.

The main branch of MacKenzie creek cuts through Nikanassin range in the southwest part of township 46, range 22, and shows Paleozoic rocks overthrust on to lower Colorado shales or Blackstone formation. About a mile to the northeast down MacKenzie creek the Bighorn formation of the Colorado is perpendicular. About two miles to the southeast from this point along the strike of the strata the Bighorn beds are overturned and over-ridden by the limestones of Nikanassin range. To the northwest of MacKenzie creek the Bighorn has a steep dip to the northeast, which decreases to about 20 degrees in section 3, township 47, range 23. The low ridge in the left of Plate III,A, facing Nikanassin range, is underlain by these Bighorn beds.

Wapiabi shales of the Colorado group lie east of the Bighorn formation and show a rapid decrease in dip to about 25 degrees northeast, at the contact with the Saunders. Saunders beds continue downstream with decreasing dip until the axis of the syncline is reached. Here the creek turns northwest and almost parallels the strike for about a mile northeast of the axis of the syncline. Saunders beds dip to the southwest with increasing dip down through the section and Wapiabi shales occur in regular succession with a dip to the southwest. The Bighorn formation outcrops again on the creek near the north boundary of township 46, range 22, and conforms in dip with the Wapiabi beds to the southwest. Thus the strata between the two outcrops of the Bighorn formation mentioned above form a well defined syncline with Saunders beds lying in the basin. This syncline of Saunders extends to the northwest almost to the east boundary of the Cadomin sheet, and forms the capping of a hill with an altitude of 6,000 feet. This hill is about three miles southeast from Leyland station. These Saunders beds also extend to the valley of Pembina river with the same synclinal relations.

Continuing down MacKenzie creek the Blackstone shales of the Colorado group are exposed to the east of the Bighorn formation. These conform in dip to the Bighorn beds for a short distance to the northeast, but beyond this they are folded and faulted, allowing Wapiabi shales to be brought to the surface again in sections 4 and 5, township 47, range 22. Approximately in the northeast quarter of section 5, Wapiabi shales are overturned and, dipping 80 degrees to the southwest, grade into the Saunders strata, which are also overturned, and form the west limb of an assymetrical syncline. The axis of this syncline crosses MacKenzie creek in section 9, township 47, range 22. The east limb has an average dip of about 50 degrees to the southwest, and is composed of Saunders beds, Wapiabi shales, Bighorn strata and a part of the Blackstone shales. The contact of Wapiabi and Saunders strata occurs in the northeast quarter of section 17, township 47, range 22, where the beds dip 55 degrees to the southwest. Eastwards to the Bighorn beds in section 20 the succession is regular with an increase in dip to 60 degrees southwest. Blackstone shales to the east are folded and faulted similar to the exposures of the same formations occurring further up stream, and the Saunders beds have a fault contact with them in the northeast quarter of section 20, township 47, range 22. These Saunders beds dip 85 degrees to the southwest and represent the west limb of a sharp anticline. The east limb dips steeply to the northeast, and since basal Saunders beds form this anticline, the uppermost beds of the Wapiabi formation are exposed on MacKenzie creek in the centre of this anticline. The dip of the beds of the east limb decreases rapidly to the east as shown in the exposure at the mouth of MacKenzie creek.

McLeod river in the southwest part of township 47, range 23, exposes a different structure from that at the corresponding strike positions on MacKenzie creek.

In section 31, township 46, range 23, the Paleozoic strata are overthrust on to overturned Jurassic[19] and Kootenay rocks, which dip about 40 degrees to the southwest. No general structure can be stated for the Kootenay rocks exposed along the McLeod to the south or north of Cadomin station. They show several close folds, and at Cadomin Collieries are on the average overturned and steeply dipping to the southwest.

The contact of the Kootenay with the Colorado shales is mapped as a fault passing through the centre of section 5, township 47, range 23. While it would not be necessary to have a fault contact at this position since the stratigraphic sequence could give the formational relations as mapped, the attitude of the Kootenay beds at the contact is quite different on the two sides of McLeod river, and also different from that of the Blackstone strata to the north. Blackstone shales extend from this contact downstream to the mouth of Luscar creek in section 16. These beds are much folded and faulted, being soft black shales, thus no general structure can be ascribed to them.

19The lowest Mesozoic rocks exposed on the west side of McLeod river gap through Nikanassin range have a lithological appearance similar to the Fernie shales. Since no fossils were found in these beds some doubt remains as to whether they are Fernie shales or basal Kootenay beds, although they have been mapped as Fernie.

At the mouth of Luscar creek the Bighorn formation crosses the river and dips about 60 degrees to the northeast. Folding and faulting caused this formation to be repeated three times in less than half a mile of exposures below the mouth of Luscar creek. These deformed Bighorn strata form the ridge along the north side of Luscar creek and cap the 6,200-foot hill about a mile northwest of Luscar. Wapiabi shales, much folded and broken, occur to the northeast of the Bighorn strata on McLeod river. In the southwest quarter of section 22, township 47, range 23, they are overturned and dip about 80 degrees to the southwest. These grade into the Saunders beds, which are similarly overturned, the contact occurring in L.S. 6, section 22, just west of a restricted part of the river channel, known locally as "Hell's Gate". Plate IV,B and V,A.)

From this contact eastwards the structure is practically the same as that exposed at the corresponding strike position on MacKenzie creek, being an assymetrical syncline of Saunders beds with an overturned west limb. The eastern limb shows dips to the southwest of about 45 degrees near the axis and increases to 70 degrees in the southeast quarter of section 25, where Saunders strata grade into Wapiabi shales in regular stratigraphic succession. The section downstream from this contact is regular showing the Wapiabi and Bighorn formations dipping to the southwest. Beds of the Blackstone formation occur to the east, but these are folded into many minor structures. The fault contact with the Saunders is exposed in L.S. 1, section 30, township 47, range 22, near the railway crossing of McLeod river. A sharp anticline of basal Saunders beds with the upper Wapiabi beds in the centre is exposed east of this fault and above the mouth of MacKenzie creek. Downstream from the mouth of MacKenzie creek the Saunders beds flatten rapidly and remain so to the mouth of Beaverdam creek. Here the dip changes rapidly to 75 degrees to the northeast, as shown by the exposures in the southeast quarter of section 14, township 48, range 22.

Continuing the section northeast across the strike of the formations from the big bend in the McLeod, the Saunders beds form a syncline with the west limb as described above and the east limb well defined at Coalspur. The beds of the west limb flatten out rapidly to the northeast from a 75 degree dip in section 14 to 34 degrees dip at Mercoal and to flat-lying strata in section 30, township 48, range 21, where the axis of the syncline occurs. From the axis eastwards the dip to the southwest increases gradually and at Coalspur is 55 degrees. This east limb of the syncline is also the west limb of a broken syncline, which has its axis east of Coalspur in the southwest quarter of section 3, township 49, range 21. Eastwards from this axis the Saunders beds flatten out. At the Balkan mine in section 14, the dip is 38 degrees to the northeast, and in section 36, township 49, range 21, the beds are flatlying.

McLeod river from the big bend to the northwest in township 48, range 22, follows in general strike of the formation through township 48, ranges 22 and 23. In township 48, range 23, the beds have a low angle dip seldom greater than 10 degrees.

The varying strike as shown at the mouth of Mary Gregg creek in township 48, range 23, and on the lower part of Antler creek in township 49, range 23, represents the southern termination of the broken anticline, which is well defined to the northwest on Gregg river.

Where McLeod river turns to the northeast in township 49, range 23, it again crosses the strike of the strata. In the northeast quarter of section 5, township 49, range 23, the Saunders beds show a sharp change in dip from 15 degrees to 85 degrees to the northeast. This structure is similar to that at the big bend of the river in township 48, range 22.

Through sections 8 and 17, the dip decreases, and in the northwest quarter of section 17 the coal seams mined at Mercoal outcrop with associated sediments showing a dip of 60 degrees to the northeast. The dip continues to decrease eastwards and in the northeast quarter of section 20 and in section 28, they are flat-lying except for a few small open folds. The exposures on the McLeod from section 20, to the mouth of Gregg river are very discontinuous. The position of the fault shown to cross this stream was interpolated from the exposures on Gregg river about a mile to the northwest.

East from the position of the fault the beds dip to the northeast from 20 to 25 degrees. East from the mouth of Gregg river the dip decreases and they are flat-lying in township 51, range 22.

Gregg river and its main tributaries have in general a direction across the strike of the strata and a good section is exposed throughout most of its course. Unfortunately the headwaters of this stream do not expose much of the Kootenay rocks where the structure is important. From exposures that do occur on the head of Gregg river in township 47, range 24, the Kootenay beds appear to form an assymmetrical syncline with the west limb overturned and in some places showing Jurassic beds on the southwest between the Kootenay and the limestone strata of the ranges.

The assymmetrical syncline has numerous minor folds and faults within it, especially on the western limb. The northeast limb is also considerably broken and folded, as shown by exposures of the Kootenay strata that occur along Gregg river at the forks in the northwest quarter of section 27, township 47, range 24, and downstream from this point. At this locality the Kooteany conglomerate bed near the base of the formation dips 50 degrees southwest and forms a part of the east limb of the syncline referred to above. Gregg river here turns to the northwest and follows along the strike for about two miles, cutting through Kootenay beds. In the northeast quarter of section 32, it turns south across the conglomerate, then in a short distance recrosses it again and flows, in general, northwards. At these points the conglomerate dips 35 degrees to the southwest as part of the east limb of the syncline.

Kootenay beds closely folded into many minor folds and faulted at several points occur downstream into the northwest quarter of section 5, township 48, range 24. As a result of this close folding and faulting the conglomerate with associated sandstones caps the 5,700-foot ridge that parallels the river on the northeast, in section 33, township 47, and section 4, township 48.

In the northwest quarter of section 5, township 48, range 24, Kootenay beds grade into the Colorado shales, and the beds are practically vertical. This has been mapped as a fault contact since the relations in almost all other parts of the area are faulted, and this gradational relation only appears to be a local condition.

Continuing downstream from this contact a part of the Blackstone formation, the Bighorn formation, and the Wapiabi shales are exposed in regular succession. These also are standing almost vertical. The Wapiabi shales show a small amount of duplication through minor folding. These grade into the Saunders formation, dipping 85 degrees to the northeast in the northeast quarter of section 7, township 48, range 24. From this contact northeast Saunders beds as a syncline occupy the area as far as the north half of section 31, township 48, range 24.

The beds of the west limb of this syncline of Saunders show an abrupt change in the dip to the northeast from 70 degrees to 18 degrees in L.S. 1, section 18. This change occurs in a distance of less than 500 feet across the strike of the strata. From this point northwards the beds flatten out and the base of the syncline, which is broad, lies about the centre of section 19.

Continuing northwards the east limb of the structure shows increasing dips downstream and reaches a maximum dip of about 30 degrees to the southwest in section 31.

The Colorado beds shown to cross the Gregg river in section 6, township 49, range 24, are not exposed in this stream valley, but from the exposures on Mary Gregg and Trapper creeks, and the lithology of the Saunders beds exposed in section 31, township 48, range 24, the Colorado beds undoubtedly cross Gregg river approximately in the position mapped, although the structure within these beds could not be determined.

Basal Saunders beds outcrop again in the northeast quarter of section 6, township 49, range 24, and are vertical. For a mile to the northeast the dip is irregular and a fault occurs in the southwest quarter of section 8, township 49, range 24. East of this fault the Saunders beds are flat-lying except right at the fault, where they show a sharp upturn with a dip to the northeast. These flat-lying beds extend downstream through section 8. In section 17 and the west half of section 16 they have a southwest dip of 45 degrees and form the west limb of a faulted anticline which exposes Wapiabi shales in the north half of section 16. These shales are not exposed on McLeod river to the southeast since the break does not extend that far. This broken anticline is represented by low dips in basal Saunders beds on Antler creek in section 5, township 49, range 23.

Saunders beds with a northeast dip of 55 degrees form the east limb of this structure exposed in section 15, while in the west half of section 23 they show an increase in dip to 85 degrees. This corresponds to the same change that occurs on the McLeod in section 5, township 45, range 23, and represents the northwest continuation of the monoclinal axis.

East from the axis the dip decreases gradually and is 70 degrees to the northeast in section 23, at the mouth of Teepee creek where coal seams are exposed. The dip continues to decrease eastwards, and the beds are flat-lying in sections 29 and 30, township 49, range 23. These flat-lying beds form the base of the syncline as indicated on the map by the synclinal axis. A few small open folds are exposed in the southwest quarter of section 33. Approximately a mile above the mouth of Gregg river the fault as mapped crosses the stream. The beds on the west side are not exposed, but those on the east side are almost vertical. From this point to the confluence with McLeod river the dip to the northeast decreases to about 25 degrees.

Drinnan creek in township 48, range 25, shows a structure similar to that on the upper part of Gregg river, but the exposures are fewer, and it was not possible to obtain any details on the structure of the Kootenay rocks through which this creek passes. The southern end of Folding mountain terminates at this creek and exposes the Kootenay rocks much folded and faulted. The Kootenay conglomerate and associated hard sandstones form the top of this mountain.

Owing to the presence of a heavy cover of lake and river sands (Plate VII) that have been, to some extent, transported by wind, and now occupy the area along the east shore of Brule lake, it is impossible to ascertain the structure along this part of the Athabaska drainage, but from the exposures at the head of Prairie creek, and around the north end of Folding mountain, the structure has been interpreted as mapped. In projecting the structure north of Prairie creek towards the lake, the geological contacts shown in MacVicar's[20] sketch map of the area northwest of Brule lake, have been used as a guide.

The first exposure on Athabaska river east of Brule lake occurs in section 29, township 50, range 26. Here basal Saunders beds dip about 70 degrees to the northeast, forming the western limb of a very broad syncline of Saunders beds that has its axis in the southwest quarter of section 1, township 51, range 26. West of this syncline of Saunders another belt of Saunders strata with similar structure is believed to extend to the Athabaska since it crosses Prairie creek as a syncline and can be traced northwest to the height of land between Prairie creek and the Athabaska. These two synclines of Saunders are separated by a fault on Prairie creek, and this break extends southeast across the map area.

The broad syncline of Saunders beds on the Athabaska is assymmetrical and has a more steeply dipping east limb. This is

[20]Geol. Surv. Can., Sum. Rept. 1923, Pt. B, p. 21.

shown by the basal Saunders beds exposed on the Athabaska in section 6, township 51, range 25, and at the mouth of Prairie creek, where they dip 80 degrees to the southwest. From the axis of the syncline east through section 1, township 51, range 26, the dip increases gradually to 40 degrees, but an abrupt change to 80 degrees occurs in L.S. 13, section 6, township 51, range 25.

This syncline is separated by a fault from Saunders beds to the east which are higher stratigraphically, and dip from 15 to 20 degrees to the northeast.

The strike of the beds exposed along Athabaska river in township 51, range 26, averages north 80 degrees west. This is about 15 degrees more to the west than the average strike throughout the area.

The structure at the north end of Folding mountain at the head of Prairie and Drystone creeks in township 49, range 26, presents local conditions which are of interest. Folding mountain, as mapped, is a relatively high part of the area capped by Kootenay rocks. (Plate II.) The north end exposes Jurassic and earlier rocks, including Paleozoic limestone and shale. (Plate III,A.) The general structure is anticlinal with a plunge to the south. The north end has been eroded and exposes Paleozoic rocks with anticlinal structure. Erosion by Athabaska river, presumably during development, has truncated a very steep north face on Folding mountain.

The Paleozoic rocks underlying Folding mountain appear to be connected by a synclinal structure with the range to the west of which Roche a Perdrix is a summit point at the Athabaska valley.

Folding mountain does not appear to have a counterpart in strike alignment with it on the northwest side of Brule lake, and since the recent deposits cover practically all the rocks between Folding mountain and Brule lake it is difficult to interpolate the structure for the area lying between Folding mountain and the west side of Brule lake. Dowling,[21] in discussing the coal fields of Jasper Park, makes note of this lack of alignment of structure on the north and south sides of Brule lake. He suggests either a rapid dip northwards of the axis of Folding mountain, or a transverse break across the outer ranges. At that time he thought the latter explanation as most suitable. The field evidence gained on traversing the south and north ends of Folding mountain show definitely that the axis of the anticline dips to the southeast. As for the transverse fault, if such is the case it does not appear to have displaced the Saunders beds exposed on the upper part of Prairie creek, which lie about three miles northeast of Folding mountain. Thick, massive, basal Saunders sandstones and conglomerates continue regularly across Prairie creek towards Athabaska river. Similarly the strata in the vicinity of Entrance, and for three miles west on the Athabaska, are continuous across this river and to the hills both north and south of the valley.

21Geol. Surv. Can., Sum. Rept., 1910, p. 150.

If a traverse fault occurred at Folding mountain, or at the site of the present valley of the Athabaska through the front ranges, its influence was dissipated in the Colorado shales before reaching the Saunders beds to the east. Unless the transverse fault is assumed the only alternative suggestion is that the lack of continuity of the Folding mountain structure with that to the northwest is due to a series of folds and faults of short lateral extent which are not exposed. The steep north face of Folding mountain, while perhaps indicative of a cross faulting, appears to be more of an erosional feature.

A notable feature on Athabaska river is that the structural deformation has not brought Colorado beds to the surface east of range 27. This is especially significant since the valley of the Athabaska is, on the average, 1,000 feet lower than the corresponding strike positions on Gregg or McLeod rivers, yet on Gregg river two belts of Colorado rocks are brought to the surface in township 49, range 24, and one of these is continuous from Gregg river to the southeastern end of the map-area. A possible explanation of this is that, in the vicinity of Brule lake, there has been more overthrusting of Paleozoic strata on to Cretaceous than to the southwest, where Nikanassin range as a spur and Folding mountain have lifted the Cretaceous rocks to relatively higher levels.

The above describes in considerable detail the essential structural features of this map area. Numerous local structures have not been mentioned since their significance is not of particular importance, except in such cases as they affect mining development. Such of these as are locally important are discussed in the chapter on economic geology.

The structure sections accompanying the map (Plate I) have been made across the strike of the formation, and where exposures are absent at points along these structure section lines the structure has been interpolated from the exposures on the nearest stream valleys.

CHAPTER IV.

TOPOGRAPHY.

Physiography.—The area shown on the accompanying map lies in the foothills belt and includes features grading from gentle sloped uplands on the east to mountain ranges on the west. The average strike of the formations is north 60 degrees to 70 degrees west, so that the higher areas resulting from the erosion of folded or faulted beds of unequal hardness form a series of dissected uplands, which, in general, are parallel to the strike of the underlying formations. (Plate VIII,A.) Along the front of Nikanassin range, however, the numerous small headwater streams which flow in general across the strike, have dissected the Cretaceous rocks to such an extent that the remnant hills appear more as spurs projecting out at right angles to the trend of the range. A general physiographic feature of the area is the northern termination of the pronounced strike ridges at the valley of Prairie creek.

The relative elevation of the uplands with respect to stream courses is greater in the western part of the area than in the east, and the stream gradients decrease to the east.

It must be emphasized that, with the exception of the area shown within the boundaries of the Cadomin sheet, *the topography has been sketched* and hence the accuracy attached to such is limited by the absence of control points over a large part of the area sketched.

The physiography is described from northeast to southwest across the area mapped. The most easterly ridge follows along the faulted anticline east of Coalspur. This ridge continues northwest towards McLeod River valley for about nine miles from Coalspur. The crest is poorly defined and broad, with an average elevation of 4,700 feet. The slopes from this ridge are very gentle, and grade off gradually to the surrounding valleys. This ridge does not extend to within six miles of McLeod river, but slopes off from 4,700 feet to 4,000 feet elevation in this distance. This upland is well defined as a strike ridge to the southeast of this map-area, and extends as far south as the Pembina[22] river.

Between McLeod and Athabaska rivers this ridge is represented by high gently sloped areas that rise to an elevation of about 5,000 feet in the northern part of township 50, and in township 51, range 24. These uplands do not form a ridge with a northwest trend, but represent an erosion highland, separating the McLeod and Athabaska drainages.

High-Divide ridge in township 50, ranges 24 and 25, is one of the most pronounced uplands in the northern part of the area. It represents the remnant of an eroded syncline, and has an average elevation of 5,700 feet along the crest. The Forestry branch trail

22Rept. No. 9, p. 17.

from Gregg river to the Athabaska follows along the crest of this ridge for about five miles. This ridge stands out prominently with respect to the surrounding country, from which it is separated by valleys 1,000 feet or more in depth.

High-Divide ridge does not have a corresponding ridge in strike alignment to the south of Gregg river. McLeod river appears to have eroded these corresponding areas to lower levels, so that the area between McLeod river and the railway line to the south in strike alignment with High-Divide ridge, consists of a series of smaller hills and valleys and large areas covered with muskeg.

The northern end of the next well-defined ridge, west of the High-Divide, is in the southwest corner of township 50, range 25. This ridge bifurcates to the southeast, as shown in township 49, range 25. One branch extends in a more easterly direction towards Gregg river, and has a detached portion south of Gregg river, represented by the 5,100-foot hill in the southeastern part of township 49, range 24. The southern part of this branch of the ridge owes its origin, largely, to the underlying faulted anticline structure described in the previous chapter.

The west branch of the main ridge to the northwest takes a more southerly trend and extends into the southeastern corner of township 49, range 25, almost as far as Gregg river. At this locality it, in turn, splits into two parallel ridges which extend southwest across the Cadomin sheet and McLeod river, into the area drained by the headwaters of Beaverdam creek. These parallel ridges have been considerably dissected into rows of parallel hills, by the numerous branches of the McLeod which drain to the northeast. These parallel ridges are the most continuous in the map-area, extending almost across it from the southeast to northwest. West of this the ridges are of shorter length, due largely to more irregular underlying structure.

In the northeast half of township 49, range 26, another well-defined northwest-southeast ridge, with a maximum elevation of 5,800 to 6,000 feet, extends from Prairie creek southeast to Drinnan creek, although it is broken through at places by small transverse streams. This ridge is formed by the northeasterly dipping basal Saunders beds. Plate V,B shows the conglomerate in the lower Saunders beds which forms the crest of this ridge at the north end. This ridge is paralleled on the west by a row of hills averaging 6,000 feet in elevation. These hills represent the dissected remnants of a ridge formed by the steeply dipping Bighorn strata of the Colorado group.

The most pronounced upland in the area, namely, Folding mountain, lies west of this last mentioned row of hills. This mountain rises abruptly at the north end to an elevation of 5,800 feet (Plate III,A), and about two miles southeast another abrupt rise to a 6,900-foot peak forms the highest part of the mountain. (Plate II.) Folding mountain is well defined as a continuous upland as far south as Drinnan creek. The southern end has an elevation of approximately 6,000 feet. The difference of 900 feet in elevation between this end and the peak to the northwest gives the mountain a long gentle slope to the southeast. The east face of Folding mountain is relatively regular, but the west side has been much dissected by the headwaters of Drinnan creek. The north end of the mountain is connected by a high divide to Fiddle range on the west. This divide separates the waters flowing into Drystone creek and a headwater branch of Drinnan creek.

In the area around Luscar and Cadomin the ridges are short and irregular, and do not have any appreciable areal extent. The headwaters of Gregg river and the McLeod tributaries have dissected this part of the area to a greater extent than the corresponding strike area northwest of Gregg river, thus many of the uplands appear as interstream spurs projecting out from the east face of Nikanassin range. Many of these short ridges, however, show a parallelism with the structural trend of the underlying rocks.

In the area between Leyland and the head of the Pembina the ridges all have a trend parallel to Nikanassin range, but have been much dissected by the numerous tributaries of MacKenzie creek and the headwaters of Beaverdam creek. It is noteworthy that almost all the well-defined, long, pronounced ridges are underlain by Saunders beds which form limbs of folds.

A noticeable physiographical feature is the termination of the ridges to the northwest at the valley of Prairie creek. It is highly probable that this valley was at one time a part of Athabaska River valley, either as the main outlet of Athabaska river from the mountains, or an outlet for part of the stream. The parallel truncation of the four main ridges on the south side of the valley of Prairie creek would have required a much stronger stream action than could have been afforded by Prairie creek in the past, even when it may have been a much larger stream. This truncation is especially noticeable on the north end of Folding mountain, which rises abruptly about 2,000 feet from the level of the head of Prairie creek and has a steep face to the northwest in alignment with the steep north end of Fiddle range to the west.

The area lying between Prairie creek and Athabaska river is relatively low, having a maximum elevation of approximately 4,100 feet. It is elongated in parallelism with the above streams and across the strike of the formations, and is believed to have resulted from erosion by Athabaska river in the past. The higher part of this drainage divide may have been an island in the older Athabaska channels.

The present valley of the Athabaska, however, does not appear to be any younger than that of Prairie creek, therefore it cannot be said, definitely, that all the water from the Athabaska at one time flowed through Prairie creek valley. It is more probable that the Athabaska, on coming through the gap in the front ranges, spread into two or more channels where it could more easily erode through the Cretaceous beds which are relatively much softer than the Paleozoic rocks of the front ranges.

There appears to be undoubtable evidence of considerable laking of Athabaska river in the northern part of this area. The present Brule lake may be interpreted as a remnant of a much more extensive impounding of the waters. The evidence for this is the extensive gravel and sand deposits along the east side of Brule lake and also at the mouth of Prairie creek, at elevations about the same as the present level of Brule lake. These gravel beds have been reworked by Athabaska river as it has deepened its channel and they now remain as long river terraces. The station of Hinton, on the abandoned Grand Trunk Pacific grade, is situated on one of the uppermost terraces. These terraces extend intermittently, all the way up the river from Prairie creek to Brule lake.

Nikanassin range does not lie within this map-area, but borders it along the west. Its average elevation is from 7,500 feet to 8,000 feet, which is considerably above the highest points within the area. (Plate III,B.) Nikanassin range is cut cross by McLeod river and MacKenzie creek, and a number of the small headwater streams have eroded deep channels into the eastern face.

Drainage.—The entire system of streams draining this area belongs to the Athabaska river system. Athabaska river itself forms the northern boundary of this map-area. It has its headwaters within the Rocky Mountains, and at the gap through the front ranges is a sluggish stream having numerous channels, islands, and lake-like expansions. Brule lake shown on the accompanying map is the most easterly of these slow flowing portions of the Athabaska.

The southern end of the lake is becoming silted up rapidly, and numerous sandbars project above the water level. The northern end is deeper and is the outlet. The current is swift from the outlet eastwards, and a channel has been cut across the Cretaceous beds by this fast moving water. During low water some parts of the stream between the lake outlet and the mouth of Prairie creek exhibit small rapids. In this part of the course the stream is cutting across steeply dipping rocks.

Brule lake is undergoing a process of extinction through the silting up at the inlet and the relatively rapid cutting of the river at the outlet. This process, however, does not indicate, as Dowling[23] has mentioned, that the lake will become extinct in the near future, since the gradient of the outlet is quite uniform and the lake does not depend on any individual barrier that might readily give way to rapid erosion.

The Athabaska river gradient lessens below the mouth of Prairie creek and the stream becomes broader.

There are no public traffic bridges across this stream, within the area mapped. The Canadian National Railway bridge east of Entrance is the only crossing. Some years ago a ferry operated just below the mouth of Prairie creek, but this has been abandoned. The stream cannot be forded during the summer months.

23Geol. Surv. Can., Sum. Rept., 1911, p. 203.

The stream channel of the Athabaska exposes an almost continuous section of rocks from Entrance east to the mouth of Prairie creek. West of Entrance the river sediments and vegetation extend to the waters edge and conceal most of the underlying rocks. East of Prairie creek the rock exposures in the stream channel are few and discontinuous.

Prairie creek is the main tributary entering the Athabaska in this area. It flows in a broad, gentle sloped valley and is a sluggish stream throughout most of its course. It appears to be occupying a valley that was originally formed by a much larger stream, presumably a part of Athabaska river. Rock exposures are few, except for the first mile above its mouth, where good sections are exposed in the sides of a narrow valley, which is often 200 feet deep.

McLeod river with its various tributaries drains most of the area. The main branch has its headwaters southwest of Nikanassin range, and it flows through the gap in this range south of Cadomin. This is a fast flowing stream throughout most of the area, but can be forded easily during the summer. It increases rapidly in size as it flows across the area from west to east, due to the addition of water from many tributaries. Its channel exposes an almost continuous section from Cadomin to the mouth of MacKenzie creek. Plate V,A shows McLeod river above the mouth of MacKenzie creek. East of MacKenzie creek the exposures are not continuous, but sufficiently numerous to indicate the structure of the underlying rocks.

A marked feature in the course followed by this stream is the right-angle change in direction from northeast to northwest in township 48, range 22. This change is due to the underlying monoclinal structure as described above. After flowing northwest along the strike of the formations it gradually resumes its northeasterly trend in township 49, range 23.

The main tributaries of the McLeod are Beaverdam creek, MacKenzie creek, and Gregg river. These are all shallow streams with an average water depth of about two feet, and an average stream width of 25 feet. Gregg river below the confluence of Drinnan creek is somewhat larger.

Beaverdam creek flows, in general, parallel with the strike of the underlying beds, and does not expose good sections of the strata except in the lower three miles of its course. MacKenzie creek flowing across the strike of the formations exposes good sections of the strata throughout most of its course. Gregg river, the largest of the three, exposes good sections of the strata especially in the upper part of its course. It shows an almost continuous section from the mouth of Berrys creek in township 47 down to the mouth of Drinnan creek. East of this point rock exposures do not occur as frequently, and the stream channel meanders through gravel beds most of the way.

On the accompanying map are shown several creeks which hitherto had not been named. The writer has suggested the following names for the more permanent streams: Drinnan creek; Warden creek; Mercoal creek; High-Divide creek; Quigley creek; McPherson creek. (NOTE.—These names were submitted to the Geographic Board of Canada; all except "High-Divide creek" being approved by the Board in June, 1925.)

Drinnan creek is a tributary to Gregg river and carries as much water as does Gregg river above the mouth of this creek. The name suggested is after R. G. Drinnan, a mining engineer, who did considerable early prospecting in the Kootenay rocks in the area drained by this creek. Warden creek has been so named as it is followed by the park warden who traverses the part of Jasper Park drained by this creek. Mercoal creek is so named because its headwaters cross the railway at Mercoal station. High-Divide ridge is a prominent upland in the northern part of the area, and the creek, which has branches up into the east side of the ridge, has been called High-Divide creek.

Quigley creek and McPherson creek are named after the company of McPherson and Quigley, which carries on lumbering operations at the mouth of these creeks on McLeod river.

All the above streams are tributaries to the McLeod river system. In addition to the above mentioned streams the headwater of Pembina river drains a small portion of the south part of the area. A branch of Embarras river drains the area in the vicinity of Coalspur.

With the exception of Beaverdam creek and a part of McLeod river below Beaverdam creek, most of the streams have courses transverse to the structural trend of the underlying formations of the area.

Forests.—Most of the area shown in the accompanying map is, or has been forested, but at various times large parts have been burned over by forest fires. (Plate VIII,B.) At present there is very little merchantable timber in the area between the Pembina and McLeod rivers.

There are several good areas of spruce and pine between McLeod and Gregg rivers, especially at the headwaters of Antler creek in township 48, range 24.

Between Gregg river and the Athabaska there are also some good timber areas. These lie west of High-Divide ridge and are best along the valleys at the north and east sides of Folding mountain. The best and most accessible timber in the whole area is a spruce forest that is situated at the north end of Folding mountain, and extends towards Brule lake. The proposed Jasper Highway passes through this in the northwest corner of township 49, range 26. This forest extends up a branch of Prairie creek along the east side of Folding mountain, as far as range 25.

Other timber belts, chiefly of spruce, occur east of High-Divide ridge, especially on the McLeod river drainage. These are being cut at several places along the McLeod valley by the McPherson and Quigley Lumber Company.

Several belts of spruce and pine occur in the area east of McLeod river, in townships 48 and 49, range 22. The Burnt Mountain Lumber company at Mercoal secures its material from a part of the area surrounding Mercoal.

Fauna.—Among the larger animals deer and moose are plentiful throughout most of the area. Black and brown bear and coyotes were frequently observed during traverses. These animals are more plentiful in the eastern part of Jasper Park, where special protective laws exist.

CHAPTER V.

DESCRIPTIVE GEOLOGY.

General Statement.—The part of the foothills discussed in this report is bordered on the southwest by the Nikanassin range, and the front range of the Rocky Mountains, known as Fiddle range. These ranges are made up largely of Paleozoic rocks. Within the area proper the rocks exposed are mostly Cretaceous with some Jurassic and Triassic. Paleozoic rocks occur within the area at one locality, namely, the north end of Folding mountain. (Plate III,A.)

Since the field investigation was chiefly with respect to the coal-bearing formations, no attempt was made to study or subdivide the Paleozoic and early Mesozoic rocks, so that the discussion below refers mainly to rocks of Cretaceous age.

The lithological character of the Cretaceous rocks in the areas to the southeast has been described in previous reports.[24] These descriptions are not repeated in this report, but additional information obtained during the past season's work and changes in previous conclusions resulting therefrom are given below.

JURASSIC.

Definition. — In general, the strata known as Fernie shale throughout the foothills belt constitute the chief member of the Jurassic. It is known, however, that the Jurassic includes more than the black marine Fernie shales. There are often sandstones, stratigraphically above or interbedded with the upper marine shale, that have Jurassic fossils. These are usually included in the Fernie formation. The lower limit of the Jurassic can only be determined by fossil evidence. In this area it extends below the base of the black marine shales and is represented by cherty and calcareous strata similar lithologically to the Paleozoic rocks. The contact of the Fernie with the other formations is difficult to map, since the lowest beds in this area, from fossil evidence, have a lithological character similar to much of the Paleozoic, whereas the upper Fernie beds have a lithological appearance very similar to those of basal Kootenay beds.

FERNIE FORMATION.

Distribution.—The black marine shales form the most easily recognizable part of the Jurassic beds in the foothills. In this area they occur at several places along the front of Nikanassin range, from Cadomin gap to the north end of Folding mountain. At Cadomin gap and south of Luscar they have been overturned with the Kootenay beds and are over-ridden by Paleozoic rocks.

[24]Sci. and Ind. Res. Coun., Alta., Repts. Nos. 6 and 9.

South of Luscar they carry definite Fernie fossils, and some Jurassic beds lower than the marine shales are overturned with the upper strata. South of Cadomin no Jurassic fossils were found in the black shales, but on lithological evidence the shales occurring in the southwest quarter of section 31, township 46, range 23, were mapped as Fernie.

A small area of the Fernie is mapped in the southern part of township 48, range 25, on a branch of Drinnan creek. Black shales occur here in the creek bed, and carry fossils which appear to be Jurassic, although these could not be definitely determined. Structural and lithological relations to the Kootneay beds at this locality indicate that these beds are Fernie and that the occurrence is probably much more extensive than mapped.

A southeast dipping anticlinal structure at the north end of Folding mountain exposes the Fernie as well as the beds immediately above and below. The anticlinal structure and small head streams cutting into Folding mountain form an outcrop as mapped, showing the two isolated small areas on the sides of the mountain. Fernie beds probably occur along the southwest side of the Kootenay in township 48, ranges 25 and 26. This is inferred from the structure and relations to the southeast, although exposures of Fernie beds were not observed at these localities.

Lithological Character and Stratigraphical Relations.—At several places in the area the stratigraphical relation of the Fernie to the overlying Kootenay can be observed. At a few places the relation of this formation to strata lower than the Fernie can be determined from exposures.

The Fernie formation is essentially a black marine fissile shale which grades down into calcareous and arenaceous beds carrying Jurassic fossils, but with a lithological appearance similar to the Paleozoic rocks. The Fernie shales grades upwards into arenaceous and non-marine deposits of the Kootenay formation.

Exposures showing the lower relationship occur south of Luscar on the headwaters of a branch of Luscar creek in section 11, township 47, range 24. At this locality the black shales of the Fernie are in contact with limestone beds carrying Jurassic fossils.

Throughout most of the area the upper limit of the Fernie formation is poorly exposed owing to the shaly nature of these strata which are easily eroded and concealed by debris and vegetation. The exact relations between the Fernie and Kootenay formations are well exposed on the top of the north end of Folding mountain. (Plate II.) The following section includes lower Kootenay beds up to the well-defined conglomerate in the Kootenay formation below.

Section Exposed on the Top of Folding Mountain.

	Thickness in feet.
Conglomerate, with sandstone, caps top of Folding mountain	100
Shale, hard-ribboned with sandstone bands	250
Sandstone, ribboned with thin shale bands	150
Sandstone, hard, fine grained, ribboned with shale bands, sandstone bands up to 10 feet thick	300
Shale, ribboned with thin sandstone bands	70
Sandstone, massive, very fine grained, hard	75
Shale, ribboned with thin sandstone bands, fossils (58-69-24) near top	45
Note: From fossil evidence the base of the Kootenay and top of the Fernie occur in this member.	
Sandstone, fine grained, hard	15
Shale, ribboned with thin sandstone and limestone bands. Fossils 1-9-24 in upper 75 feet	175
Shale, black fissile thin bedded, very few ribbons of coarse material. Fossils 2-9-24 near the top of this member	140
Concealed, probably black shales.	

This section shows that the Kootenay and Fernie formations are conformable locally at least. Regionally there may be considerable difference in the stratigraphical position of the base of the Kootenay or top of the Fernie formation, but in all exposures of this contact observed in this area, and areas to the southwest, these two formations appear conformable. Fernie rocks were not exposed in the area to the southeast discussed in Report No. 9, but in the Nordegg area still farther to the southeast the lithological character of the Fernie and its relations to the Kootenay are very similar to those in this area.

Thickness.—Although the entire section is not exposed on Folding mountain the formation is estimated to be between 500 and 600 feet in thickness. Less than 400 feet are exposed and about 200 feet of concealed strata are believed to be largely Fernie in age. The exposures below this section on Folding mountain are of Triassic and Paleozoic ages. This thickness is larger than that believed to be present in the Nordegg area[25] although the entire section was not exposed in that area where an estimated thickness of 300 feet was given.

Palaeontology.—The following fossils were collected from the Jurassic beds in this area and areas to the southeast, discussed in Reports Nos. 6 and 9. Dr. P. S. Warren has identified these fossils and written the accompanying notes regarding them.

25Rept. No. 6, p. 36.

JURASSIC FOSSILS FROM BRULE AND MOUNTAIN PARK COAL AREAS.

Field Number	Name	Locality
1-9-24	*Pentacrinus* sp. undet.	Folding mountain
2-9-24	*Ostrea* sp. undet. *Gryphaea impressimarginata* McLearn *Trigonia* sp. undet. *Belemnites* cf. *densus* Meek and Hayden	Folding mountain
58-69-24	*Inoceramus?* sp. nov.	Folding mountain
7-28-24	*Cyprina?* sp. undet.	Drinnan Cr'k Branch, Tp. 48, Rg. 25.
23-50-24	*Cucullaea livingstonensis* McLearn *Belemnites* cf. *densus Meek and Hayden*	South of Luscar, Sec. 11, Tp. 47, Rg. 24.
22-46-24	*Rhynchonella gnathophora* Meek *Cucullaea livingstonensis* McLearn *Gryphaea impressimarginata* McLearn *Gryphaea* sp. undet. *Pleuromya obtusiprorata* McLearn *Olcostephanus* sp. undet. *Cardioceras?* sp. undet. *Ammonite* undet. *Belemnites* cf. *densus* Meek and Hayden	From railway cut four miles south of Cadomin. Just south of this map area.

JURASSIC FOSSILS FROM NORDEGG COAL AREA.

Field Number	Name	Locality
23-16-23	*Inoceramus* sp. nov. *Trigonia* sp. nov. *Plagiostoma* sp. nov. *Pleuromya* sp. undet. *Cyprina?* sp. nov. *Belemnites* cf. *densus* Meek and Hayden	Blackstone river gap in Bighorn Range. Sec. 12, Tp. 42, Rg. 19.
1-3-23	*Trigonia ferrieri* McLearn *Pleuromya postculminata* McLearn *Pleuromya* sp. nov. *Cyprina? cinnabarensis* Stanton? *Cyprina? iddingsi* Stanton? *Cyprina?* sp. undet. *Tancredia?* sp. undet. *Tellina?* sp. undet.	From small branch of Shunda Creek in northeast corner of Tp. 40, Rg. 15.
171-280-22	*Trigonia* sp. nov. *Pleuromya summissiornata* McLearn *Pleuromya* sp. undet. *Homomya gallatinensis* Stanton? *Cyprina?* sp. nov. *Astarte?* sp. undet. *Pelecypod*, undet. *Cardioceras?* sp. undet. *Belemnites* cf. *densus* Meek and Hayden	Dutch creek in southern part of Tp. 40, Rg. 14, west side of Brazeau Range, near Saskatchewan river.

"The fossils identified in these lists apparently represent but one horizon which on the evidence of the pelecypods may be correlated with the Fernie shale of the Blairmore area.[26]. Dr. F. H. McLearn, of the Geological Survey of Canada, considers the marine Fernie of that area to be about Callovian age according to the

[26] McLearn, F. H., "New Pelecypods from the Fernie Formation of the Alberta Jurassic," Trans. Roy. Soc. Can., 1924, Sec. IV, p. 39.

European classification.[27] It is to be noted also, that forms identical with, or approximating certain species from the Sundance formation of Wyoming are present in the collection. As the Sundance is now correlated with the Argovian of Europe, it is possible that this collection represents a little higher horizon than the Callovian. Without the aid of ammonites, which are but poorly preserved in the present collections, exact correlation is not possible."

CRETACEOUS FORMATIONS.

The Cretaceous strata in this area are represented by three groups, namely, Kootenay, Colorado, and Montana. These underlie most of the area covered by this report.

A summary of the formations in these groups and their outstanding lithological character is as follows:

GROUP	FORMATION	DESCRIPTION
Montana	Saunders	Continental deposits; sandstones and clay shales in alternating beds; some conglomerates especially near the base of the formation; coal seams about the middle of the formation which is at least 10,000 feet thick; lower beds harder than upper ones.
Colorado	Wapiabi	Black fissile shale carrying marine fossils and numerous nodules.
	Bighorn	Hard massive fine grained sandstone interbedded with black shales.
	Blackstone	Black fissile shale of uniform character; relatively free from other types of sediments; carrying marine fossils.
Kootenay	Kootenay	Continental deposits; sandstones, clay shales and coal seams; marked conglomerate near the base of the formation.

KOOTENAY GROUP.

Definition.—In Report No. 9, dealing with the area to the southeast the term *Kootenay* was used to represent a group of strata of continental deposition, stratigraphically above the marine Jurassic and below the marine Colorado beds.

Various authors reporting on foothill and mountain areas in Alberta have split this group into two formations, using the term Kootenay for the lower strata and another name for the upper strata.

27McLearn, F. H., Geol. Surv. Can., Sum. Rept., 1922, Pt. B, p. 6.

The earlier workers[28] in the foothills made a tentative correlation of these upper strata with the Dakota formation and designated them by the same name. Later workers[29] have used the name "Blairmore" formation for these beds in the Crowsnest Pass and adjacent areas. MacVicar[30] in working the foothills north of Athabaska river calls these beds the "Sunset Sandstone."

In Report No. 9 covering an area adjacent to this one, the Kootenay strata were divided into the "Coal bearing member" and the "McLeod member". The only basis for this division was the difference in lithological appearance between the lower and upper strata of the entire series of continental deposits between the marine Jurassic and Colorado beds.

Distribution.—The strata of this group form a continuous belt in this area extending along the east side of Nikanassin range from a few miles southeast of Cadomin, to the north end of folding mountain. They have been shown on the map to extend northwest beyond Folding mountain, almost to Brule lake, and are represented to the northwest of this lake at the Blue Diamond Collieries near Brule station. It is to be noted that Kootenay beds underlie a wider belt at the headwaters of Gregg river than either to the southeast at Luscar and Cadomin where coal is mined from them, or to the northwest at the north end of Folding mountain where they have have been extensively prospected.

Lithological Character.—The Kootenay group has been mapped as a unit in this area and consists of continental deposits of sandstones, clay shales, coal seams and conglomerates. The beds have been too badly deformed in this area to obtain a detailed section of even the major part of the formation and no reasonable estimate of the thickness can be given. A thickness of about 6,600 feet is assigned to the strata equivalent to the Kootenay group by MacVicar[31] in the area northwest of Brule lake. Of this, he assigns 3,600 feet to the Kootenay coal measures and 3,000 feet to the Sunset sandstone.

The sandstones of the lower strata of the Kootenay are more carbonaceous than the upper beds, which weather to a light greenish grey colour. The gradational relation with the Jurassic beds has been referred to above. This is marked by the gradual disappearance of black marine Fernie shales which become arenaceous and are replaced by very fine grained hard sandstones of the basal Kootenay. These relations are illustrated by the section of a part of the basal Kootenay given on page 32. (Plate II.) The shales between these sandstones are often carbonaceous and show many markings which appear to be worm tracks.

The most easily recognizable lithic unit in this formation is a conglomerate bed made up almost entirely of chert pebbles cemented together with fine sand grains. The pebbles are on the average well

[28]Malloch, G. S., Geol. Surv. Can., Mem. 9E, 1911.
Cairns, D. D., Geol. Surv. Can., Mem. 61, 1914.
[29]Rose, B., Geol. Surv. Can., Sum. Rept. 1916, p. 107.
Stewart, J. S., Geol. Surv. Can., Mem. 112, 1919.
[30]Geol. Surv. Can., Sum. Rept., 1923, Pt. B, p. 21.
[31]Geol. Surv. Can., Sum. Rept., 1923, Pt. B., p. 30 and 34.

rounded and less than 1 inch in diameter. The thickness averages about 25 feet, although often a considerable thickness of sandstone is associated with it. This conglomerate is one of the hardest members in the Kootenay and can be traced intermittently across the area from the north end of Folding mountain southeast to where it is over-ridden by Nikanassin range in the northeastern part of township 46, range 23, at the headwaters of a branch of MacKenzie creek. The position of this conglomerate has been indicated on the map by a symbol in the areas adjacent to the mines working the Kootenay seams.

At the north end of Folding mountain the conglomerate lies about 900 feet above what has been taken as the base of the Kootenay strata (Plate II), and apparently has the same approximate stratigraphic position throughout the area. A conglomerate has been observed in the basal Kootenay beds as far southeast as the Saskatchewan river, in the Nordegg area, where it occupies a similar stratigraphic position with reference to the Kootenay beds and to the Fernie shales below.

Since the base of the Kootenay strata is not well defined but is transitional into the Jurassic below, the exact stratigraphic position of the conglomerate cannot be given for the whole region. It does, however, indicate a lower Kootenay horizon.

The rest of the Kootenay group of strata consists of sandstones, clay shales, carbonaceous shales, and coal seams. The coal seams are more fully referred to in a later chapter. The commercial seams lie about 700 feet stratigraphically above the conglomerate.

As stated above, no division has been made in the Kootenay group since there is no well-defined break in the series that can be mapped regionally. It is, however, comparatively easy to distinguish the greenish grey sandstones which are high in the group, from the beds associated with the coal and conglomerate which occur in the lower strata. The presence or absence of coal cannot be taken as an indication of the stratigraphical position within this group since some seams occur within a short distance of the top of the series or within those beds which other workers have designated as a formation younger than the Kootenay.

In the areas to the southwest the writer could not find any lithological break in this group of strata that could be used to separate it into formations for purposes of mapping.

The writer has examined in the field the succession reported on by Malloch[32] in the Bighorn basin, and, while able to differentiate lower Kootenay beds from what he calls the Dakota formation, on a lithological basis, there was not a member that could be used as a basis of division into two formations that could be traced regionally.

Similarly in the area northwest of Brule lake MacVicar[33] is very indefinite with respect to the boundary between the Kootenay and what he calls the Dakota. Dowling[34] in a later note on the

32Geol. Surv. Can., Mem. 9E, 1911.
33Geol. Surv. Can., Sum. Rept., 1919, Pt. C, p. 11.
34Geol. Surv. Can., Sum. Rept., 1923, Pt. B, p. 34.

same area assigns a separate formational name for these beds, but from this report there is no field evidence given for grouping these upper beds into a formation separate from the Kootenay beds below.

Throughout the foothills in Alberta there are no unconformable or disconformable relations that have been noted within this thick series of continental deposits below the Colorado marine strata. In the Crowsnest area a thick conglomerate is used to separate these continental deposits into the Kootenay below and Blairmore formation above. This conglomerate is a good horizon marker, although the lithological character of the beds above and below it are similar in many respects. In the foothills between the North Saskatchewan and Athabaska rivers there is no conglomerate or other stratum that could be used for a similar purpose.

The Kootenay group carries plant remains at several horizons and a few fossil shells, but the latter are, in most cases, too poorly preserved for identification or determination. In this connection some fossils were collected in 1923, at Cadomin, just above the coal seams. These have been identified as resembling *Pleuromya* and *Pseudomelania*. A fossil horizon is also present in the Kootenay beds a few feet above the conglomerate. This horizon carries numerous gastropods and a probable *Astarte*. Dr. P. S. Warren is of the opinion that these Kootenay fossils are undoubtedly marine.

Apparently the only basis of division of the group will be from palaeobotanical determinations. McLearn[35] has recently, by this means, made some correlations of the strata in the Peace River canyon with those of the Blairmore district in southwestern Alberta.

Summarily, from our present information, it may be stated that the strata here defined as the Kootenay group form a series of sediments that were nearly all deposited in non-marine waters, and consist of sandstones, shales, conglomerates, and coal seams. There is no evidence to date in this or other foothill areas of a break in this series that will serve as a formational boundary. In the area between the north Saskatchewan and Athabaska rivers there is no lithological basis for a division of the group into two formations. The coal seams of commercial thickness are found in the lower part of the formation and there is a large thickness of sediments in which there are no coal seams. It would seem that the Kootenay can only be divided into two formations on palaeobotanical evidence, and in the foothills between the North Saskatchewan and Athabaska rivers the beds have been so much deformed and exposures are so scattered that a division of the group on the above basis could only be made locally, and could not be used for regional mapping.

COLORADO GROUP.

Definition.—The strata comprising this group consist of three formations, namely, *Blackstone*, *Bighorn* and *Wapiabi*. The sediments of this group are almost entirely of marine deposition. The

[35] Geol. Surv. Can., Sum. Rept., 1922, Pt. B, p. 6.

upper (Wapiabi) and lower (Blackstone) formations are essentially dark marine shales, while the Bighorn formation carries thick sandstone beds, as well as some shales. This threefold division of the Colorado was made by Malloch[36] in the Bighorn Basin north of North Saskatchewan river. These divisions were adopted by the writer for the areas to the southeast; the same names have been retained for this map-area. On the accompanying map, the Colorado strata have been shown in one colour as a group, since it is practically impossible to map the formations separately in the inter-stream areas where exposures are relatively few, owing to the soft character of the shale. Furthermore, these shales in many places have been closely folded in many minor structures which cannot be traced regionally.

Distribution.—The Colorado strata underlie belts parallel to the structural trend of the area. The most continuous belt occurs along the southwestern side of this map-area, extending from Pembina river almost to the Athabaska. This belt is much broader in the southeast part of the area where it extends up to Nikanassin range. In the northwest part it is separated from the Paleozoic rocks to the west by Kootenay and older Mesozoic strata. On account of the heavy cover of recent deposits along the east side of Brule lake (Plate VII), it cannot be stated with certainty that Colorado rocks underlie the exact area as shown north of Folding mountain, but from the structural trend of the formations and the geological contacts shown by MacVicar[37] in the area northwest of Brule lake, the distribution of the Colorado as shown on the accompanying map is approximately correct.

Another narrow belt of Colorado extends from Pembina river northwest to Gregg river. Northwest of Gregg river this belt is cut off by faulting, and there are no Colorado beds associated with this fault on the Athabaska.

Two small areas of Colorado beds occur northeast of these two main belts. One of these occupies a small area near the mouth of MacKenzie creek. This surface outcrop of Colorado rock is due to stream erosion through the anticlinal structure of basal Saunders and upper Colorado beds at this location.

The other small area of Colorado beds occurs on Gregg river about the centre of township 49, range 24, where this stream cuts across a faulted anticline exposing the uppermost strata of the Colorado group.

It is noteworthy that these two last mentioned surface exposures of Colorado beds are not represented on Athabaska river, which has a channel that is, on the average, a thousand feet lower in elevation than Gregg river or the upper part of McLeod river. The reason suggested for the absence of Colorado on the Athabaska is structural. There seems to have been more overthrusting of Paleozoic rocks west of Brule lake than to the southeast, where

[36]Geol. Surv. Can., Memoir 9E, 1911.
[37]Geol. Surv. Can., Sum. Rept., 1923, Pt. B (map), p. 22.

there appears to have been more uplifting and folding of the Cretaceous rocks, accompanying the forming of the Nikanassin range.

Blackstone Formation. — This formation is composed almost entirely of black fissile shales carrying a marine fauna. There is a notable absence of arenaceous material in this formation. A few lenses of impure limestone averaging less than one foot in thickness are quite common.

Owing to the soft nature of these beds they are usually contorted and folded into numerous small folds. It was not possible to obtain a complete section of this formation so as to measure the thickness and establish the stratigraphical position of fossil horizons. In previous work on areas to the southeast the same difficulty was experienced and no total thickness could be obtained. Malloch[38] in the Bighorn Basin measured 1,050 feet of shale in this formation, but his section was incomplete.

In this map-area the Blackstone is at least 1,500 feet thick and probably much thicker. The best sections of Blackstone strata exposed in this area are those along McLeod river in the vicinity of Leyland station. An almost continuous section of these beds is exposed from near the mouth of Luscar creek in section 17, up the river to the centre of section 5, just north of Cadomin station. The shales are here much broken and folded, but in places as much as 600 feet of beds occur in regular succession. The branch of the railway to Luscar exposes Blackstone shales along the railway cut in sections 17 and 18, township 47, range 23. A small part of the upper Blackstone strata is exposed at several other localities, but the greater part of the Colorado as mapped is represented by the Bighorn and Wapiabi formations.

Stratigraphical Relations.—During three field seasons in the foothills between North Saskatchewan and Athabaska rivers the writer has only seen one exposure which apparently shows the stratigraphical relations of the Colorado strata to those of the Kootenay group. This exposure occurs on Gregg river, in the northwest quarter of section 5, township 48, range 24, and shows a conformable relation between the Kootenay and the Colorado. The Colorado shales grade abruptly into continental deposits which carry a coal seam over four feet in thickness. This seam is about 500 feet stratigraphically below this contact. Approximately 1,000 feet stratigraphically below this contact about 50 feet of black fissile shales occur. These shales carry ironstone nodules, have some fossils, and possess a lithological appearance almost identical with the marine Colorado shales above. It was not possible to determine whether this shale member carries a Colorado fauna or whether it was a marine member of the upper strata of the Kootenay group.

From all that has been observed the Colorado strata appear to be conformable with those of the Kootenay group, but as in the case of the Kootenay-Fernie relations, it cannot be stated that the

[38]Op. Cit., p. 23.

contact between these two groups of strata has the same stratigraphical position throughout the area, much less so throughout the foothills beyond this area.

Palaeontology.—Certain horizons within the Blackstone formation carry an abundance of fossils, but unfortunately the stratigraphical position of these could not be determined, because of the deformation to which these beds have been subjected.

Some fossils, however, have been collected from a known stratigraphical position with respect to the Bighorn formation above. These, as designated below, have a greater significance for purposes of correlation of the Blackstone strata with beds of the same age in other localities.

Dr. P. S. Warren has identified the fossils in the following list which were collected from the Blackstone beds.

LIST OF FOSSILS FROM BLACKSTONE FORMATION.

FIELD NO.	NAME.	LOCALITY.
10-32-24	*Pinna* sp. undet. *Inoceramus labiatus* Schlotheim *Ostrea* sp. undet. *Anomia*, n. s. *Gastropod* undet. *Prionotropis woolgari* Mantell	Near mouth of Luscar creek in sections 16 and 17, Tp. 47, Rg. 23.
11-32-24	*Inoceramus labiatus* Schlotheim *Inoceramus* sp. nov. *Gastropod* undet. *Prionotropis woolgari* Mantell	McLeod river, vicinity of Leyland.
17-35-24	*Inoceramus labiatus* Schlotheim *Scaphites* sp. undet.	North side Mary Gregg lake.
20-43-24	*Inoceramus labiatus* Schlotheim	Luscar Creek, Sec. 18, Tp. 47, Rg. 23.
21-45-24	*Inoceramus labiatus* Schlotheim	Northeast quarter of Sec. 8, Tp. 47, Rg. 23.

NOTE.—Number 10-32-24 were collected from beds just below the Bighorn formation.

Bighorn Formation.—This formation consists of interbedded sandstone and shales which are partly marine and partly of fresh or brackish-water deposition. It is the presence of comparatively thick, massive, hard, fine grained sandstones that serves to limit the boundaries of this formation. (Plate IV,A.) These sandstone beds are the hardest members in the whole Colorado series, and being more resistant to erosion are frequently the cause of the higher ridges in areas underlain by Colorado strata. The outcrops of Bighorn have been indicated on the map and in the structure sections by a special symbol.

NOTE: A change has been made in the mapping at the head of the Pembina river. In Map No. 5, Report No. 9, Saunders beds are shown to be almost adjacent to Nikanassin range. In the work of 1924 these were found to be Bighorn beds. Bighorn beds occupy the area shown as Saunders in Map No. 5, in sections 1 and 2, township 46, range 22, and on the south side of Pembina river, in section 36, range 22, and in section 31, range 21, in township 45.

A section of Bighorn formation exposed on McLeod river at the mouth of Luscar creek is as follows:

Sandstone, hard, massive, fine grained, shaly at base	35 feet
Shale, black, poorly laminated, ribboned within standstone bands	41 "
Shale, black, hard, marine (?)	26 "
Shale, poorly laminated, mixed with shaly sandstones apparently non-marine deposits	25 "
Sandstone, hard, fine grained, crossbedded	3 "
Shale, poorly laminated, mixed with sandstone bands apparently non-marine deposits	85 "
Sandstone, hard, fine grained, light coloured, same as the 35-foot member at top of section	27 "
Total thickness of Bighorn formation	242 feet

Above and below this section there are beds of sandstone in the shale which are as much as three feet in thickness, but the two thick sandstones given at the top and bottom of the section are the best limits for the formations, since the contacts with the formations above and below are gradational, and any boundary chosen is, of necessity, arbitrary. These two thick, hard, sandstone members are responsible for the physiographical prominence caused by the Bighorn formation.

Sometimes some of the shales in this formation are very carbonaceous and form what may be classed as an impure coal seam. These carbonaceous beds are exposed in the Bighorn formation on the west side of McLeod river, just below the mouth of Luscar creek. Similar conditions were noted on North Brazeau river, in 1923.[39] These separated occurrences indicate that the carbonaceous bands are not merely a local occurrence.

While the stratigraphical position of the Bighorn formation with respect to the other Colorado strata may be different in separated localities, and the thickness of the formation varies from one locality to another, these sandstones and arenaceous beds within the Colorado group have been noted throughout the foothills belt from Crowsnest pass to Peace river, wherever the rocks have been examined. They appear to indicate shallow water conditions in the foothills during a part of Colorado time, and the increase in thickness which this formation shows from east to west indicates a probable shoreline condition, since a part of the formation was deposited in fresh or brackish waters.

Palaeontology. — The Bighorn strata are, on the whole, poor in fossil remains, yet at several localities there are lenses of sandstone that carry numerous Inocerami and other fossils. The following from the Bighorn formation have been identified by Dr. P. S. Warren:

[39]Rept. No. 9, p. 32.

LIST OF FOSSILS FROM BIGHORN FORMATION.

FIELD NO.	NAME.	LOCALITY.
9-28-24	*Corbula?* sp. undet.	Drinnan creek, Tp. 48, Rg. 25.
25-51-24	*Inoceramus* n. s.	East of Leyland, Sec. 3, Tp. 47, Rg. 23.
26-52-24	*Cardium pauperculum* Meek	Southeast quarter Sec. 12, Tp. 47, Rg. 23.
28-52-24	*Cardium pauperculum* Meek	Sec. 16. Tp. 47, Rg. 22.
29-52-24	*Inoceramus* n. s. *Cardium pauperculum* Meek	MacKenzie creek, Sec. 20, Tp. 47, Rg. 22.

Wapiabi Formation.—This, the upper member of the Colorado group, is composed of black marine shales, similar in many respects to those of the Blackstone formation. It differs from the Blackstone in having numerous clay-ironstone nodules. These are most abundant in the upper and lower parts of the formation, while the middle strata are relatively free from nodules. The nodules range in size from an inch up to over a foot in diameter, the average diameter being approximately 6 inches.

No complete section of this formation was exposed in this area. A fairly complete section was measured in 1923, on the Blackstone river in township 42, range 16. This section[40] measured 1,900 feet, which appears to be about the same thickness that the Wapiabi formation has in this area. The Wapiabi is much more fossiliferous than the Blackstone formation.

The Wapiabi formation shows conformable relations with the Bighorn formation below and the Saunders above. The relations with the Saunders show an abrupt transition from marine to non-marine conditions of deposition, yet the formations are conformable. Fossils from this transition were collected at a number of localities. These are tabulated below.

Wapiabi shales occupy the largest portion of the areas shown as Colorado beds on the accompanying map.

In the area northwest of Brule lake MacVicar[41] apparently included the equivalent of the Bighorn and Wapiabi formations with the younger fresh-water deposits and called the whole series the "Upper Sandstones and Shales." His "Berland shales" appear, from the description given, to correlate with the Blackstone formation.

Dr. P. S. Warren has determined the following fossils collected from the Wapiabi formation:

40Rept. No. 9, p. 31.
41Geol. Surv. Can., Sum. Rept., 1922, Pt. B, p. 34.

LIST OF FOSSILS FROM WAPIABI FORMATION.

FIELD No.	NAME.	LOCALITY.
3-10-24	*Inoceramus* n. s. *Scaphites* sp. undet.	Prairie creek, headwaters about centre of Tp. 49, Rg. 26.
14-33-24	*Inoceramus n. s.* *Oxytoma nebrascana* (Evans and Shumard) *Ostrea* sp. undet. *Tellina?* sp. undet. *Scaphites ventricosus* (Meek and Hayden) *Scaphites vermiformis* (Meek and Hayden)	Gregg river, southwest quarter of Sec. 8, Tp. 48, Rg. 24.
14a-33-24	*Scaphites* sp. undet. *Baculites asper?* Morton	Approximately same loc. as 14-33-24.
18-43-24	*Ostrea* sp. undet. *Pelecypod* undet. *Scaphites vermiformis* (Meek and Hayden) *Baculites asper?* Morton	McLeod river, Sec. 16, 21, 22, Tp. 47, Rg. 23.
30-54-24	*Inoceramus* n. s. *Scaphites vermiformis* (Meek and Hayden)	MacKenzie creek, northeast corner Tp. 46, Rg. 22.
37-68-24	*Baculites* sp. undet.	McLeod river, southwest quarter of Sec. 30, Tp. 47, Rg. 22.

LIST OF FOSSILS FROM UPPERMOST BEDS, WAPIABI FORMATION.

FIELD No.	NAME.	LOCALITY.
5-22-24	*Oxytoma nebrascana* (Evans and Shumard) *Pholadomya papyracea* (Meek and Hayden) *Baculites ovatus* Say	Gregg river, Sec. 16, Tp. 49, Rg. 24.
13-33-24	*Ostrea* sp. undet.	Gregg river, northwest quarter Sec. 8, Tp. 48, Rg. 24.
19-34-24	*Oxytoma nebrascana* (Evans and Shumard) *Ostrea*, sp. undet. *Cyrena?* sp. undet. *Liopistha undata* (Meek and Hayden) *Baculites* sp. undet.	McLeod river, southwest quarter Sec. 22, Tp. 47, Rg. 23.
27-52-24	*Oxytoma nebrascana* Evans and Shumard *Cardium pauperculum?* Meek *Tancredia americana* Meek and Hayden *Pelecypod* undet.	Railway track, northeast quarter Sec. 24, Tp. 47, Rg. 23.
31-54-24	*Ostrea*, sp. undet. *Pelecypod* sp. undet.	MacKenzie creek, northeast corner Tp. 46, Rg. 22.
32-55-24	*Pelecypod* undet. *Baculites* sp. undet.	MacKenzie creek, Sec. 5, Tp. 47, Rg. 22.

MONTANA GROUP.

Saunders Formation.—Throughout the foothills of Alberta the term *Montana* refers to all upper Cretaceous beds above those of Colorado age. In the plains area of the province this group is usually comprised of several formations representing an alternation of conditions of deposition from marine to non-marine. In the foothills belt the beds of Montana age are nearly all of non-marine deposition so that a division into formations is more difficult.

The name Saunders[42] was given to the beds of Montana age lying stratigraphically above the marine Colorado. A twofold division was then made based on the position of the coal seams. In Report No. 9 this twofold division was dropped since it was found that the division could not be applied regionally. After the field work of 1924 it still seems advisable to put all these strata into one formation, since no basis of division was observed that had a regional significance.

Distribution.—The Saunders strata underlie more than half of this map-area and form a continuous belt along the northeastern side of the area. Along the southwest half, older rocks are exposed and in places Saunders rocks occupy the basins of synclines such as that shown in township 46, range 22.

A long belt of Saunders beds having synclinal structure is that shown to cross McLeod river in township 47, range 23. This same syncline extends across Prairie creek to the northwest, in township 50, range 26, and southeast across the Pembina in township 46, range 21. From previous work in 1923[43] this synclinal belt is known to continue southwest across the Blackstone river in township 41, range 17. In places the limbs are more steeply dipping than in others, making the belt narrower. The narrowest place is along Pembina river in township 46, range 21. The southwest limb is overturned about 15 degrees where this belt crosses MacKenzie creek and McLeod river. (Plate V,A.)

Saunders beds are shown on the accompanying map to occupy a part of the northeast corner of township 46, range 21, which was all shown as underlain by Colorado beds, in Map No. 5.[44] The information in this locality for Map No. 5 was obtained from the exposures along Pembina river, which shows a continuous section of Colorado beds. In 1924 it was found that Saunders beds cap the hills to the north of the Pembina valley, although this contact of the two formations is concealed in the valley sides.

No general structural statement regarding the distribution can be given for the wide belt of Saunders occupying the northeast half of the area, other than the fact that there is a general prevalence of younger Saunders strata along the northeast side.

Lithological Character.—The general lithological character of this formation given in Reports Nos. 6 and 9, for areas to the

42Report No. 6, p. 51.
43See Map No. 5, Rept. No. 9.
44Accompanying Rept. No. 9.

southeast applies equally well to the Saunders formation in this area. There are some changes that the formation shows and these are discussed below.

The Saunders formation consists essentially of interbedded sandstones, clay shales, conglomerates and coal seams. The term "Clay shales" is applied to shales that are of fresh-water deposition and which break irregularly, in contrast to the fissile and laminated character of Colorado shales, which were deposited in marine waters.

The Saunders strata are lithologically similar in many respects to those of the Kootenay group. The Kootenay beds have been subjected to greater pressure through deeper burial and mountain building forces, and are thus on the whole harder rocks. The basal Saunders beds, however, have a lithological appearance very similar to the uppermost beds of the Kootenay group, both having about the same hardness, colour, texture, and thicknesses of lithological units.

While, as stated above, the formation cannot be readily divided in two or more divisions based on lithology, the upper strata of the formation are quite easily distinguishable from the beds near the base of the formation. The upper beds are in general much softer, not so well consolidated and are more often of a yellowish to brownish colour, whereas the basal beds, especially the sandstones, are usually light grey or greenish grey in colour. The difference in hardness is believed to be largely due to deeper burial of the older strata.

The most outstanding lithological unit of the Saunders strata in this area is a well defined conglomerate near the base of the formation as shown in the tabulated section given below. This conglomerate is similar in many respects to the conglomerate in the basal Kootenay beds, being composed of rounded chert and quartite pebbles averaging about one inch in diameter, of various colours, and cemented together with sand grains.

The best exposures of this conglomerate occur on McLeod river and MacKenzie creek where these streams cut across basal Saunders beds. A restricted part of the river channel in section 22, township 27, range 23, known locally as "Hell's Gate" (Plate V,A) is caused by this conglomerate which is overturned and dips 80 degrees to the southwest. The thickness of the conglomerate at this locality is 75 feet. This conglomerate forms the crests of many of the ridges underlain by Saunders beds, especially along the outer edges of limbs of synclines. (Plate V,B.)

South from McLeod river this conglomerate becomes more arenaceous as shown in the outcrop at the head of the Pembina river in the southeast corner of township 46, range 22. Still farther to the southeast on Blackstone river, in township 42, range 17, it is more of a pebbly sandstone than a true conglomerate, with the pebbles occurring as lenses in a well cross-bedded sandstone.

Northwest of McLeod and Gregg rivers there are several conglomerates in the basal Saunders beds, and it is often difficult to determine which of these correlates with the thick conglomerate exposed on McLeod river. This series of conglomerates is well exposed on the north side of Athabaska river opposite the mouth of Prairie creek and along the old Grand Trunk grade in sections 29 and 32, township 50, range 26, and also in several of the hill tops along the south side of the valley of Prairie creek towards its headwaters.

In almost all the conglomerates in the basal part of the formation the pebbles are seldom over two inches in diameter and more often less than one inch. At different horizons higher up in the formation there are frequently lenses or rows of quartzite pebbles that have diameters as great as twelve inches, and averaging about six inches. These occurrences are usually local and have only a small lateral or vertical extent.

In one locality a bed of these large pebbles is rather extensive, and forms a coarse pebble conglomerate that in part caps High-Divide ridge in township 50, ranges 24 and 25. (Plate VI.) The pebbles in this bed average from two to six inches in diameter, and are poorly cemented with fine sand. The erosion of this member is responsible for the coarse gravel extending all the way across the top of High-Divide ridge. A section of this conglomerate exposed at the north end of the ridge shows it to be at least 50 feet in thickness. This conglomerate is high in the Saunders formation, and is very similar in appearance to a conglomerate that occurs in the Saunders beds on the ridge top, east of Sterco on the Alberta Coal Branch, in township 47, range 20. These two conglomerate beds cannot be correlated other than that both are stratigraphically high in the Saunders formation, but there is nothing in their lithology that is not common to other strata of the Saunders, except that they represent local thick aggregations of material that is much coarser than the average of the Saunders beds.

In addition to coal seams in the Saunders, which are discussed in the chapter on economic geology, there are many coaly lenses and tree remains in the Saunders beds. These appear to represent driftwood remains or parts of trees which were rafted to their site of deposition.

Thickness.—As yet it has been impossible to obtain a complete section of the Saunders in order to ascertain its thickness. The chief reason for this is that the formation is so thick that a complete section is not exposed in one locality and horizon markers within the formation are difficult to find. Moreover, this is the uppermost formation of consolidated rocks in the area and the top has been eroded away.

In the area considered by Report No. 6 the thickness was estimated to be over 11,000 feet. In the area covered by Report No. 9 which lies adjacent to this area to the southeast, the thickness of Saunders beds was believed to be at least 13,000 feet. In this area there is no evidence to indicate that the thickness is less than

13,000 feet. Continuous exposures of 1,000 feet of strata are common, and in several places as much as 4,000 feet of beds can be measured in regular succession.

On Athabaska river a section from the fault below Prairie creek to the base of the syncline opposite Entrance station gives at least 10,000 feet of Saunders beds. This is a conservative estimate since concealed parts of the section have been omitted wherever a possibility of duplication of strata by folding might occur. To this section at least 2,000 feet may be added since the axis of the syncline passes through High-Divide ridge, which is 2,500 feet higher than where the axis crosses Athabaska river. Thus there seems to be direct evidence for the presence of at least 12,000 feet of beds in the Saunders formation in the area, and probably the complete section is some thousands of feet greater.

Stratigraphical Relations.—From several well separated exposures of the contact of the basal Saunders beds with the Wapiabi formation, these two formations appear to be conformable, although regionally the stratigraphical position of the base of the Saunders may vary. The fauna of the uppermost strata of the Wapiabi formation given on page 43, indicates the stratigraphical horizon of the base of the Saunders for purposes of correlation with areas at some great distance.

The section is given below as exposed on McLeod river in sections 22 and 27, township 47, range 23, indicates the relation of the thick conglomerate in the Saunders to the base of the formation, and the relation of the Saunders and Wapiabi formations.

Section of Basal Beds in Saunders Formation.

	Thickness in feet.
Sandstones and shales, alternating beds averaging 10 to 15 feet in thickness	4,000
Conglomerate, massive (Plate 5,A)	75
Clay shales, ribboned with thin sandstone bands	60
Sandstone, with lenses of pebbles, grey cross-bedded, thin shale layers	30
Clay shales, with thin bands of sandstone	185
Clay shales, with sandstone bands up to 5 feet thick. Some plant remains	210
Clay Shales, with few arenaceous bands	50
Shales, black-ribboned with thin sandstone lamellae. Look like marine deposits	50
Sandstone, hard, massive, fine grained, shaly towards the top (Plate 4,B)	80

The Colorado shales carrying clay ironstone nodules occur stratigraphically below this 80-foot sandstone at the base of the section, and carry the fossils number 19-34-24 listed on page 43.

The 50 feet of shales above the 80-foot sandstone have a lithological appearance very much like the Wapiabi shales, but no fossils could be found in them. In the corresponding section on Gregg river in section 16, township 49, range 24, no fossils were found above the base of the thick sandstone. For purposes of mapping the base of the Saunders formation was placed at the bottom of the 80-foot sandstone or 655 feet below the conglomerate on McLeod river. The stratigraphical position of this conglomerate may vary throughout this area, but 600 to 700 feet above the base should be a fair approximation for most occurrences.

The Saunders beds are remarkably free from fossil animals, and while fossil plants are quite abundant in some localities at certain horizons there are often exposures of a thousand feet of strata without fossils.

A noteworthy feature is the occasional occurrence of vertebrate remains in the Saunders. One bone about 18 inches in length was observed in the basal Saunders beds in section 6, township 50, range 25. Odd bone fragments have been observed in the Saunders in the area to the southeast towards north Saskatchewan river. Still further southeast in the Highwood area south of Bow river, vertebrate remains have been noted[45] in the Allison formation. This formation is at least in part the equivalent of the Saunders formation.

As yet no complete specimens have been found in the rocks of Montana age in the foothills, but the indications point to possibilities of finding good specimens and perhaps, ultimately, a better correlation with the Belly River series in eastern Alberta, that carries many fossil vertebrates in certain localities.

The exact age of the upper part of the Saunders is still undetermined, and as stated in Reports Nos. 6 and 9, it may be of Tertiary age. The whole series of continental deposits represented by the Saunders may be the equivalent of the Belly River, Edmonton and part of the Paskapoo formation represented in the plains of central and eastern Alberta. As yet sufficient evidence has not been obtained to substantiate this correlation, or to divide the Saunders beds into separate formations. This same problem appears to be characteristic of the whole foothills belt of Alberta for, as pointed out by Rose[46], the same difficulty is met with in the succession shown in the northern part of the Crowsnest coal field, where there are 10,000 feet of continental deposits conformably above what he calls the Allison formation.

No fossil animals have been found in the lower Saunders beds with the exception of the vertebrate remains mentioned above. In the upper beds, however, *Unio danae* occur in pockets of the sandstones. These have been found on Brazeau river in section 7, township 45, range 16, and are apparently stratigraphically high in the formation. The corresponding strata in this area occur along the northeastern edge of the map or probably east of the area shown as Saunders.

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[45]Rose, B., Geol. Surv. Can., Sum. Rept. 1919, p. 17C.
[46]Geol. Surv. Can., Sum. Rept., 1919, Pt. C, p. 17.

In this connection McEvoy[47] records the following fossils from exposures in a creek that joins the Athabaska about 6 miles east of Hardisty creek in township 51, range 25:

Physea copei.
Patula sp.
Zonites or *Conulus.*

He places the beds carrying these as equivalent to the Edmonton formation.

In summary the Saunders may be said to be a thick series of continental deposits represented largely by interbedded sandstones and shales, and this series may be the equivalent of all the Montana beds in the plains areas, as well as possibly some beds of Tertiary age.

QUARTERNARY.

PLEISTOCENE AND RECENT DEPOSITS.

The unconsolidated rocks in this area consist of boulders, gravel, sand, and clay of glacial and fluviatile deposition. Over most of the area there is a mantle of soil and unconsolidated rock which has been derived from the erosion of the underlying strata. In the major stream channels there are river flood plains composed of silt and gravel that are of relatively recent deposition. Such deposits are common along McLeod river, which in general has a valley that is wide at the bottom with a shallow stream channel which changes its course within the valley with periodic floodings. There are, however, no thick beds of fluviatile deposits on the sides of the valley of this stream.

The valley of the Athabaska has thick deposits of recent material throughout the whole part of the course shown on the accompanying map. Dowling[48] refers to the gravel terraces in the Athabaska valley above the entrance to Brule lake, and suggests that they may be correlated with the "Saskatchewan gravels",[49] as described by Dawson in southwestern Alberta.

The deposits of recent material in the Athabaska valley from the south end of Brule lake to the eastern edge of this map-area, consist of gravel and sands, often intimately mixed, but in some places one of the two forms dominates.

Fine lake silts extend along the east side of Brule lake practically continuously from the south end to the north. These are as much as 100 feet thick in places. They appear to have been deposited in part under water (Plate VII) when Brule lake was higher, but a part of the sand has been wind carried material. The abandoned Grand Trunk Pacific railway grade cuts through these sand deposits at several places, and the drifting of the sand in the grade gave considerable trouble in keeping the track clear. This is one reason why this part of the Grand Trunk grade was abandoned in the consolidation of the railway lines through the mountains.

47Geol. Surv. Can., Ann. Rept., Vol XI, 1898, Pt. D., p. 26.
48Geol. Surv. Can., Sum. Rept., 1910, p. 153, and 1911, p. 203.
49Bull. Geol. Soc. of Amer., Vol. 30, 1895, p. 31.

It is difficult to determine how far back from the shore of Brule lake these sands occur, since this part of the area is well covered with vegetation. The area shown on the map as covered with sands is believed to be the minimum. The recent deposits are not indicated on the map along Athabaska river below Brule lake because there are sufficient outcrops of the underlying formations to determine the boundaries of the formations and the underlying structure.

The transportation and deposition of these sands is going on at present. The south end of Brule lake is silting up rapidly and even during high water numerous sand bars are exposed. The strong winds coming down the Athabaska valley through the gap in the limestone ranges lift these sands and deposits them along the east shore of Brule lake.

From the mouth of Brule lake eastwards the recent deposits are mostly gravel deposits in the form of river terraces. The highest terraces show considerable stratification and sorting of the material into gravel, sand, and silt layers. A good example of this is well exposed for about half a mile west of the Grand Trunk bridge across Prairie creek in section 5, township 51, range 25. These appear to indicate lake deposits rather than river terraces, and some thin bands of lignite coal are present in the stratified deposits. The base of this deposit rests on the steeply dipping Saunders beds. The elevation of the contact is about 3,265 feet, which is about 30 feet higher than the present level of Brule lake.

From the north end of Brule lake almost to the mouth of Prairie creek the terraces are practically all on the north side of Athabaska river. From Prairie creek east beyond the border of this area there are well defined terraces on the south side of the river, as well as on the north. The station of Hinton on the abandoned Grand Trunk grade is built on one, and also Bliss station on a lower one. These terraces are composed largely of gravel, which is of excellent quality for railway ballast. (Plate VIII,A.)

Above the level of the Hinton terrace towards Prairie creek there is a concentration of sand with very little gravel in it. Both the Hinton and Bliss terraces extend east of the area mapped and have less gravel and more sand in them to the east.

It seems that during the past history of the Athabaska there was considerable laking of this stream in the vicinity of Bliss and Hinton, similar to present day conditions of the Athabaska west of Brule lake, and that during this laking large quantities of sand and gravel were accumulated, which were later resorted and deposited as river terraces while Athabaska river gradually cut its valley deeper. The only deposits that appear to be remnants of the laking and not resorted are those along the Grand Trunk grade near the mouth of Prairie creek. Most of the other recent deposits in the valley show evidence of river sorting and deposition.

CHAPTER VI.

ECONOMIC GEOLOGY.

The presence of coal in commercial quantities in this area is the chief basis of the industry. Two coal bearing formations are present, namely, the Kootenay and Saunders. The chief object of investigation from the economic standpoint has been to trace the coal-bearing strata from McLeod river and Coalspur districts north to Athabaska river.

The Kootenay and Saunders beds are separated by over three thousand feet of marine Colorado beds, thus the character of the coal in the two formations is different and they are discussed separately.

Kootenay Coal.—The general character and distribution of the Kootenay rocks is discussed in Chapter Five, and, as mapped, these rocks are all confined to one belt along the southwest part of the area.

The present day mining operations are confined to the southern end of this belt, at Cadomin, by the Cadomin Coal Company, Ltd., and at Luscar by the Luscar Collieries, Ltd. Considerable prospecting and development work was carried on to the northwest at the north end of Folding mountain. These prospects are locally referred to as the "Drinnan mine" or the "Drinnan prospects." The abandonment of the Grand Trunk railway line along the east side of Brule lake caused the cessation of development on these claims, so that they did not become actual producers.

At Cadomin the operations are believed to be confined to one seam. Since this location is in close proximity to Nikanassin range, the Kootenay beds have been intensely folded and broken so that the coal seams and associated strata are often repeated in section. The coal seam mined is repeated three times on the west side of McLeod river at Cadomin. These three occurrences of the seam appear to represent two limbs of a syncline nearest Nikanassin range to the south, and the third occurrence to the north is a limb of an anticline; the south limb of this anticline being the north limb of the syncline mentioned above. The crest of the anticline has been eroded away. In all cases the beds dip steeply to the southwest, being on the average overturned. The two outcrops of the seam forming the syncline are known as No. 3 (south) and No. 2 (north). The coal is mined from these through a rock tunnel driven in below the base of this syncline. No. 3 is overturned and dips 70 degrees to the southwest at McLeod river, but flattens out to the west in the mine workings to about 55 degrees. The Kootenay rocks in contact with the Paleozoic rocks in Nikanassin range to the south of No. 3 are overturned, and dip 45 degrees to the southwest. No. 2 is overturned and dips 30 to 35 degrees to the southwest. No. 1, the northern one of the three, is overturned and dips 70 degrees to the southwest.

The first mining at Cadomin was done on the east side of McLeod river, but these openings have been abandoned on account of fire. At present mining operations are confined to No. 3 and No. 2, on the west side of McLeod river. The coal property of this company extends east to the west headwaters of MacKenzie creek, which is about the southeast limit of the Kootenay rocks in this area, as they do not occur along the east face of Nikanassin range on the main branch of MacKenzie creek.

The seam mined at Cadomin averages 22 to 25 feet in thickness, but folding and faulting causes many local variations in thickness from this average. This seam at Cadomin lies about 700 feet stratigraphically above the conglomerate in the lower Kootenay beds. Adding to this the thickness of beds exposed below the conglomerate on Folding mountain, the seam is about 1,700 feet above the base of the formation.

Although Luscar is relatively close to Cadomin, the conditions are different structurally, and the mines at Luscar are at present working on seams that lie northeast of the Cadomin strike.

The structure across the Kootenay rocks at Luscar is in general a syncline. The southwest limb is overturned and carries the coal that is mined at Cadomin. Luscar is situated on the northeast limb, which has a fault contact with Colorado beds to the northeast. While the general structure is synclinal, the detailed structure appears to be complicated from the few exposures that are present. Undoubtedly there are many minor structures within this syncline which are important to mining operations, but the details of these can only be determined by prospecting, drilling and development.

While it is fairly certain that there is only one coal seam of commercial thickness at Cadomin, the prospecting and drilling at Luscar indicate several seams. The drill records of the Luscar Collieries show the presence of four thick coal seams in addition to several thinner ones. These four occur within less than 800 feet of strata. The uppermost one is called the *Jewel seam*, and is 42 feet thick. It is the one being mined at present by the company. Five hundred and sixty-five feet stratigraphically below this seam the drill records indicate a 49-foot seam, a 36-foot seam at 674 feet, and a 28-foot seam at 757 feet.

Drilling also indicates the presence of three seams 3 to 6 feet in thickness occurring within the first 400 feet of strata above the Jewel seam. There is a possibility that the occurrence of some of these thick seams below the Jewel is due to duplication of the strata through folding and faulting, but there is no reason why the Kootenay strata should not contain several seams of coal.

According to the records of the Alberta Mines Branch, the Cadomin Mine was opened on June 1st, 1917, and the Luscar Mine in 1921. The total output from the mines at Cadomin and Luscar up to the current year is approximately one and a half million tons.

Northwest of Luscar on the headwaters of Gregg river the Kootenay strata have been prospected, and most of the coal property in township 47, range 24, lying along the Luscar or Cadomin strike is held by different companies or private individuals. The general synclinal structure of the Kootenay rocks and numerous minor structures within this syncline are shown on Gregg river above Berry's creek.

Along Drinnan creek there are some coal outcrops on the south side of the creek opposite the south end of Folding mountain. These coal outcrops are the result of old prospects, and the thickness of the seams could not be obtained. Because of the relative inaccessibility of this part of the district, and the distance from the railway, it has not been prospected in recent years, so that its possibilities can only be inferred from what is known of the adjacent areas to the southeast and northwest.

The Drinnan prospects lie in the northern part of the area of Kootenay rocks. The prospecting was done prior to 1913, and since then erosion has concealed most of the evidence of coal seams. A private report made on this property when development was being done, states that there are four workable seams of coal in the series. According to stratigraphic sequence these are as follows:

No. 4 seam, 5-foot.
No. 3 seam, 12-foot.
No. 2 seam, 10-foot.
No. 1 seam, 12-foot.

Nos. 2 and 3 seams were tunneled and prospected for considerable distances along the strike and were proven to be continuous. The strata are overturned and dip about 65 degrees to the southwest. The Kootenay strata here form a part of the northeast limb of the anticlinal structure of Folding mountain. The heavy cover of lake silts and sands northwest of Folding mountain has concealed all the formations, so that the coal seams have not been proven to extend to Brule lake. Northwest in the area in which the Blue Diamond Collieries are situated, MacVicar[50] reports seven workable seams within 1,800 feet of strata. Five of these seams are each seven feet thick, one is 14 feet thick and another is 12 feet thick.

From all available data there appears to be several workable seams of coal in the Kootenay rocks. Where the area underlain by these rocks is narrow, owing to structural deformation such as at Cadomin or at the north end of Folding mountain, some of the coal seams may not be present, since only a portion of the formation has been brought to the surface.

In the area of Kootenay rocks lying between Luscar and the Drinnan prospect there should be a large quantity of coal available. This has been proven in some localities, especially in the area adjacent to Luscar. The belt of Kootenay rocks is on the

50Geol. Surv. Can., Sum. Rept., 1923, Pt. B, p. 37.

average much wider and less closely folded in this intervening area than either to the northwest at Drinnan prospect or to the southeast towards Cadomin.

Although sections were not exposed so that actual occurrences of coal could be observed, yet, from structural evidence, the writer is of the opinion that this undeveloped portion of the Kootenay rocks will probably prove to be the most productive part of the area in the future.

While it is realized that no new development of coal areas is warranted at present that would necessitate the construction of additional railway branch lines, it seems appropriate to mention here the accessibility of this part of the area, for consideration in the future. A part of this undeveloped area could be opened by extending the Luscar spur to the northwest, but this does not seem advisable since adverse grades would exist as soon as Gregg river drainage is reached, which is less than a mile west of Luscar. To the writer the most appropriate means of access is by way of McLeod and Gregg rivers. Already a spur railway line eleven miles long extends from Hargwen on the main line of the Canadian National Railway up McLeod river into township 51, range 22. This line could be extended up the McLeod to Gregg river, and up Gregg river to Drinnan creek without having to make extensive rock cuttings. For a part of the way there are good river flats that could be followed and no adverse grades would be necessary, and, in addition, the route as outlined is very direct, lacking many of the sinuousities common to stream courses in the foothills.

From the mouth of Drinnan creek a branching would be necessary. One branch would follow Gregg river to serve the coal areas at its headwaters. Another branch would follow Drinnan creek to the coal areas drained by it. Of these two, the one up Drinnan creek would be less costly, because of the broad flat valley this creek occupies all the way from Folding mountain to its mouth.

Up Gregg river from the mouth of Drinnan creek the route would be longer and more expensive to construct, as this stream valley is narrow and rugged, especially the upper part of the valley in the south half of township 48, and in township 47.

While the building of such a railway may be costly, it does not seem likely that this undeveloped part of the Kootenay will be opened by extending the railways already serving the southern end of the coal area. The suggested route has the advantage of a favourable grade almost all the way, relatively cheap to construct for this type of country, and is a very direct and short route to the main line of the Canadian National. In addition this line would permit the development of the Saunders coal mentioned below, which occurs along this route, both on Gregg and McLeod rivers.

Saunders Coal.—The Saunders formation of late Cretaceous age carries coal at several horizons within the formation. These horizons have been discussed in Reports No. 6 and 9 for the areas to the southeast, and it has been noted that the number of horizons and seams vary laterally in relatively short distances.

From observations made along Brazeau river it was found that the Saunders carried 5 coal horizons.[51] The sections in this stream have shown a greater amount of coal than any other so far observed by the writer in the area between North Saskatchewan and Athabaska rivers, although development work, prospecting and drilling have possibly indicated a greater amount of coal along the Alberta Coal Branch between Lovett and Coalspur.

The field programme for 1924 included the tracing of the Saunders coal beds from the Coalspur vicinity northwest to the Athabaska valley.

Coal was observed at a number of localities in this area, but it was difficult to determine its exact stratigraphical position with reference to the base of the Saunders formation. This is difficult to do in any exposure of the Saunders for two reasons. Firstly, the entire sequence is not exposed in any one place, and there is such a similarity of lithology throughout the thick series of beds, that key beds are hard to find which may be used to build up a columnar section from disconnected exposures that are frequently separated by faults. Secondly, there appears to be a rapid decrease in the thickness and number of coal seams from northeast to southwest across the strike of the formations. This same feature was mentioned in Report No. 9 as characteristic of the Saunders beds to the southeast of this area. This appears to be a general characteristic of the Saunders formation in the foothills belt.

The basal Saunders beds are almost always exposed in the more uplifted area adjacent to the mountains, and, as a rule, show no coal seams of commercial thickness. Thus 5,000 feet of lower Saunders beds on McLeod river in section 22, township 47, range 23, contain no coal seams. Whether the equivalent of these strata to the east carry coal is questionable, since they were not exposed, but from comparison with conditions that exist in the areas to the southeast, on Brazeau and Blackstone rivers, it is very probable that they have coal seams in them.

It was found on the Brazeau that at least some of the coal of the five horizons mentioned occurrs within 3,000 feet from the base of the formation, yet further upstream these lower Saunders beds were barren of coal seams of commercial thickness. Similar conditions occur in the Saunders beds exposed along Athabaska river from Prairie creek west, where there are no seams of commercial thickness or quality in the lower 10,000 feet of the Saunders formation. Coal seams of commercial thickness are known only along the northeast side of the area mapped as Saunders beds.

Three companies are mining these seams at the present time within this area. These are the Bryan Coal Company, Balkan Coal Company, and the Saunders Ridge Coal Company. The Balkan mine in section 14, township 49, range 21, has been operating since 1918. The Saunders Ridge Coal Company is new in the field, having taken over the property of the McLeod River Hard

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51Rept. No. 9, p. 48.

Coal Company at Mercoal, which was opened up in 1920, in section 25, township 48, range 22. The Bryan Coal Company is also new in the field, having done the preliminary development work during the summer of 1924, and started shipping in the fall of the same year. This mine is in section 15, township 49, range 21.

Other mines have operated in this area in the past, but these have been abandoned, namely, the Yellowhead Coal Company mines at Coalspur, in section 33, township 48, range 21, and in section 6, township 49, range 21.

The Balkan and Bryan mines are working in the same seam, which is believed to be the same one that was mined by the Yellowhead Company at Coalspur, and also the same as the one now being mined at Mercoal. At Balkan and Bryan mines the coal seams and associated strata dip 38 degrees to the northeast. This dip decreases to the northeast and the beds are practically flat-lying in section 36, township 49, range 21.

At Coalspur the beds dip southwest 55 degrees. The structure between Coalspur and the mines to the east is a broken anticline. From Coalspur to Mercoal the structure is synclinal, with Mercoal on the west limb. At Mercoal the coal seams and strata dip northeast 34 degrees.

From the sections exposed on McLeod river in township 49, range 23, and along the railway in the southern part of the area, it has been possible to estimate the stratigraphical position of this coal. It is estimated to be between 6,000 and 7,000 feet from the base of the Saunders formation. There are 5,000 feet of Saunders beds below the coal exposed on McLeod river in sections 8 and 17, township 49, range 23. West of this exposure of 5,000 feet there is approximately another 1,000 feet of beds before the conglomerate in the basal Saunders beds is exposed on Antler creek in section 5. This conglomerate is 600 to 700 feet from the base of the Saunders, so that 7,000 feet appears to be a reasonable estimate for the thickness of Saunders beds below the coal seams at the mines named above.

The following are the sections of the seams mined at the three localities mentioned:

Section at the Balkan Mine.	*Ft.*	*Ins.*	
Coal	2	5	No. 1 seam (not mined)
Clay, and hard shale	0	1	
Coal	2	5	
Shale and sandstone, about	10	0	
Coal	3	7	No. 2 seam (mined)
Clay and hard shale	0	8	
Coal	4	6	

The section taken at the Bryan mine during the opening development work in August, 1924, is as follows:

	Ft.	Ins.	
Coal, clean	6	0	No. 1 seam.
Shale and sandstone	8	0	
Coal	5	3	No. 2 seam.
Clay and shale	0	11	
Coal	5	0	

At Mercoal the section given on the mine plan is:

	Ft.	Ins.	
Coal	3	6	No. 1 seam.
Clay	0	6	
Coal	3	8	
Sandstone	1	0	
Coal with clay shale	1	4	
Coal	1	10	
Shale and clay	1	1	
Coal	1	5	
Clay and shale	1	4	
Coal	6	0	No. 2 seam.
Clay	0	8	
Coal	4	0	

Most of the mining has been done in No. 2 seam. Measurements made in 1924 at the face of the entries showed No. 2 seam to have in places 12 feet 8 inches of coal, with a 14-inch parting of clay and shale about the middle of the seam.

A thicker coal seam is known to occur at the three localities, but, on account of inferior quality, it is not mined. This seam lies stratigraphically below the one mined, and outcrops at Coalspur and at the Balkan mine. It has also been proven to be present at Mercoal by prospecting. A section made from prospecting work some years ago at Coalspur indicated a total thickness of 40 feet for this seam, with many thin partings of shale and clay.

There are several localities within this area where Saunders coal occurs, that are not adjacent to the railway, and thus have not been developed. The best information regarding these can be obtained along McLeod and Gregg rivers. The seams mined at Balkan mine and at Mercoal continue through to McLeod river in the surface rocks, but the seams once mined at Coalspur appear to have been faulted off somewhere between Coalspur and McLeod river.

The coal seams mined at Mercoal[52] cross McLeod river in L.S. 13, section 17, township 49, range 23. On the McLeod the coal seams dip 60 degrees to the northeast and strike north 80 degrees west. Although this dip is steeper than at Mercoal, structural

[52]Note: The coal mined at Mercoal is commonly spoken of as the "Mile 5" coal with reference to the approximate mileage of the mine on the branch line to Mountain Park.

evidence along McLeod river indicates that coal seams are continuous through the area between Mercoal and the river. A section of the coal exposed on McLeod river is as follows:

	Ft.	Ins.	
Coal	4	6	Presumably No. 1 seam at Mercoal.
Shale with sandstone	13	6	
Coal with a 12″ centre parting of clay	9	6	Presumably No. 2 seam at Mercoal.

The coal is the hardest member of the series exposed at the water's edge in this locality.

Saunders coal outcrops on Gregg river, just below the mouth of Teepee creek in section 23, township 49, range 24. This outcrop is in strike alignment with the coal on the McLeod and at Mercoal, but the section of the seam taken from the exposure does not correspond well enough to say that it is the same seam.

Section Exposed on Gregg River at the Mouth of Teepee Creek.

	Ft.	Ins.
Shale with clay	3	2
Coal with clay	0	3
Shale with clay	3	6
Coal, clean	1	0
Shale	4	6
Coal, with clay lenses	1	0
Coal, clean	3	0
Clay	0	2
Coal, clean	1	0
Shale footwall.		

No seams of commercial thickness have been observed in the area northwest of Gregg river in strike alignment with the coal on Gregg river, McLeod river, and at Mercoal. Its presence could only be determined by extensive prospecting or drilling, since the strike direction of the coal-bearing beds on the rivers mentioned would place any coal in the broad valley lying south, west of High-Divide ridge. This valley is covered with vegetation and there are no rock exposures. Some evidence of coal is shown on the small branches of Prairie creek about in the centre of township 50, range 25, but no thick seams are exposed. Some thin seams are exposed to the northwest in the Athabasca valley. In northwest quarter of section 34, township 50, range 26, a 2-foot seam is exposed on the abandoned Grand Trunk railway grade.

As stated above the structure at Coalspur is not continuous to the northwest as far as McLeod river, and thus the coal seams at Coalspur are believed to be buried at considerable depth on McLeod river.

The structure at the Balkan and Bryan mines is continuous northwest to Athabaska valley. Lack of exposures on the McLeod prevented the actual locating of the seams that are mined to the southeast at Balkan and Bryan mine, but from the evidence obtained it is believed that this coal crosses McLeod river.

Seams under two feet thick are exposed at the mouth of Gregg river and about a mile below this point on the McLeod. Indications of a thick seam are present on McPherson creek about two miles up from its mouth. Five feet of coal were observed in two places with no hanging or footwall exposed. Since no part of township 50, range 23, has been surveyed, the position of this creek is as yet undetermined, but the coal outcrop is believed to be approximately at the centre of the north end of this township.

On the Athabaska valley some coal indications have been prospected on Happy creek at the old Grand Trunk bridge in the southwest quarter of section 15, township 51, range 25. These prospects were reopened and extended in 1924, and in September the following section was exposed.

	Ft.	*Ins.*
Coal (partly decomposed by erosion)	0	6
Clay	0	2
Coal, clean	1	6
Clay	0	1
Coal	0	7
Clay with coal bands	1	0
Coal	1	2

Later reports from the prospectors in November, 1924, did not indicate that this is likely to be a workable seam.

In addition to the above occurrences some seams as much as two feet in thickness were observed on Prairie creek about a mile upstream from its mouth, and on a small tributary of this stream in section 1, township 50, range 26. This last occurrence lies in the east limb of the most western syncline of Saunders beds in this area.

Present conditions in the coal industry do not warrant the building of new railway lines or the extension of those at present in operation, in order to open up new coal fields carrying either Kootenay or Saunders coal, yet it seems advisable to consider the future possibilities of the undeveloped parts of this area.

The accessibility of the Saunders coal along McLeod and Gregg rivers was mentioned above in connection with that of the undeveloped Kootenay areas, that is, by an extension of the spur line from Hargwen up McLeod and Gregg rivers. The more immediate possibilities to consider are those along the main line of the Canadian National railway to the north. An obvious question is why are there so many mines along the branch line through Coalspur, and in addition good mining properties along McLeod and Gregg rivers, and yet not a single mine or favourable prospect has been opened in the Athabaska valley.

There appears to be two answers to this question. In the first place it is the writer's opinion that the Saunders formation does not carry as many thick seams of coal in the Athabaska valley district as it does to the southeast. It appears that this formation carries its maximum number of seams and maximum total thickness of coal in the area between Coalspur and the Brazeau river, and that both to the northwest towards Athabaska river, and to the southeast towards North Saskatchewan river, the coal content of the formation is less.

The second reason for lack of development along the Athabaska, seems to be due to the difficulty to locate seams in this valley because of the thick deposits of recent material as river terraces. These terraces occur in the lower part of the valley where stream erosion would be most active. Such deposits render ordinary prospecting methods almost useless, and the only means of obtaining valuable information would be by drilling.

The area west of the mouth of Happy creek does not seem to have any immediate possibilities, but to the east there should be good chances of finding seams of commercial thickness. To the writer the best method to prove this would be to locate the seams on the McLeod drainage in the vicinity of McPherson, Quigley, and High-Divide creeks. After locating seams on these creeks they should be traced in prospect pits and survey lines across the divide and down into Athabaska valley to the elevation of the gravel and sand terraces. From such information one could then select the best places in the valley for drilling and prospecting.

This procedure as outlined may be somewhat costly, but unsystematic prospecting in the vicinity of the railway in the valley of the Athabaska, with its heavy deposits of gravels and sands, will also be costly, and, over a large part of the area will give negative results.

Petroleum Possibilities.—The search for oil in the eastern part of this area was started a few years ago, and, although claims were staked over a rather large area in the vicinity of Coalspur and Mercoal, the only drilling done was that by the Imperial Oil Company near Coalspur.

The first well was located about a mile east of Coalspur station on the eastern limb of the broken anticline of Saunders beds. Unfavourable structural conditions were met with at depth in this well, and the drilling machinery was moved west nearer to Coalspur, and a new well was located in northwest quarter of section 34, township 48, range 21, on the west side of the structure. In August, 1924, the drill was still in the Saunders beds, and a considerable flow of gas had been struck. This was being used as part of the fuel for heating the boilers. The present drilling site is close to the centre of the anticlinal structure. It is difficult to say exactly where the centre is, and some geologists have held that the structure is anticlinal without being faulted. The evidence, however, obtained from McLeod river in township 49, range 23, and from Brazeau river[53] indicates that this anticline is broken.

From data collected at various points within the area the indications are that the new well in section 34, township 48, range

[53]Rept. No. 9, p. 9.

21, was started in beds that are stratigraphically about 2,000 feet above the base of the Saunders formation. Considering the average dip of the strata in the vicinity, a vertical hole at the present well would have to be put down at least 2,500 feet in order to reach the base of the Saunders formation. This is believed to be a minimum estimate, and structural conditions might increase this thickness.

Apparently the search for oil is based more on structure than on lithological character of the formations in this area. The Saunders beds are entirely non-marine, and their lithological character does not appear to be suitable as an oil reservoir. The Wapiabi shales underlying the Saunders stratigraphically, do not bear indications of petroliferous material in any of the surface exposures in the western part of the area. The Bighorn formation, which is about 2,000 feet stratigraphically below the base of the Saunders, does not appear to be petroliferous in itself, nor does it look like a good accumulation media, since the sandstones in it are very hard, fine grained, and low in porosity. The Blackstone formation below is probably the most likely formation of all the upper Cretaceous as a source of petroliferous material.

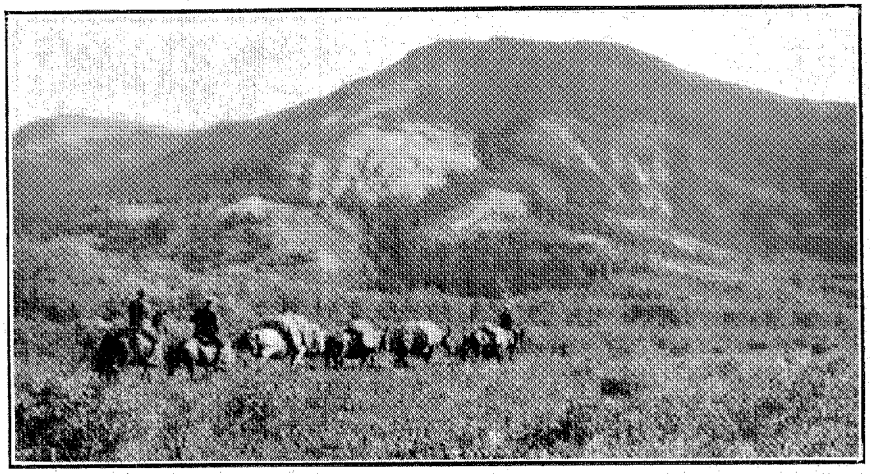
The present site of the Imperial Oil well was not located by chance, but as the result of the work of private geologists, and the writer does not wish to suggest that their location is not a good one, but, from a study of the whole area, it seems that better structural conditions are present west of Mercoal at the big bend in McLeod river in township 48, range 22, at the mouth of Beaverdam creek.

At this locality the structure is monoclinal, with practically flat-lying Saunders beds to the west up McLeod river and rather steeply dipping Saunders beds to the east of the axis. There is no evidence of faulting, and furthermore the base of the Saunders beds is believed to be less than 1,000 feet below the river at this point.

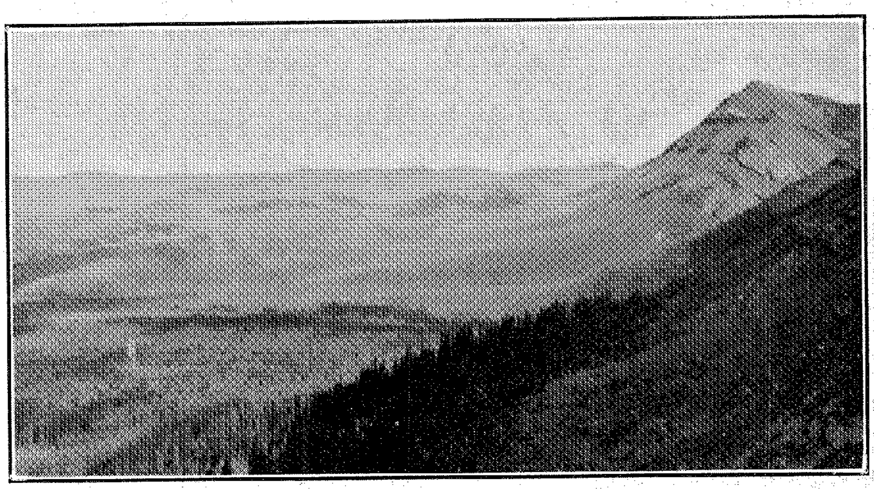
This monoclinal structure becomes anticlinal about five miles to the southeast, and Beaverdam creek lies on the west limb of this structure. Further evidence of the thinness of Saunders beds in this structure is shown on Pembina river, in township 46, ranges 20 and 21, where Colorado beds are exposed all the way along the stream course. On Antler creek, in section 5, township 49, range 23, the thick conglomerate, within 700 feet of the base of the Saunders, is exposed, and on Gregg river, in the centre of township 49, range 24, the uppermost Colorado beds are exposed.

Conglomeratic beds, presumably low in the Saunders formation, are exposed along the structural axis in section 12, township 48, range 22. This is further evidence of the thinness of Saunders strata on McLeod river.

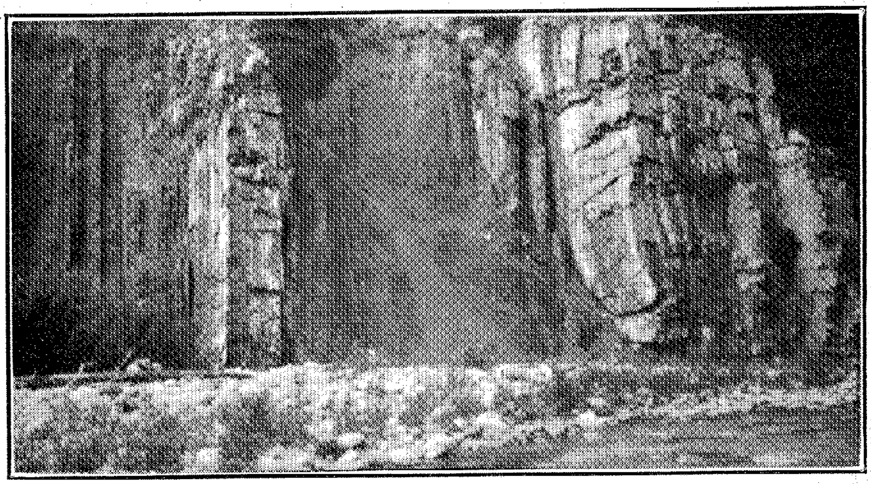
All the above evidence points to the fact that the base of the Saunders should not be more than 1,000 feet at the most below McLeod river, at the bend in section 11, township 48, range 22. The writer is of the opinion that this is the most favourable drilling site in the whole area mapped, being, in addition, favourably situated with respect to the railway.



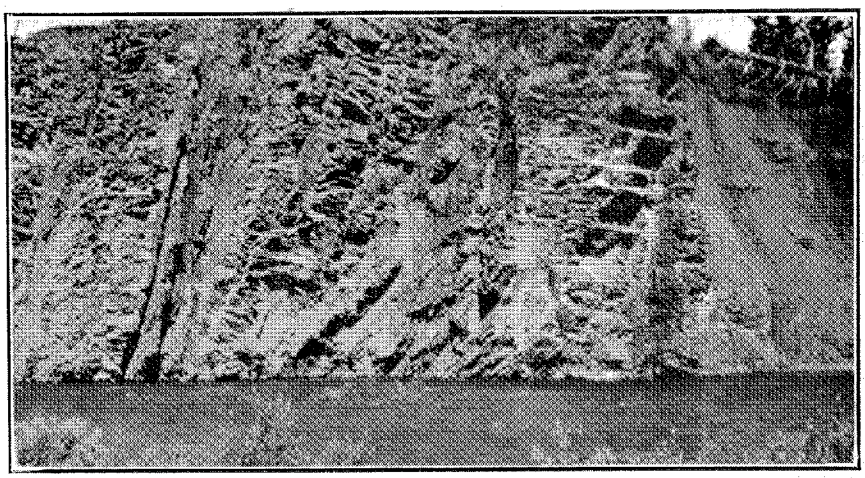
A. North end of Folding mountain from the Jasper Highway. The highest point of Folding mountain shown in the left background. Same as Plate II. The rocks on the face of Folding mountain are Paleozoic.



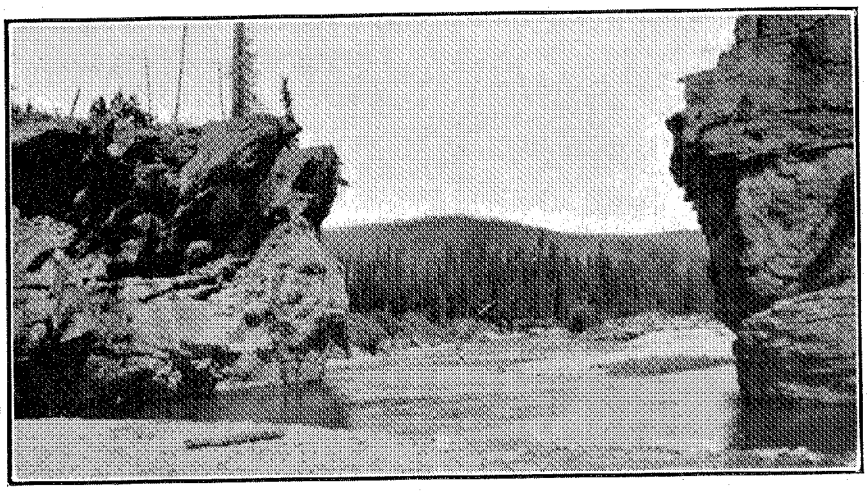
B. Looking east of the headwaters of MacKenzie creek. Nikanassin range on the right.



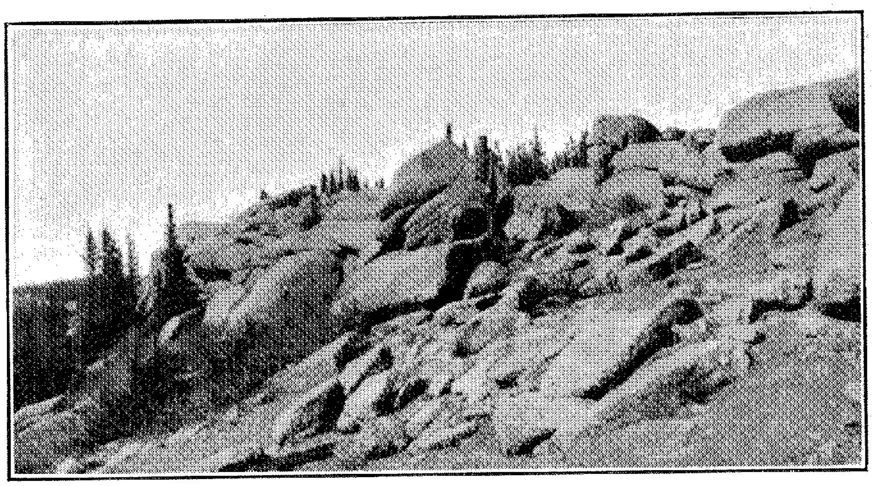
A. Bighorn formation showing hard sandstone interbedded with shale. Exposure on Gregg river, section 8, township 48, range 24.



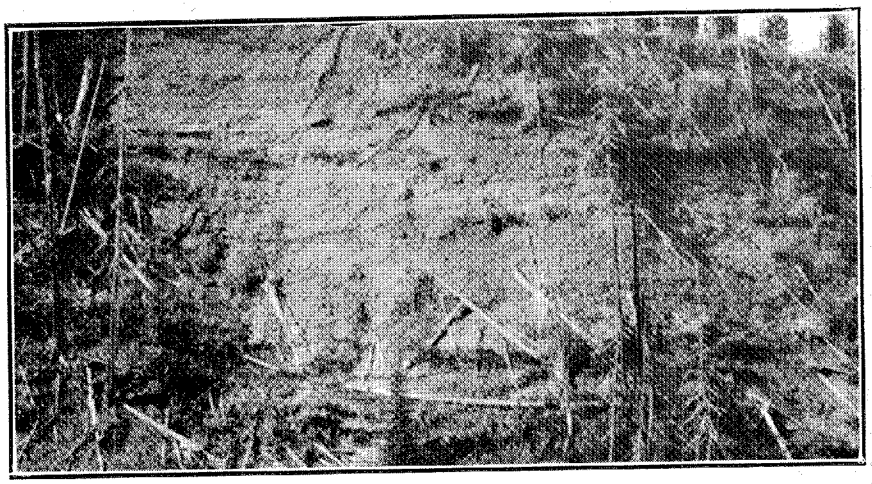
B. The base of the Saunders formation, showing massive sandstone overturned, with shale, apparently marine, on the right. McLeod river, section 22, township 47, range 23.



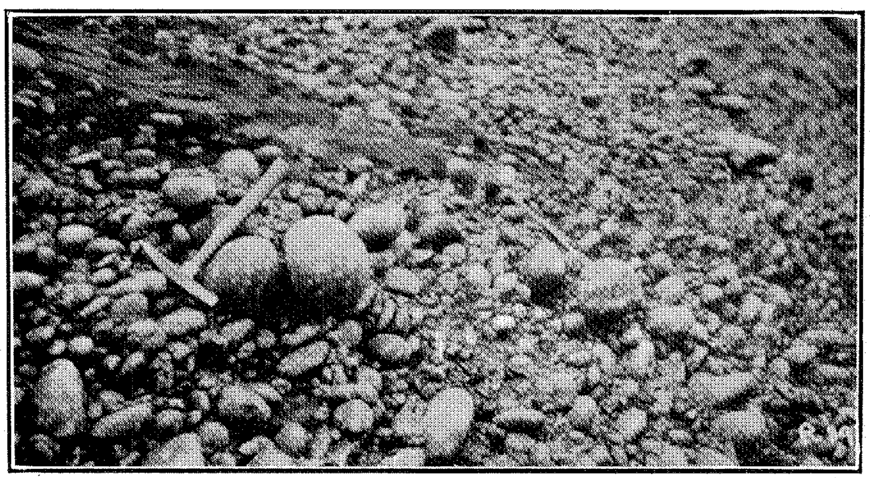
A. Conglomerate in basal Saunders beds at "Hell's Gate", McLeod river, section 22, township 47, range 23.



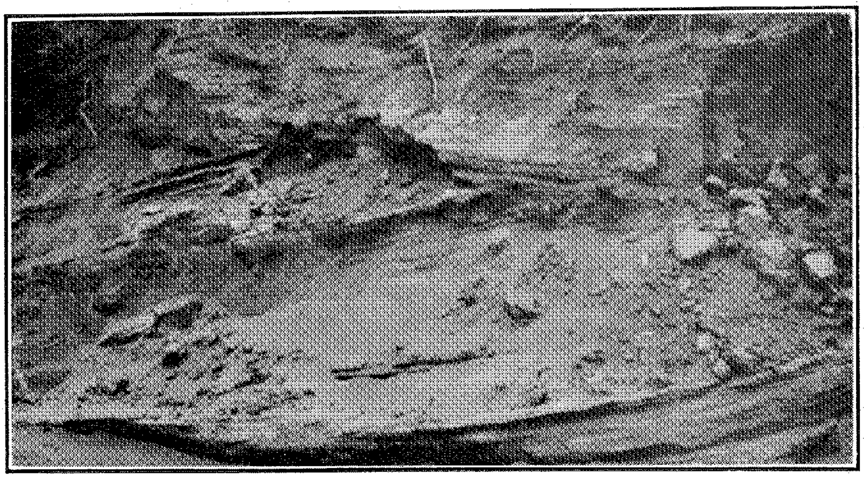
B. Conglomerate in basal Saunders beds capping the ridge in the east half of township 49, range 26.



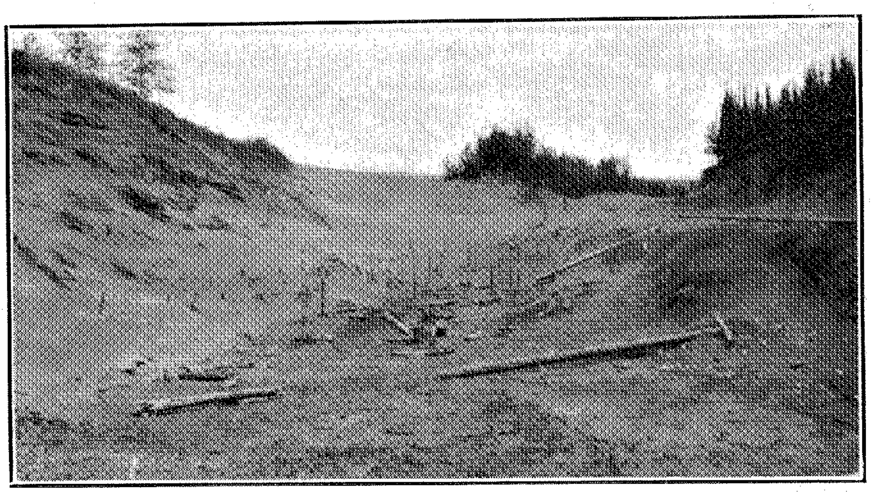
A. Conglomerate in upper Saunders beds exposed on the north end of High-Divide ridge, section 23, township 50, range 25.



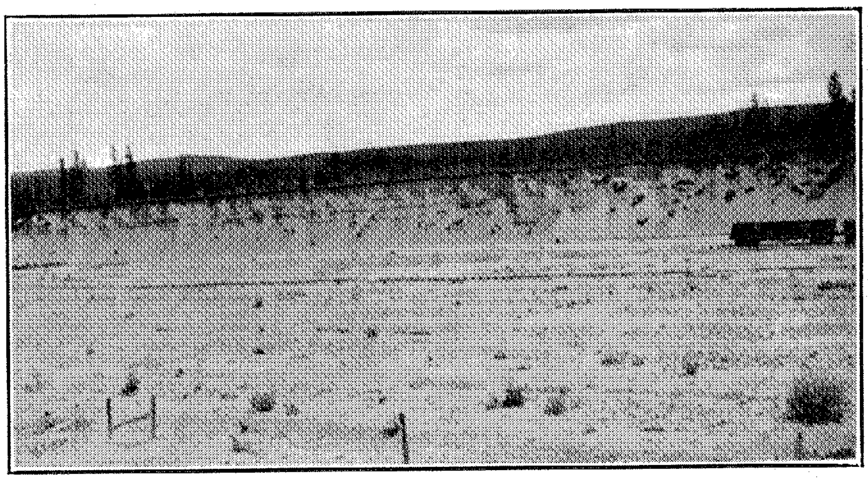
B. Enlarged view of same as VI,A.



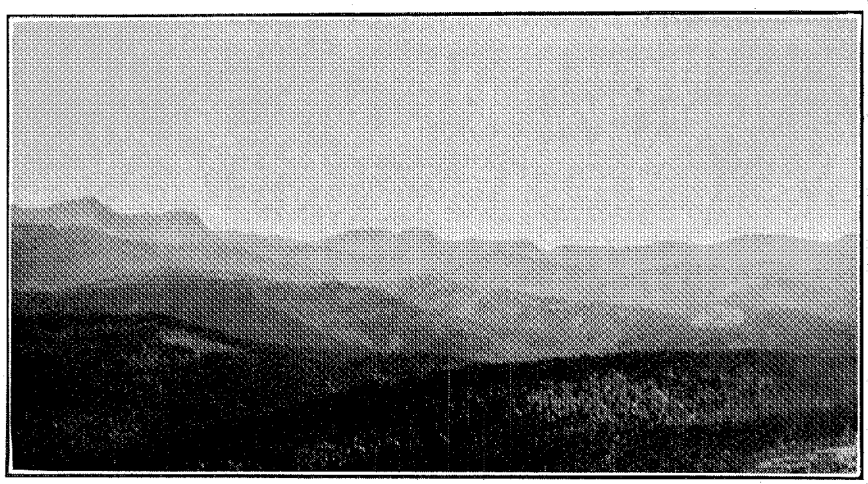
A. Recent deposits along Grand Trunk grade at north end of Brule lake, showing crossbedding.



B. Recent deposits at same position at VII,A. Showing remains of old trees that were once covered by the recent deposits.



A. Recent deposits as river terraces on Canadian National Railway at Hardisty Creek.



B. A general view of the foothills looking southwest from section 9, township 48, range 24.

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LIST OF PUBLICATIONS

OF

THE SCIENTIFIC AND INDUSTRIAL RESEARCH COUNCIL OF ALBERTA

ANNUAL REPORTS OF COUNCIL

Report No. 3 (for the calendar year 1920); pp. 36. **Price 5 cents.**

Report No. 5 (for the calendar year 1921); pp. 86. **Price 35 cents.**

Report No. 8 (for the calendar year 1922); pp. 64. **Price 35 cents.**

Report No. 10 (for the calendar year 1923); with 4-color map of Alberta coal areas; pp. 76. **Price 50 cents. Map No. 6 only, 15 cents.**

Report No. 12 (1924); pp. ....—Reviews the work done during 1924 under the auspices of the Research Council. This includes the analysis, screening, storage, and briquetting of Alberta coals, their use in domestic heaters, and for smithy purposes, and de-ashing of coal; geological investigations by survey of the foothills belt and the plains along the Red Deer valley, soil distribution in south-eastern Alberta, aluminium sulphate, placer gold near Smith, and changes in the map of Alberta coal areas; a field examination of the bituminous sands of Northern Alberta, and separation of the bitumen; the study of Alberta trees for use as mine timbers. **Price 35 cents.**

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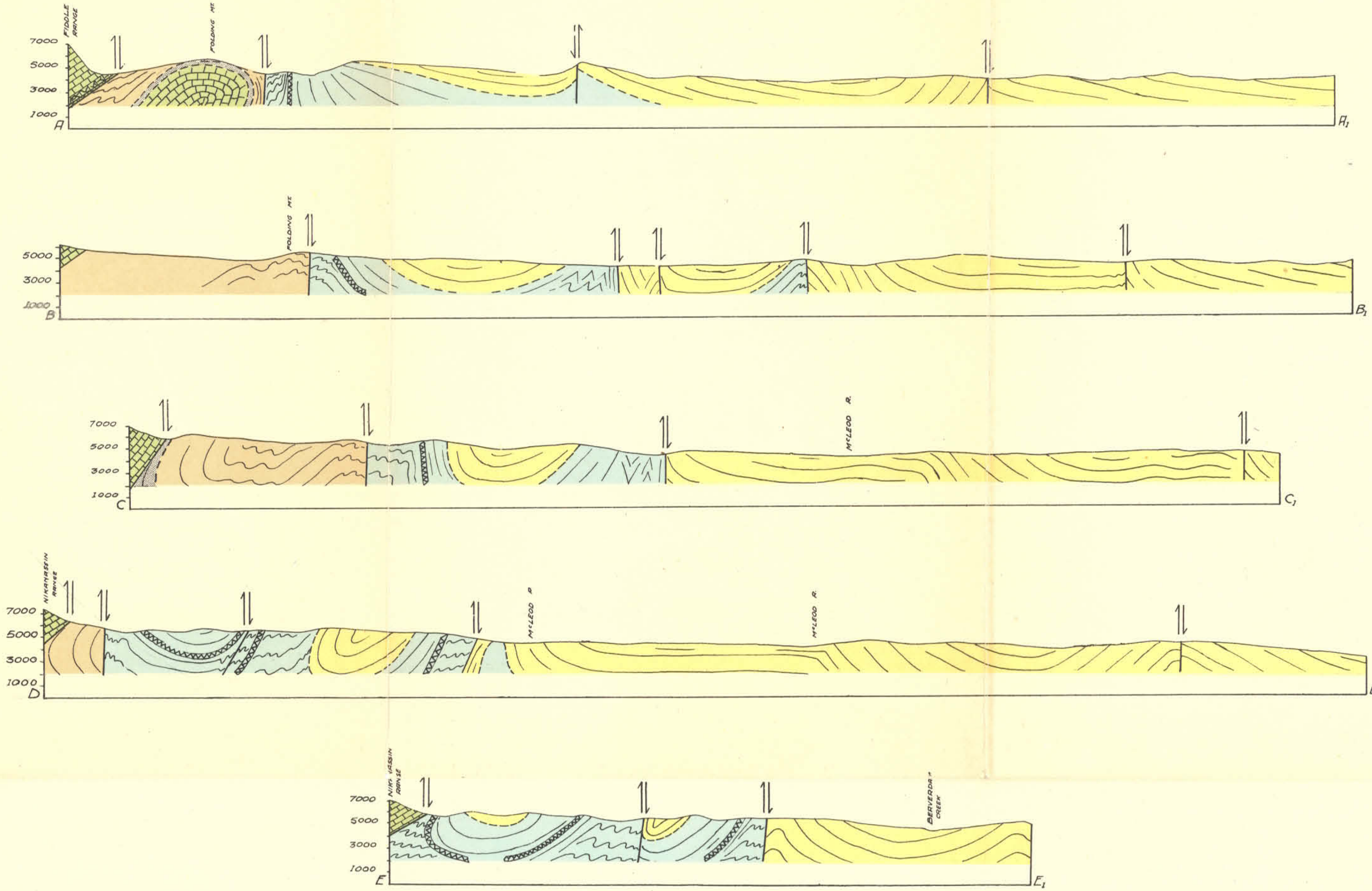
No. 9 (1923); GEOLOGY ALONG BLACKSTONE, BRAZEAU AND PEMBINA RIVERS IN THE FOOTHILLS BELT, ALBERTA, by J. A. Allan and R. L. Rutherford; pp. 48, and 6-color map (Serial No. 5). Continuation of the field work in the area described in Report No. 6. **Price 75 cents.**

No. 11 (1924); GEOLOGY OF THE FOOTHILLS BELT BETWEEN McLEOD AND ATHABASKA RIVERS, ALBERTA, by R. L. Rutherford; pp. 61, and 8-color map (Serial No. 7). One inch to two miles. Continuation of the area described in Report No. 9. **Price 75 cents.**

SCIENTIFIC AND INDUSTRIAL RESEARCH COUNCIL OF ALBERTA. REPORT No. 11 BY R. L. RUTHERFORD

PLATE No. 1

STRUCTURE SECTIONS



TO ACCOMPANY MAP NO. 7.

SCALE — 1 INCH = 10,560 FEET. DATUM = SEA LEVEL

Map 7

Scientific and Industrial Research Council of Alberta

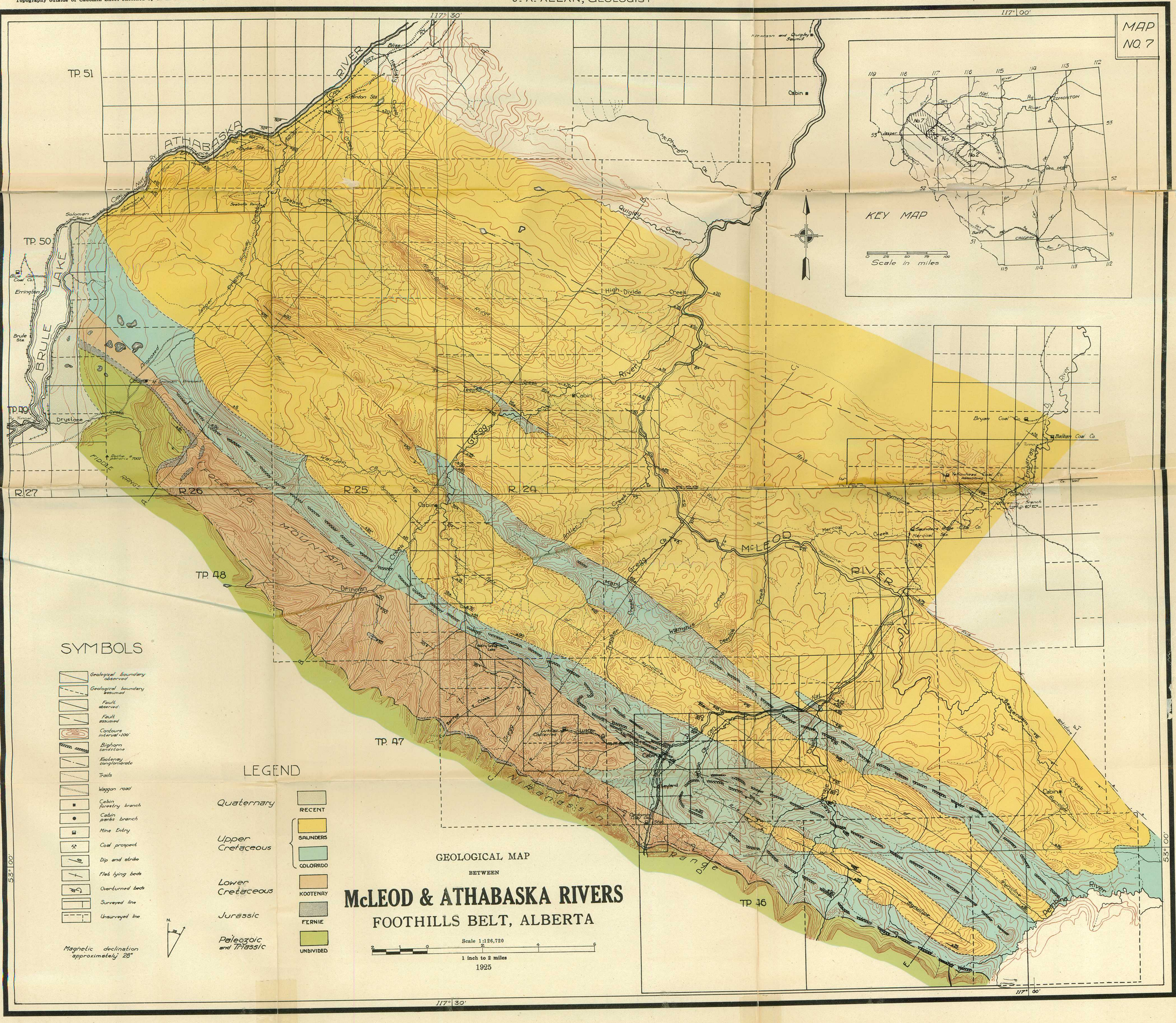
HONOURABLE HERBERT GREENFIELD, CHAIRMAN

Geological Division

J. A. ALLAN, GEOLOGIST

Base Map compiled from surveys by:
Dominion Forestry Branch.
Topographical Survey of Canada.
Topographical Division, Geological Survey, Cadomin Sheet.
Topography outside of Cadomin Sheet sketched by R. L. Rutherford, 1924.

GEOLOGY by R. L. Rutherford, 1924
To accompany Report No. 11, 1925.



GEOLOGICAL MAP

ALONG

BLACKSTONE, BRAZEAU AND PEMBINA RIVERS

FOOTHILLS BELT, ALBERTA

BY

JOHN A. ALLAN and R. L. RUTHERFORD

Scale 1 : 126,720 or 1 inch to 2 miles

ISSUED BY

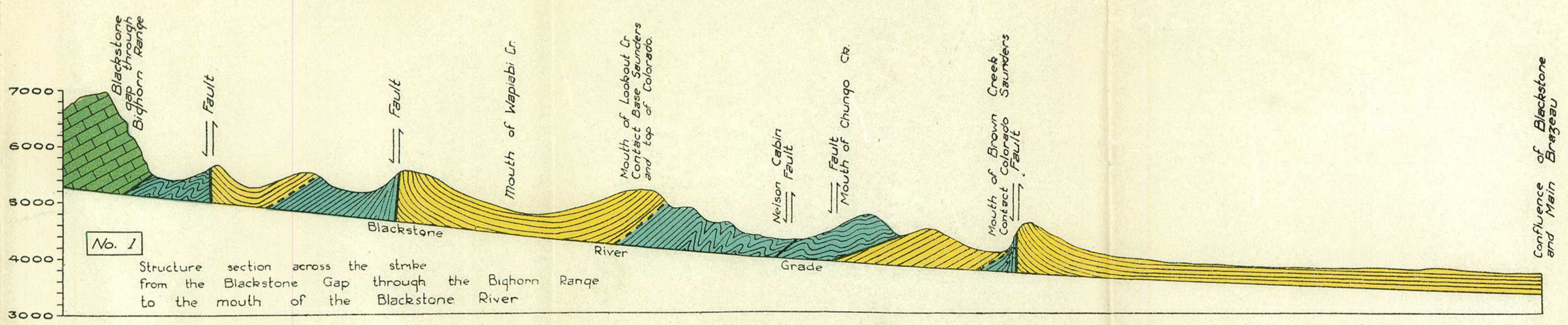
Scientific and Industrial Research Council of Alberta

HONORABLE HERBERT GREENFIELD, Chairman

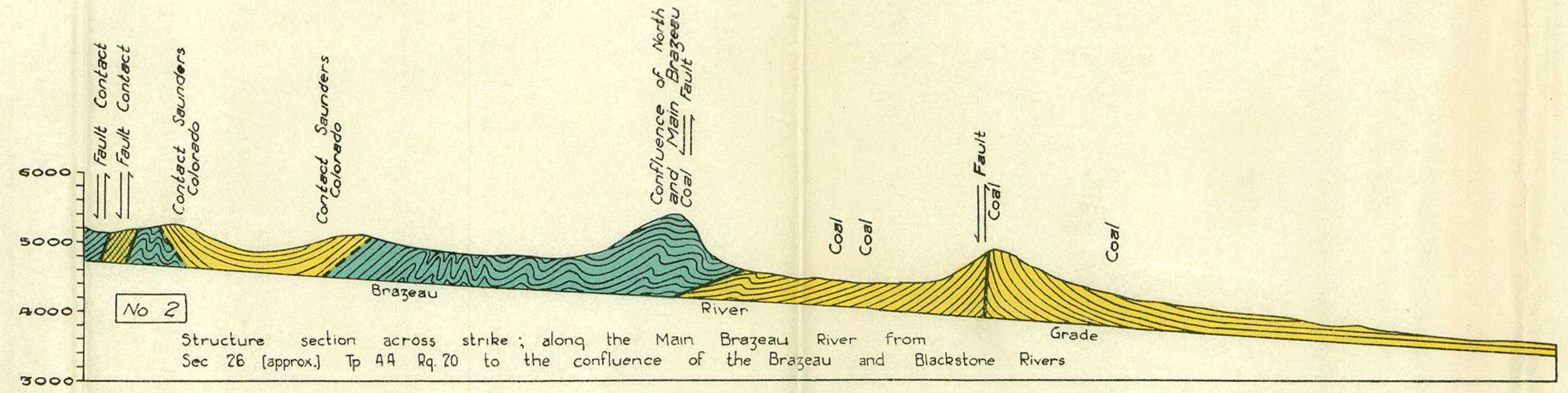
1924

To accompany Report No. 9,
by J. A. Allan and R. L. Rutherford.

Base Map compiled from Surveys by Dominion Forestry Branch and Topographical Surveys Branch.
Topography sketched in interstream areas and from river surveys.
Geology—1923.



Structure section across the strike from the Blackstone Gap through the Bighorn Range to the mouth of the Blackstone River

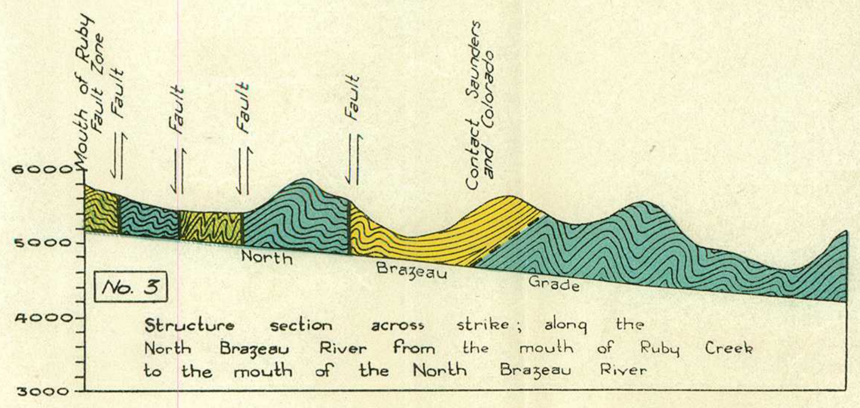


Structure section across strike; along the Main Brazeau River from Sec 26 [approx.] Tp 44 Rg 20 to the confluence of the Brazeau and Blackstone Rivers

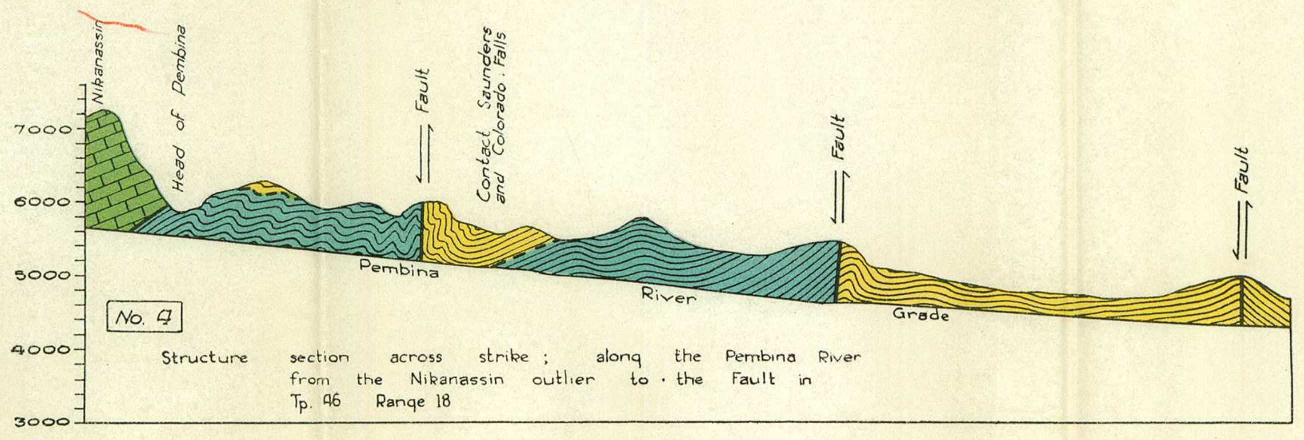
ERRATUM

By an error in drafting, all the arrow signs on the profile sections, except the most westerly one in No. 2, and the second from the west in No. 3 section, show relative movement in the wrong direction.

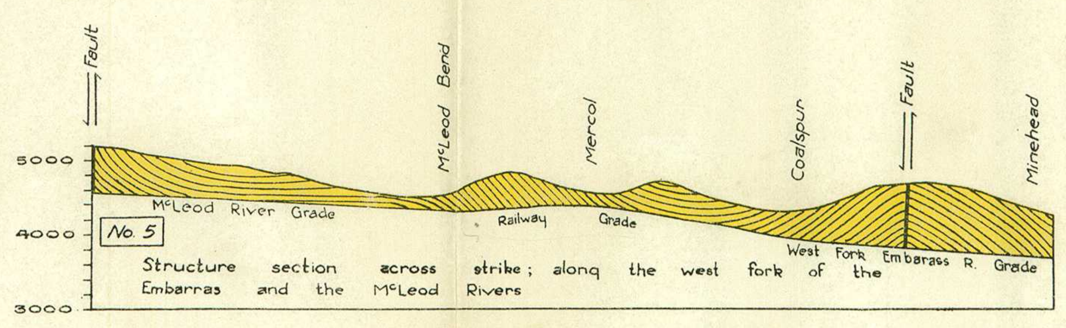
ATTENTION REQUESTED



Structure section across strike; along the North Brazeau River from the mouth of Ruby Creek to the mouth of the North Brazeau River



Structure section across strike; along the Pembina River from the Nikanassin outlier to the Fault in Tp. 46 Range 18



Structure section across strike; along the west fork of the Embarras and the McLeod Rivers