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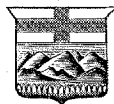
Geology Along the Blackstone, Brazeau and Pembina Rivers In the Foothills Belt, Alberta

BY

JOHN A. ALLAN
AND
RALPH L. RUTHERFORD

UNIVERSITY OF ALBERTA
EDMONTON, ALBERTA

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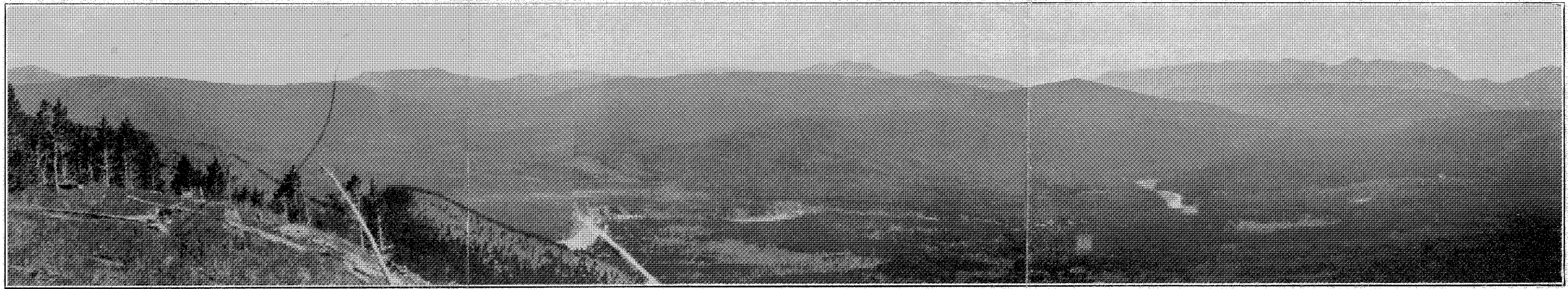


PLATE I. Panoramic view across Blackstone valley from ridge in section 13, township 42, range 17. Bighorn range in the background. (Frontispiece).

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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LETTER OF TRANSMITTAL

HONOURABLE HERBERT GREENFIELD,

Premier of Alberta,

Edmonton, Alberta.

SIR:—I have the honour to transmit herewith a report entitled, "*Geology along Blackstone, Brazeau and Pembina rivers in the Foothills Belt, Alberta,*" prepared in cooperation with Dr. R. L. Rutherford.

This report deals with the geology of the foothills west and north of the Saunders creek and Nordegg coal areas which were surveyed in 1922 and discussed in the Fourth Annual Report. The area examined extends from North Saskatchewan river on the south, to McLeod river on the north. The distribution and structural relations of the Kootenay and Saunders coal-bearing formations, and the intervening beds of the Colorado formation, have been determined and mapped. The report is accompanied by a geological map in six colors on a scale of 1 inch to 2 miles.

The field investigation has connected the Nordegg coal basin with the Bighorn coal basin to the west, and has also determined the structural relations between the coal seams mined at Saunders creek and those on the Alberta Coal Branch south of Coalspur.

It is the intention to complete the survey in the vicinity of Coalspur and Cadomin, and also to extend these field investigations to the Athabaska river and northwards into the Smoky river coal fields which are known to be extensive and important.

All of which is respectfully submitted.

Yours truly,

JOHN A. ALLAN.

Department of Geology,

University of Alberta,

Edmonton, February 16th, 1924.

TABLE OF CONTENTS

	Page
CHAPTER I.	
Introduction	1
General statement	1
Object of investigation	1
Geographical position	1
Field work and preparation of map	2
Previous work	4
Acknowledgements	4
CHAPTER II.	
General Geology	6
Table of formations	7
CHAPTER III.	
Structural Geology	9
General Statement	9
Local	9
Structure sections	11
Structure along the Saskatchewan river	11
Blackstone section (No. 1)	12
Main Brazeau section (No. 2)	13
North Brazeau section (No. 3)	14
Pembina section (No. 4)	15
McLeod section (No. 5)	16
CHAPTER IV.	
Physiography	17
Topography	17
Drainage	18
Flora and Fauna	20
Flora	20
Fauna	21
CHAPTER V.	
Descriptive Geology	22
General statement	22
Cretaceous formations (Table)	22
Kootenay group	23
Definition	23
Distribution	23
Lithological character	24
Petrography	24
Deductions and conclusions	27
Thickness	28
Colorado group	28
General statement	28
Distribution	29
Lithological character	29
Section of Upper Colorado	31
Petrography	31
Conditions of sedimentation	32
Montana group	33
Saunders formation	33
Definition	33
Distribution	33
Lithological character	34

TABLE OF CONTENTS—*Continued*

	Page
Petrography	34
Deductions and conclusions	36
Summary of Montana group	37
Quaternary	38
Pleistocene and recent	38

CHAPTER VI.

Economic Geology	40
General statement	40
Kootenay coal	40
Saunders coal	42
Table of coal horizons	48

ILLUSTRATIONS

MAPS AND SECTIONS

Map No. 5.	Geological Map. Vicinity of Blackstone, Brazeau, Pembina, and McLeod rivers in foothills belt. Scale 1: 125,000 (1 inch to 2 miles)	In pocket
	Profile sections along rivers:—1. Blackstone; 2. Brazeau; 3. North Brazeau; 4. Pembina; 5. McLeod. Vertical scale 1 inch to 2,000 feet. (Attached to map).....	In pocket

PHOTOGRAPHS

Plate I.	Panoramic view, looking up Blackstone river and Lookout creek, showing the Bighorn mountains in the distant background	Frontispiece
Plate II.	A. The south end of the Bighorn range, looking northwest from the mouth of Tepee creek. Mat-herbage in the foreground	8
	B. Nikanassin outlier, east of Cadomin, looking south across mat-herbage plain	8
Plate III.	A. Steeply dipping Saunders beds on the Blackstone in section 18, township 42, range 18, west of the 5th meridian	12
	B. Kootenay and Colorado beds on Brazeau river, section 26, township 44, range 20	12
Plate IV.	A. Bighorn (left) and Wapiabi (right) formations, on the Blackstone near the mouth of Lookout creek	30
	B. Wapiabi shales on blackstone near Lookout creek	30
Plate V.	A. Falls on Pembina river made by basal Saunders beds	36
	B. Lense of sandstone in coal seam at mile 53.5 Coal Branch	36
Plate VI.	A. Ponds in glacial moraine in the Brazeau valley	38
	B. Post-glacial valley of the Brazeau cut through Colorado shale in section 6, township 45, range 18. Herd of elk crossing bar in centre of picture	38

Geology Along the Blackstone, Brazeau and Pembina Rivers in the Foothills Belt, Alberta

By

JOHN A. ALLAN and RALPH L. RUTHERFORD.

CHAPTER I.

INTRODUCTION.

General Statement.—The coal resources of the province are annually becoming more important and the need of field investigations on the coal deposits more apparent. The coal production for the year of 1923 is represented by the record output of 6,884,538 tons or over three-quarters of a million tons more than in the previous year.

The geological survey of the foothills belt from North Saskatchewan river towards the Athabaska was continued in 1923. This is the fifth annual report on the mineral resources of Alberta and it contains the results of field investigations in the area west and northwest of the area discussed by the writers in the fourth annual report.¹

Object of Investigation.—The field work of 1922 in the Saunders Creek and Nordegg Coal basins was continued to the west to connect with the Bighorn basin, previously worked out by Malloch,² and to the northwest. In this survey the structural and lithological relations of the various formations were established insofar as it was possible to do so without the aid of a detailed map. Special attention was given to the coal-bearing formations with respect to their age, thickness, lateral persistence and continuity. The principal object of the field investigation in 1923 was to map out to the northwest the extent of the coal measures now being developed about Saunders creek and Nordegg, and if possible to connect them with the coal measures in the drainage systems of Pembina and McLeod rivers where considerable development has taken place.

Geographical Position.—The area discussed in this report and included on the accompanying geological map (No. 5) is situated in the disturbed belt known as the foothills of Alberta, between 116° and 117° west longitude. This area includes part of townships 39 to 49, ranges 16 to 23, west of the fifth meridian, and is crossed by the eleventh, twelfth and thirteenth base lines. The southern bound-

¹Allan, J. A., and Rutherford, R. L., "Saunders Creek and Nordegg Coal Basins." Fourth Ann. Rept. Min. Res. Alberta, 1922, Part I, Edmonton, Alberta.

²Malloch, G. S., Geol. Surv. Can., Memoir 9 E, 1911.

dary is the North Saskatchewan river between the Bighorn range and the western side of Map No. 2, which accompanies the fourth annual report. The McLeod and the west fork of the Embarras river between Cadomin on the west and Minehead on the east form the northern boundary.

The western limit of the area mapped is the Bighorn range in the south (Plate II, A.) and a Paleozoic outlier east of Mountain Park on the north (Plate II, B.) This outlier is a branch of the Nikanasin¹ range which it joins north of McLeod river. This outlier terminates north of the north branch of Brazeau river, but it is in alignment with the trend of the Bighorn range which terminates south of the main Brazeau river.

The most easterly point on the map is the confluence of the Blackstone river with the Brazeau in township 44, range 15. A line drawn N.45° W. from the junction of these two rivers defines the northeastern boundary of the map and also represents approximately the position of the structural change from foothills to plains upland.

The area mapped includes a belt with a northwesterly trend approximately 65 miles long and 25 miles wide, or about 1,625 square miles. This foothills area is accessible by two branch lines of the Canadian National Railway. In the south the Brazeau branch extends from Stettler west through Red Deer, Rocky Mountain House, to Brazeau station², where the Brazeau Collieries are situated. This branch has been surveyed and the right-of-way cut out to the northwest through Blackstone gap to the Bighorn coal basin.

Access to the northern end of this area is by the Alberta Coal Branch, which leaves the main transcontinental line at Bickerdike 138 miles west of Edmonton. From Coalspur, mile 37, the Alberta Coal Branch extends southeast to Lovett at mile 56. The Mountain Park Coal Branch, formerly built by the Mountain Park Coal Co., but now operated by the Canadian National Railway, extends westward from Coalspur by a sinuous line over a divide and up McLeod river to Cadomin (mile 24), and to Mountain Park (mile 32). The area between the North Saskatchewan and McLeod rivers is traversed by pack trails established and maintained by the Canadian Forestry Branch.

Field Work and Preparation of Map.—The data upon which this report is based were obtained in the field between May 20th and Sept. 15th. The junior author was in charge of the field survey and with three men and a pack train travelled over 600 miles of trail. W. G. Jewitt, a graduate in mining geology, gave efficient service as assistant geologist and draftsman. The pack train was looked after by W. E. deMille, assisted by Geo. C. Haworth, who also proved himself capable and efficient in attending to culinary duties.

The greater part of the field season was spent in traversing and compiling data from the major streams and the larger tributaries where almost continuous sections are exposed. Outcrops in the inter-

¹Cree for "Outer range." Dowling, D. B., Geol. Surv. Can., Summ. Rept., 1909, p. 140.

²The post office is Nordegg which was formerly the name of this station.

stream areas are not abundant. In some parts of the area the extent of some of the formations has been indicated only by the physiography.

West of Nordegg, in the southwestern part of the map, this survey was carried to the easterly face of the Bighorn range. Early in the season a traverse was made through the Bighorn coal basin for the purpose of examining the Cretaceous strata and of correlating these formations with those exposed in the area discussed in this report to the east and north. The traverse was also extended along the headwaters of Blackstone river from the gap to the divide, and northward to *Dowling ford* which crosses Brazeau river in township 42, range 20. On account of the extraordinary heavy rainfall during the field season several trails were impassable, and the water in the Brazeau was so high that it was necessary to use Dowling ford, which is west of the area mapped.

The senior author spent about six weeks with the party in the foothills field, and in addition visited various localities throughout the province collecting data for a geological map of Alberta which he has in the course of preparation. He also spent some time working out the core of salt well No. 2, drilled at Waterways, and correlated the results with those obtained from well No. 1, at McMurray. A report on this work is included in the Fourth Annual Report of the Scientific and Industrial Research Council of Alberta for 1923.

The geological mapping has not yet been completed in the northwest corner of the accompanying map, but it is the intention to complete the survey early in the field season of 1924.

On account of the lack of a topographical map of the area examined it was necessary to spend some time in determining the approximate position of many points, and in sketching the more pronounced physiographical features. The results of this part of the work are shown by the sketched contour lines which have been placed on the accompanying geological map, but which must of course be regarded only as approximately correct.

Through the kindness and cooperation of the Dominion Land Surveys Branch and the Forestry Branch, Ottawa, the details on the topography along portions of the Brazeau, north Brazeau, Pembina and McLeod rivers were obtained and have been added to the map. Much geographical data have been incorporated from the maps of the Clearwater and Brazeau forest reserves compiled by the Forestry Branch. The geographical precision is not uniform over the whole area shown in the map accompanying this report. This is due to the fact that to date accurate traverses have been made only along major streams such as Blackstone, Brazeau and Pembina rivers. On the other hand the position of such streams as Brown and Chungo are only indicated in a general way and cannot be regarded as accurately placed.

In preparing the base for the accompanying map (No. 5) an attempt has been made to incorporate the most accurate data available. One particular correction has been made that has not been previously shown on any published map. In township 45, range 18, the Brazeau and Pembina rivers at one point come within a distance

of two miles of each other. There seems also to be some difference in the data obtained as to the exact position of McLeod river and the railway in township 47, range 23. The position of the river as shown on the accompanying map has been obtained from railway and government surveys. During the past summer a resurvey of part of this township has been made by the Dominion Topographical Surveys Branch, but the results of this survey are not yet available.

The geology was mapped in the field on a scale of two inches to one mile. The information obtained in the field and from mine and railway surveys has been published on a scale of one inch to two miles on the accompanying map (No. 5).

Previous Work.—In 1898 McEvoy¹ made a reconnaissance survey of the "Yellowhead Pass Route" in which he briefly refers to some of the drainage features in this map-area.

Previous to the construction of the branch lines of railway into the Coalspur and Cadomin coal fields, the earliest geological work was carried out by Dowling² in 1909. In this report Dowling discusses the general geological characteristics in the coal fields south of the Grand Trunk Pacific Railway, now part of the Canadian National railway.

In 1916 Stewart³ made a traverse from Nordegg to Lovett and Coalspur. Much of his report deals with the geology in the vicinity of Brazeau collieries and Nordegg. On page 100 of this report a few remarks are made on the Pacific Pass Colliery which was then in operation at Lovett.

Allan⁴ in 1920 visited the coal mines then in operation between Coalspur and Lovett. His report gives data concerning the seams at the various mines and a few general remarks regarding the structure of the basin.

Dowling revisited the northern part of this area in 1922 and in his report⁵ briefly discusses the coal seams and structure in the vicinity of the mines.

In addition to the above, considerable geological work has been conducted in this area by private interests. The structure in the vicinity of Coalspur and to the southeast stimulated this investigation in a search for oil. This information is not available for public use.

Frequent reference is made to the geology of the Bighorn Coal basin which lies west of the area discussed in this report. This basin was reported on in 1911 by Malloch⁶.

Acknowledgments.—The authors have pleasure in recording their thanks and appreciation to various mine and government officials for the assistance and courtesy shown. The information, assistance and accommodation supplied by Mr. John Shanks, General

¹McEvoy, J., Geol. Surv. Can., Ann. Rept., Part D., 1898, pp. 1-44.

²Dowling, D. B., Geol. Surv. Can., Summary Rept., 1909, p. 139.

³Stewart, J. S., Geol. Surv. Can., Summary Report, 1916, p. 94.

⁴Allan, J. A., 2nd Ann. Rept., Min. Res., Alberta, 1920, p. 50.

⁵Dowling, D. B., Geol. Surv. Can., Summ. Rept., Part B., 1922, p. 101.

⁶op. cit.

Manager Brazeau Collieries, Nordegg, were much appreciated by all members of the party when working in the Nordegg district. Special thanks are offered to Mr. W. Shankland, Forest Supervisor at Nordegg, for his courtesy and for the storage of saddles and other camp equipment at headquarters; and to Mr. D. M. MacKenzie, Supervisor of the Forestry Branch at Coalspur for various kindnesses. Mr. Thomas Horne, provincial mine inspector for the Coal Branch and Cadomin district rendered valuable assistance. Among the mine officials thanks are due for information supplied and courtesies shown by Mr. Wm. Onions and Mr. Wm. Duggan, Foothills Collieries; Mr. F. L. Hammond and Mr. J. McMillan, Cadomin Coal Co.; Mr. W. B. Hetherington, Luscar Collieries; Mr. J. R. McDonald, Leyland; Messrs. J. G. Scott and W. P. Beak, at Mercor, and Mr. L. Stupor, at Minehead. Without the assistance and cooperation of those carrying on mining operations in the district much valuable information would not have been obtained.

CHAPTER II.

GENERAL GEOLOGY.

A brief outline of the geological succession is given here as a basis for the following discussions on structure and physiography.

Rocks of Mesozoic age and belonging chiefly to the Cretaceous, occupy the area discussed in this report. Paleozoic rocks border this map-area on the west, but these have not received any special attention by the writers. Beds of Jurassic age do not outcrop in this part of the foothills, but some observations were made on these strata in the Bighorn area to the west.

The Cretaceous rocks are represented by three lithologic groups. The lowest group consists of sandstones and shales of continental or fresh water deposition. These are overlain by a group of strata that are mostly dark marine shales. The uppermost group consists of a series of sandstones and shales of continental deposition, representing a return to conditions somewhat similar to those that prevailed during the deposition of the lowest 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.

			Along the Blackstone, Brazeau and Pembina rivers; Foothills belt.		Bighorn Coal Basin 1	Moose Mountain 2	S.W. Alberta 3	Highwood Coal Area 4	Crowsnest Coal Field 5
		Group	Formations						
CENOZOIC	Quaternary			Glacial and Fluvialite	River drift Glacial deposit		Alluvium and Glacial drift		
	Tertiary						Porcupine Hills fmt. Willow Creek fmt. St. Mary River fmt. Bearpaw fmt. Belly river fmt.	St. Mary River?	
MESOZOIC	Cretaceous	Montana	Saunders	Upper member Lower member	Brazeau ss	Edmonton fmt. Bearpaw shales Belly river beds		Allison fmt.	Allison fmt.
		Colorado	Wapiabi Bighorn Blackstone		Wapiabi sh Bighorn ss Blackstone sh	Claggett shales Niobrara Benton	Benton	Benton	Benton Crowsnest volcanics
		Kootenay	Kootenay	McLeod member	Dakota	Dakota beds	Blairmore fmt. (Dakota)	Blairmore fmt.	Blairmore fmt.
				Kootenay coal-bearing member	Kootenay	Kootenay fmt.	Kootenay	Kootenay	Kootenay fmt.
	Jurassic	Jurassic	Fernie		Fernie	Fernie shales		Fernie shales	Fernie
	Triassic				Upper Banff shales			Upper Banff fmt.	
PALEOZOIC		Not subdivided.							

- 1 Malloch, G. S., Geol. Surv. Can., Mem. 9E, 1911.
- 2 Cairns, D. D., Geol. Surv. Can., Mem. 61, 1914.
- 3 Stewart, J. S., Geol. Surv. Can., Mem. 112, 1919.
- 4 Rose, B., Geol. Surv. Can., Summ. Rept. 1919, Pt.C., p. 150.
- 5 Rose, B., Geol. Surv. Can., Summ. Rept. 1916, p. 108.

In the Saunders creek and Nordegg area the writers did not find evidence of a break in the Cretaceous sequence below the Colorado strata. Consequently, all strata between the Fernie (Jurassic) and Colorado formations were included in the Kootenay and mapped as one formation in the fourth annual report. Field work during the past summer has shown that there is a thick series of beds above those that carry coal seams of commercial thickness in the Kootenay. These upper strata have a somewhat different lithological character from those with which the coal is associated. In this part of the foothills belt the best exposures of these beds are on McLeod river in township 47, range 23, and the name "*McLeod member*" has been given to them. The name "*Kootenay*" has been assigned to all Cretaceous strata below the Colorado shales and designated as a group name similar to the terms *Colorado* and *Montana*.

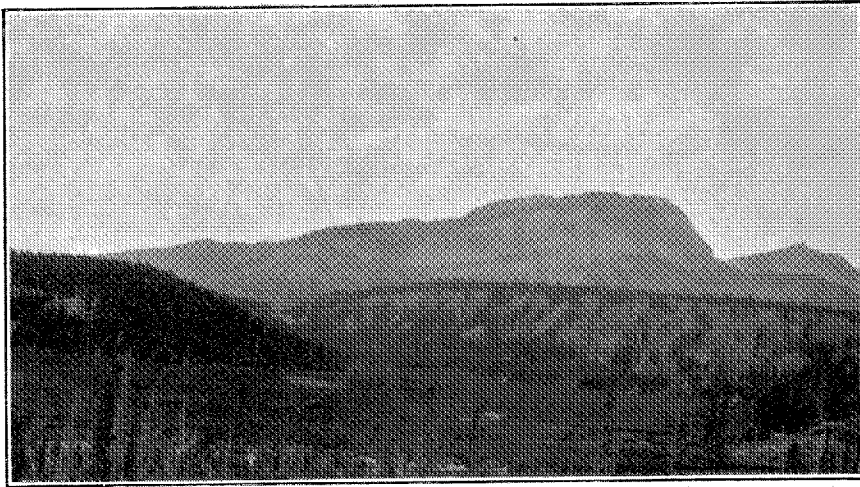
The Colorado strata overlying the Kootenay were divided by Malloch¹ into the Blackstone shales, Bighorn sandstones, and Wapiabi shales. Malloch's division has been adopted in this map-area, but the Colorado group is mapped as one unit, since it is difficult to trace the members separately for any distance from the river exposures.

The uppermost Cretaceous is represented by a thick series of fresh water deposits. These beds were divided into the *Upper* and *Lower Saunders* formations separated by the Saunders coal series in the Fourth Annual Report. The field work in 1923 has shown that this division will not apply regionally since there are several widely separated coal horizons in the Saunders strata. Since no definite break in these strata has been recognized *all the Saunders beds are included in one formation in this report*.

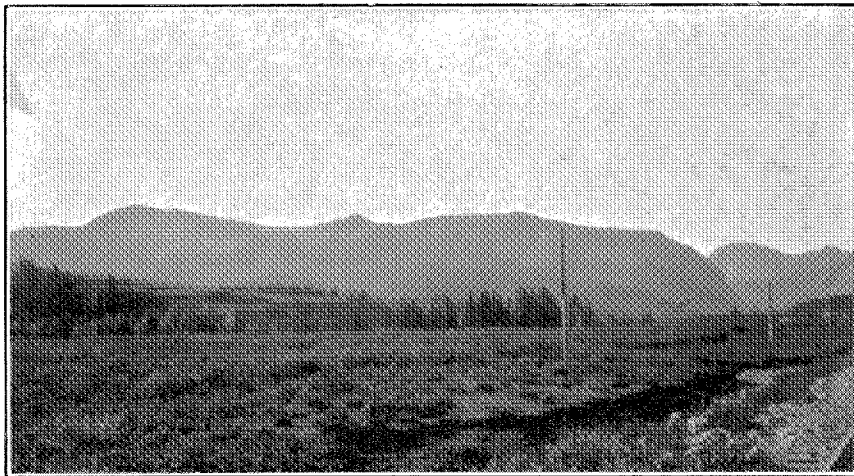
In the table of formations the upper member of the Saunders is shown to possibly include some early Tertiary beds which are recognized east of the foothills belt.

¹op. cit., p. 21.

PLATE II.



A. The south end of the Bighorn range, looking northwest from the mouth of Teppee creek. Mat-herbage in the foreground.



B. Nikanassin outlier southeast of Cadomin, looking south across mat-herbage plain.

CHAPTER III.

STRUCTURAL GEOLOGY.

General Statement.—The structural relations in this map-area are similar to those of the Saunders creek and Nordegg areas and show the characteristic structure of the Alberta foothills. The rocks have been deformed by mountain-building forces which have resulted in a series of folds and faults with a general trend of north 45 degrees west.

Characteristic of the foothill belt, the deformation in this area increases from east to west, and any general section across the strike shows relatively open folded upper Cretaceous beds on the eastern side. Proceeding westward the folds are closer, more numerous, faulting is more prevalent, and in general lower strata are brought to the surface. This increased deformation culminates in the overthrusting of the Paleozoic beds on to the Cretaceous, forming the front range of the Rocky mountains. Frequently the Paleozoics are raised to the surface forming isolated mountain outliers along the western edge of the foothills belt. Such Paleozoic exposures are in part due to erosion having removed the softer Cretaceous beds. This map-area is bordered on the west by two such outliers, namely the Bighorn range (Plate II,A), and a branch of the Nikanassin range (Plate II,B).

The Brazeau range¹ terminates south of this area, and has no representative to the north. The structural relations for the whole area have been traced from the Saunders creek and Nordegg areas, northwest to Pembina river, and as far north as Mountain Park branch of the railway in the eastern part. The structure is described from east to west across the area mapped.

Local.—The most continuous break along the eastern side of this area is the continuation to the northwest of the fault shown near the mouth of Brown creek on Blackstone river in township 43, range 16. This fault crosses Brazeau river in section 19, township 45, range 17; Pembina river in section 4, township 46, range 18; and, the west fork of the Embarras in section 3, township 49, range 21. This break has been named the *Lovett fault* and is the northwest continuation of the "second fault" in the Saunders creek area.

The displacement along this fault decreases to the northwest. Beds of Colorado age are exposed on the west side of the fault at the mouth of Brown creek, whereas on the main Brazeau, only Saunders beds are exposed.

The main Brazeau has eroded to a deeper level where this fault crosses than at the respective point on Blackstone river, consequently in the distance between these two rivers along the fault line there is

¹ 4th Annual Report, page 14.

evidence of less displacement to the north. At the crossing of the Embarras the fault becomes almost a fold with very little external evidence of displacement of the beds on either side. The evidence of displacement on the Embarras has been obtained from oil drilling operations.

The next major break west of the Lovett fault has been named *Chungo fault* and is the continuation to the northwest of the "third fault" as mapped on the fourth annual report at the mouth of Chungo creek on the Blackstone. This fault is well defined where it crosses the main Brazeau in section 8, township 45, range 18, near the confluence of the north and main Brazeau rivers. It is also quite marked at an intermediate position, namely, where it crosses Brown creek in the southwest corner of township 44, range 17. Northwest from the main Brazeau, Chungo fault is not so well defined, and its exact position on Pembina river is not clearly exposed. It cannot be traced northwest of this stream, but it may be represented by the fold exposed in the Saunders beds where McLeod river turns sharply to the northwest in section 14, township 48, range 22.

In the fourth annual report the "main fault" lying along the front of Brazeau range was described in detail. It was believed then that this fault crossed Blackstone river in section 19 (approximately), township 42, range 16, near Nelson cabin. Owing to concealed structural relations it is difficult to state that this fault, which crosses the Blackstone at the point indicated, is the "main fault" in the Saunders creek and Nordegg areas. Nevertheless, this structural break as indicated, continues for some distance northwest of the Blackstone and traverses badly broken beds on Chungo creek. The closely folded Colorado beds on the Brazeau, north Brazeau and Pembina rivers may represent the position of this fault. It does not, however, form one of the well defined structural breaks north of the Blackstone.

The next well defined break to the west is shown on the Blackstone river in township 42, ranges 17 and 18. Blackstone river follows along this break through the greater part of section 18, township 42, range 17, and section 24, township 42, range 18. This break has been termed the *Blackstone fault*. Southeast from this location the fault apparently runs into Colorado beds and cannot be connected with any of the structural breaks on Saskatchewan river.

To the northwest it is well exposed on Brazeau river, in section 36, township 44, range 20; on the north Brazeau in section 16, township 45, range 20; and on the Pembina in section 9, township 46, range 21. Since this is a well marked break on the Blackstone and on the Brazeau it has been projected across the intervening distance and shown to cross Brown and Chungo creeks. The exact location of this fault on these two creeks has not been ascertained as these are not surveyed. It has not been possible with the information on hand to definitely connect this structure through to McLeod river. It may be represented by the fault as shown near the mouth of MacKenzie creek in township 47, range 22, or it may be represented by some other structural line farther west on McLeod river. Further field work will determine this relation.

The most westerly major break is that shown along the front of the Bighorn range, and indicated as the *Bighorn thrust fault*. This break extends almost from the Saskatchewan river northwest to the main Brazeau. Between the main Brazeau and the north Brazeau it is not so well defined as a distinct break, but is represented by a series of minor faults and folds in Cretaceous beds. North of the north Brazeau a well defined thrust fault passes along the front of the Nikanassin outlier. This fault crosses McLeod river west of Cadomin in section 31, township 46, range 23.

These constitute the major structural lines in this map-area. There are numerous other faults of considerable length, but for the most part these cannot be traced through from one major stream to another with any degree of accuracy. The "first fault" as mapped in the fourth annual report crosses Brazeau river east of the area shown in this map. It has not been ascertained yet whether this break is continuous northwest to Embarras river. Structure sections (Nos. 1, 2, 3, 4, and 5) described below, show the relations between the various formations insofar as these relations are dependant on structure.

STRUCTURE SECTIONS.

Structure Along Saskatchewan River.—Since the geological information has been gathered mainly from exposures along the rivers, these sections are described in some detail.

The southern boundary of the map-area is the north Saskatchewan river. A structure section has not been made along this water course. Colorado beds occupy most of the area and the exposures are few, so that a detailed structure section has not been made.

In the Nordegg area the most westerly beds shown are the Kootenay. These southwesterly dipping strata continue as far west as Black Canyon, which enters the Saskatchewan in section 31, township 39, range 15. From this point Colorado shales are exposed at intervals along the river into section 28, township 39, range 16. These Colorado beds are in many places folded into minor structures, but in general have a westerly dip varying from 15 to 45 degrees.

On the west they are faulted against the Kootenay beds that are highly folded. This small belt of Kootenay is shown as glacial drift on Malloch's map¹. These Kootenay beds are exposed only along Saskatchewan river and in one small outcrop on the upper part of Tepce creek. The apparent continuation of these to the south is shown on the map of the Bighorn coal basin as "K.1," on the south side of Saskatchewan river.

Bighorn range ends abruptly before reaching the Saskatchewan river (Plate II.A.). The general northwesterly strike of the Cretaceous beds has been changed by this uplift to a northeasterly strike, with a dip to the northwest and a steep face to the southeast in the southern end of the Bighorn basin. Exposures at the headwaters of Haven creek show that Paleozoic rocks forming the Bighorn range have been thrust over middle Colorado beds. Thus from the Bighorn mountains eastward to Brazeau (Nordegg), a generalized section

¹Map 7A., Accompanying memoir 9 E., Geol. Surv. Can., 1911.

would show a rather wide belt of westerly-dipping Colorado beds as far east as Black Canyon creek. East of this creek, Kootenay beds, including the McLeod member, occur and have a dip to the west.

Blackstone Section, (No. 1).—Structure section No. 1 has been made from observations on exposures along Blackstone river from its mouth westwards to the gap through Bighorn range. The average strike of the formations is N. 45° W. The contacts and structural lines have been projected from their positions on the river to a line drawn at N. 45° E. across this area.

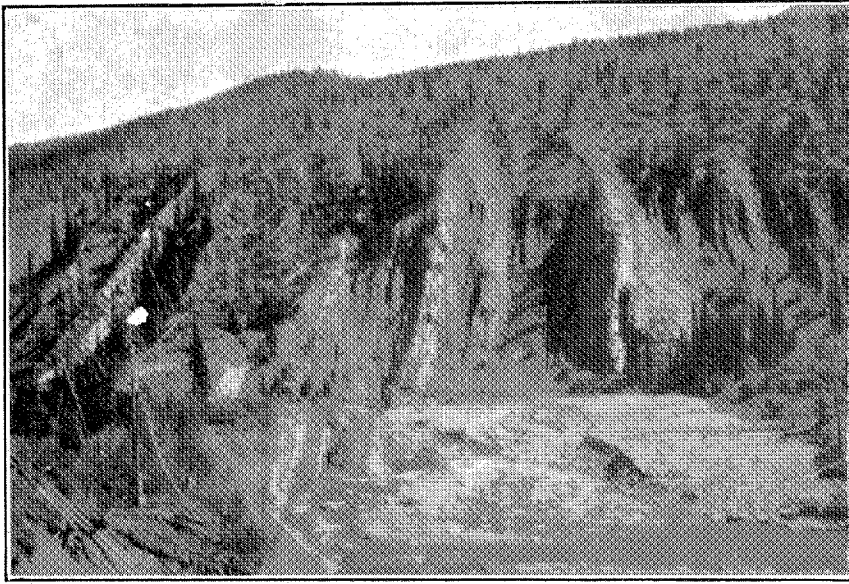
At the mouth of the Blackstone the strata are flat-lying and belong to the upper member of the Saunders formation. This structure continues upstream to section 15, township 44, range 16, where the strata show a gentle dip to the northeast. This dip increases westward, bringing successively lower strata to the surface. In section 28, township 43, range 16, the strata reach their maximum dip of about 75° northeast, and are terminated on the west by the *Lovett fault*.

The lowest strata exposed on the east side of the fault are the coal-bearing beds. In the Saunders creek area¹ the beds above this coal horizon were grouped as the "Upper Saunders formation." In this report they are considered as the upper member of the Saunders formation.

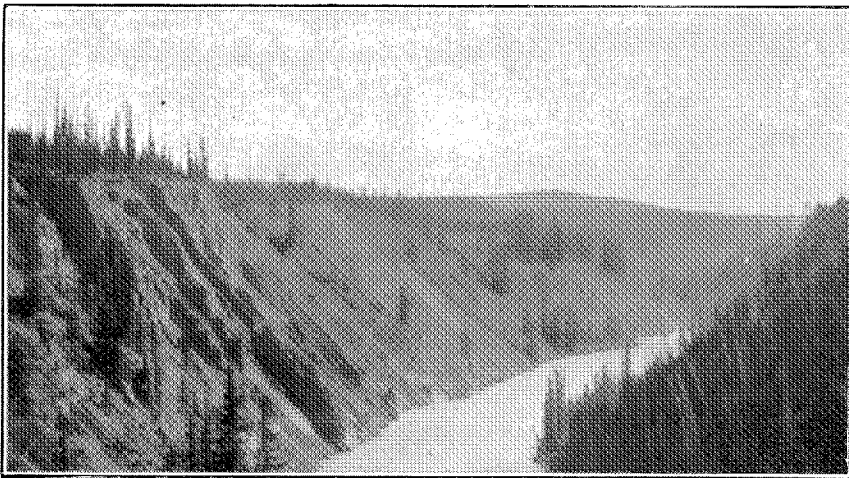
This fault shows considerable displacement since the top beds of the Colorado, dipping approximately 45° S.W., are exposed on the west side at the mouth of Brown creek. From this fault westwards to a point above the mouth of Chungo creek in section 18, township 43, range 16, a continuous section shows the lower member of the Saunders formation dipping to the southwest. The dip has decreased from 45° at Brown creek to about 15° at Chungo creek. A short distance up the Blackstone from the mouth of Chungo creek these Saunders beds are overridden by lower strata that form a high point known locally as *Grass mountain*. The exact age of these overthrust strata is still uncertain. In the fourth annual report they were included in the Colorado. The authors are now of the opinion that they represent the transition from the McLeod member of the Kootenay to the basal Colorado. They are separated from the Saunders formation below by a well defined fault which is continuous over a considerable part of this map-area. This break has been called the *Chungo fault*. Between Chungo fault and the northeast quarter section 19, township 42, range 16, near Nelson cabin, there is a continuous exposure of tightly folded and broken beds which have been tentatively mapped as Colorado. The "*main fault*" in the Saunders creek area crosses the Blackstone at this point and is represented by a fault zone in the extreme northeast corner of this section. Upstream from this fault zone the succession is more regular, and in the northwest quarter section 18, township 42, range 16, the Colorado shales are well exposed, dipping 60 to 90 degrees to the southwest. In the northeast quarter section 13, township 42, range 17, the dip becomes more regular at 65 degrees, and a section of the middle and upper members of the Colorado is exposed. The contact between the

¹Allan, J. A., and Rutherford, R. L., Op. cit. p. 54.

PLATE III.



A. Steeply dipping Saunders beds; on the Blackstone in section 18,
township 42, range 18.



B. Kootenay and Colorado beds on the Brazeau in section 26,
township 44, range 20.

Saunders and Colorado beds lies near the mouth of Lookout creek¹, and the harder basal Saunders beds form a ridge on both sides of the Blackstone.

The Saunders formation is exposed up the Blackstone from the mouth of Lookout creek to the northwest quarter section 18, township 42, range 17. In the area between these two points the beds form a well defined syncline. The dip on the east limb flattens out rapidly and at the mouth of Wapiabi creek in section 14, township 42, range 17, the beds are flat-lying. West from this point these beds have a small northeasterly dip through the greater part of sections 15 and 16. The dip increases rapidly in the eastern half of section 18 and reaches about 60° N.E. at the western side of this syncline, where basal Saunders beds are faulted against Colorado beds. This break is the *Blackstone fault*, which is another of the well defined structural lines in this area.

Blackstone river follows this structure for two miles through the northwest quarter section 18, township 42, range 17, and the southeast quarter section 24, township 42, range 18. In the northwest quarter section 24, it flows on basal Saunders beds, but swings westward in the southeast quarter section 26, and crosses the fault again.

Closely folded and faulted Colorado beds occupy the area west of the fault for about one-half mile. In sections 21 and 22 a regular westerly dipping succession of Colorado beds is shown. These grade up into the Saunders formation with the contact in the southwest quarter section 21, township 42, range 18. For a mile and a quarter west of this contact the Saunders formation forms an asymmetric syncline in which the beds dip more steeply on the western limb (Plate III, A). This syncline is bounded on the west by a fault which separates the Saunders beds from Colorado strata.

The Colorado beds extend from this fault west to the Paleozoic rocks of the Bighorn range that have overridden the younger rocks along the Bighorn thrust fault in section 7, township 42, range 18. As a result of this overthrusting the Colorado strata have been broken and closely folded.

Brazeau Section, (No. 2).—The structural relations along the main Brazeau river from the mouth of the Blackstone west to section 27, township 44, range 20, are shown in structure section No. 2. The eastern part of this section is similar to that along the lower part of Blackstone river, and shows flat-lying beds of the Saunders formation as far west as section 4, township 45, range 16. At this point the beds show a small dip to the northeast. This dip increases to the west and the strata are vertical in section 18, township 45, range 17. This change in dip occurs in a short distance, and throughout most of township 45, range 17, the dips are less than 50 degrees to the northeast.

Close to the west boundary of township 45, range 17, the *Lovett*

¹Since 1913 when Blackstone river was mapped by the Forestry Branch the mouth of Lookout creek has moved about 500 yards upstream. This is due to the fact that its channel is temporary where it enters the loose gravels in the Blackstone valley.

fault crosses the Brazeau. This is the same fault that crosses the Blackstone near the mouth of Brown creek. On the west side of the fault the lower member of the Saunders formation is exposed, dipping steeply to the southwest.

The relative displacement along this fault on the Brazeau does not appear to have been as great as on the Blackstone, where upper Colorado beds are shown on the west side.

West of *Lovett fault* on the Brazeau the dip in the Saunders beds decreases rapidly to 25 degrees in the northwest quarter section 15, township 45, range 18. The same formation flattens out farther up stream and is overridden along *Chungo fault* in the southwest quarter section 8, township 45, range 18, near the mouth of north Brazeau river. The structure is similar to that in Grass mountain south of the Blackstone, and the overthrust strata appear to be the transition beds at the base of the Colorado.

Colorado beds outcrop along the Brazeau from near the mouth of the north Brazeau, as far west as the southwest quarter section 33, township 44, range 19, where the upper Colorado strata are overlain conformably by the basal Saunders beds. The average dip is 60 degrees to the southwest. The structural relations at this point are similar to those at the mouth of Lookout creek on Blackstone river. West of *Chungo fault* for two miles open folds occur, but the Colorado strata become more closely folded, in places nearly vertical, and faulted to the west. The Saunders strata form a syncline from the contact in section 33, west to *Blackstone fault*. The base of this syncline lies in the southwest quarter section 32, and in the southeast quarter section 31, township 44, range 19. Folded Colorado beds with various dips, in general quite steep, are exposed west of this syncline up stream to the northeast quarter section 26, township 45, range 20, where Kootenay beds are exposed. The Kootenay forms a narrow belt less than half a mile wide, dipping steeply to the west and bounded on both sides by Colorado beds (Plate III, B).

A detailed traverse was not carried west of this belt of Kootenay, but it is known that a second belt of Kootenay crosses the Brazeau in township 43, range 20, where prospecting has been carried on by the British Collieries.

Cretaceous beds occupy the area to the west for several miles until the front range of the Rocky mountains is reached. The Big-horn range terminates south of the valley of the Brazeau, and the outlier of the Nikanassin range stops about eight miles northwest of Brazeau river, so that the Cretaceous rocks extend up the valley of Brazeau river beyond the boundary of this map.

North Brazeau Section, (No. 3).—The structural relations in the Colorado strata along the lower part of the north Brazeau are similar to those observed along the main Brazeau. The west side of the synclinal structure in the Saunders formation on the Brazeau is represented by a series of twisted and folded strata of the same age in the north Brazeau. West of *Blackstone fault* the Colorado strata are folded and the harder members form ridges. About the centre of section 18, township 45, range 20, a fault near the mouth of Grave

creek¹ separates the Colorado from the Kootenay. These Kootenay beds belong to the coal-bearing member, and form a belt about three-quarters of a mile wide between two faults. The beds are folded, and in some places crumbled, so that the detailed structure cannot be shown on the accompanying section.

Another belt of closely folded Colorado beds, less than one mile wide, lies west of these Kootenay measures, and extends upstream into the northeast quarter section 11, township 45, range 21. This belt is bounded on the west by a fault, and is followed by a series of closely folded Kootenay beds which are exposed for at least one-half mile west of the mouth of Ruby creek. A fault passes through this belt near the mouth of Ruby creek, and the Kootenay beds to the east have a more northerly strike than those to the west. This fault seems to represent the southward continuation of the break along the front of the Nikanassin outlier. The Kootenay beds west of Ruby creek appear to be the southeasterly extension of those at Mountain Park.

Pembina Section. (No. 4).—The structural relations along Pembina river from *Lovett fault* in township 46, range 18, to Nikanassin outlier are shown in structure section No. 4. Erosion in the Pembina valley has not proceeded to as great a depth as in the Brazeau, so that a less continuous section is exposed.

The exposures on the Pembina show Saunders beds dipping to the northeast, and to the southwest on the east and west sides of the Lovett fault respectively. The dips close to the fault vary from 45° to 90°. West of the fault the beds flatten out and the dip decreases to an average of 10 to 20 degrees. In the west half of township 46, range 19, several open folds occur in which the dips are small. A fault zone crosses the river about the centre of township 46, range 20. This zone has been taken to represent the continuation of *Chungo fault* that is exposed near the mouth of the north Brazeau. Exposures are few and disconnected along the Pembina east of this fault, so that detailed structure has not been determined. In general, however, the Saunders formations, lying between *Chungo fault* and *Lovett fault* form a synclinal structure with several minor folds within it. It is to be noted that this synclinal structure is represented on the Brazeau by a monoclinical succession and that a rapid change in structure occurs in the comparatively short distance between these two streams.

Colorado beds folded into large synclines and anticlines with many minor folds occupy the area from Chungo fault to the centre of township 46, range 21, where they are in contact with Saunders beds dipping 30° southwest. A small waterfall is formed on the basal beds of the Saunders (Plate V,A). This contact represents the

¹A forestry Branch traverse of north Brazeau river extends to the west side of section 17, township 45, range 20. West of this the location of points on the river is more indefinite. The general (1 inch—3 miles) forestry map shows Grave creek entering the Brazeau in the southwest quarter section 18, township 45, range 20. This stream enters the north Brazeau at least one-half mile farther east in the northeast quarter section 18, and on the east side of the Blackstone fault. This alteration has been made on the accompanying map.

northwest continuation of the one exposed on the Blackstone at the mouth of Lookout creek. Saunders beds are exposed westwards into the southwest quarter section 16, township 46, range 21, where *Blackstone fault* crosses the Pembina, and Colorado beds are exposed on the west side. The structure in the Saunders formation to the east of this fault is that of an asymmetric syncline with a much broken western limb similar to that shown on the north Brazeau.

Colorado beds are exposed in the river valley from this fault up to the head of the Pembina, which lies at the base of the Paleozoic rocks in the Nikanassin outlier. Near the head of the Pembina the hills to the north and south of the stream are capped by gently folded Saunders beds, which in some places lie close to the Paleozoic rocks.

McLeod Section, (No. 5).—This structure section illustrates the relations between the formations along the railway from Minehead, in township 49, range 21, to the mouth of MacKenzie creek in township 47, range 22. This section includes in part the exposures along the west fork of Embarras and McLeod rivers.

The Saunders formation exposed at Minehead dips 40° to the northeast, but the beds flatten out rapidly to the east. West from Minehead the succession is regular up to a fault zone which crosses in the southeast quarter section 3, township 49, range 21. The strata on the west side of the zone dips 35° to 45° to the southwest. This structure represents the *Lovett fault* which appears to be continuous from the point where it crosses Blackstone river below the mouth of Brown creek. On the Embarras between Minehead and Coalspur the exposures indicate an anticline rather than a fault. The same coal seams are exposed at Coalspur and Minehead, but the greater thickness of beds between Minehead and the fault than between Coalspur and the same fault, is taken as evidence of displacement along this break.

Between this break and the big bend in McLeod river in sections 11 and 14, township 48, range 22, the Saunders beds occur as a syncline. The base of this syncline is concealed, but it lies about midway between Mercol and Coalspur.

A rather abrupt change in dip takes place in section 11, township 48, range 22, and the Saunders beds flatten out rapidly to the west. These strata are exposed nearly flat-lying up the McLeod to the southeast quarter section 33, township 47, range 22. West of this position the beds dip to the northeast, and at the mouth of MacKenzie creek in the southeast quarter section 29, township 47, range 22, they are upturned to a vertical position. Saunders beds are exposed up the McLeod for a short distance above MacKenzie creek, and show a faulted contact with the Colorado shales in the southeast quarter section 29.

The data obtained do not warrant a completion of this section westward to the Paleozoic rocks near Cadomin. It may be said, however, that Colorado and lower Cretaceous beds occupy the intervening area as far west as Cadomin. The geological mapping of this part of the area has not yet been completed.

CHAPTER IV.

PHYSIOGRAPHY.

Topography.—Most of the area shown on the accompanying map lies in the foothills belt, so that it includes surface features grading from sloping uplands along the east to mountainous ridges along the west (Plate I).

The general trend of the structure is N. 45° W., so that the higher lands resulting from the erosion of folded beds appears as a series of dissected uplands.

The stream gradients increase westward and the relative elevations of the land areas above their respective stream courses increase to the west. Continuous ridges are better defined in the east where they show a closer relation to the underlying structure than they do in the west.

An attempt has been made to give a general idea of the surface aspect of the country by sketch contours, which are shown on map No. 5. These lines are very general and the only control used was the elevation of points established by river traverses and railway surveys.

The most pronounced upland in the eastern part of the area is the ridge which follows the Lovett fault and extends from the mouth of Brown creek on the Blackstone to the region between Minehead and Coalspur. This ridge extends north of the boundary of this map-area. The elevations of the highest parts occur farthest away from the major stream channels that cut through the ridge. An area of low relief, without surface expression of the underlying fault, between Brazeau and Pembina rivers in township 45, range 18, is the most notable break in the continuity of this ridge.

An upland on the Blackstone in the southern part of township 43, range 16, locally known as *Grass mountain*, owes its origin to the underlying Chungo fault structure. The continuation of this fault to the northwest produces similar high areas north of Brown creek in the southwest of township 44, range 17, and also on the main Brazeau at the mouth of the North Brazeau river. At this latter point the surface rises very abruptly for 1,300 feet above the river. These various high interstream areas represent the remains of a second ridge which is, however, much more dissected than is the ridge to the east. This second ridge does not appear in the area drained by Beaverdam river. The area lying between these two ridges is underlain by Saunders beds, which are relatively soft, so that the slopes are usually gentle.

The westerly dipping basal Saunders beds exposed at the mouth of Lookout creek on the Blackstone, form a third ridge that continues northwest across Brazeau and Pembina rivers, but apparently does

not continue to McLeod river. This ridge is dissected similarly to the one to the east but it is more continuous. Most of the area between this third ridge and the one on the east is underlain by folded Colorado beds that produce much more irregular topography than that between the first and second ridges. This irregular surface has been produced by the several hard thick sandstone members in the middle Colorado formation, which are folded and are resistant to erosion.

The basal members of the Saunders formation that occur in the third ridge rise again to the west to form a fourth ridge. This ridge crosses the Blackstone east of *Blackstone fault* in township 42, range 17, and continues northwest across the Brazeau on a trend parallel with this fault. It is less poorly defined as a distinct ridge at the crossing of the Pembina in township 46, range 21.

The depression between this fourth ridge and the one to the east, being underlain by Saunders beds, has gentle slopes and a less rugged surface than the area between the second and third ridges.

The average elevation of the ridges increases from east to west. It is difficult to trace any particular physiographical form west of the fourth ridge. The interstream areas have elevations ranging from 6,000 to 6,500 above sea-level, and in general do not show continuity with each other along the general direction of the strike.

The ridges outlined above only extend for short distances south of the Blackstone and north of the Pembina. In the area south of the Blackstone and drained into the Saskatchewan there are several high hills, but these do not owe their origin to the general structural lines that cross the rivers to the north.

An elevation in the southwest of township 41, range 16, locally known as *Black mountain*, is due to a hard sandstone member capping the lower Colorado shales. This upland rises over 900 feet above the valley of Shunda and Lookout creeks and has a steep face on the northeast.

An area of lower relief lying between Black mountain and Brazeau (Nordegg) extends southwest to Bighorn river, and is drained by Haven creek and its tributaries. Between this low area and Saskatchewan river there are several higher points along the lower part of Black Canyon creek.

West of Coalspur and along McLeod river to MacKenzie creek, there are several relatively higher points, but no pronounced ridges with continuity to the southeast. The area drained by Beaverdam creek and Embarras river west of Coalspur has lower relief and more gentle slopes than the districts to the southwest.

Drainage.—This area is drained by two large systems, one of which slopes to the Arctic ocean, and the other to the Atlantic. The height of land follows a sinuous course across the foothills in townships 45 and 46 between Brazeau and Pembina rivers. South of the watershed the drainage is part of the North Saskatchewan river system, but north of this divide the drainage forms part of the MacKenzie river basin.

The North Saskatchewan river system drains the southern portion of the area by four main rivers, namely, North Saskatchewan, Blackstone, Brazeau, and North Brazeau. The last three constitute Brazeau river at the eastern side of the foothills. The Brazeau joins the North Saskatchewan further east in township 45, range 9, west of the 5th meridian, 40 miles north of Rocky Mountain House.

The North Saskatchewan drains only about sixty square miles in the southwest corner of the area by such minor tributaries as Haven and Black Canyon creeks. The water supply in these creeks varies to a large extent with local seasonal precipitation.

Blackstone river has its headwaters in the Bighorn basin, but derives a large amount of its water from such streams as Wapiabi, Lookout, Chungo and Brown creeks. It is a rapid-flowing stream and exposes an almost continuous section from the Bighorn range to its mouth. The rock exposures at several points along this river are nearly 100 feet high (Plates III,A., and IV).

The main Brazeau river is the largest and swiftest stream within this area. In many places the velocity of the current is over 15 miles an hour. During the greater part of the summer months it cannot be crossed with pack trains except at the Dowling ford west of the Bighorn range in township 42, range 20, west of the 5th meridian. The main Brazeau is about 200 miles long and rises within the front ranges of the Rocky Mountains in the vicinity of Brazeau lake in township 38, range 22. The headwaters are fed by small glaciers within the mountains so that the volume of water does not depend upon local precipitation. The valley of the Brazeau in the foothills is wide with gently rounded slopes that indicate glacial origin. The river today is confined to a narrow valley of post-glacial origin, in places over 200 feet deep (Plate III,B).

The north Brazeau is a relatively short stream and smaller than the Blackstone. The post-glacial channel of this river exposes a very continuous rock section that is on the average 100 feet deep.

The above streams with their minor tributaries constitute a part of the Saskatchewan river system that drains to the Atlantic ocean through Hudson's Bay. North of the height of land the rivers drain into the Arctic ocean through Athabaska river, which is a part of the Mackenzie basin.

Pembina river rises on the east side of the Nikanassin outlier and flows with a general easterly trend across the foothills. A noteworthy feature of this drainage is the proximity of the Pembina to the Brazeau in township 45, range 18, where the divide, between the Arctic and Atlantic drainage is low, relatively flat, and about 2 miles wide. One small tributary of the Brazeau extends to within a mile of the Pembina. It is quite probable that at one time the Pembina and Brazeau waters had a common course in this locality.

* The Pembina, although larger than the north Brazeau, does not expose a continuous rock section. The post-glacial valley is not distinct and the stream is bordered by broad tree-covered flats similar in many respects to those along the lower portion of Nordegg river east of range 15, in the Saunders area. The main tributary of the Pembina has its source about half way between Lovett and Coalspur

on the Alberta Coal Branch. It follows a southeast course that is subsequent to the structure and joins the Pembina in section 23, township 46, range 19. Below the forks the Pembina follows the same trend for a linear distance of five miles to the southern boundary of township 46, range 18. From this point the course of the river turns sharply to the northeast.

McLeod river follows a broad, rounded, transverse valley from Cadomin gap through Nikanassin outlier, northeasterly as far as section 11, township 48, range 22, where the course of the river turns at right angles to the northwest. At this sharp bend Beaverdam creek enters from the south where it flows for most of its length over flat-lying beds of the Saunders formation.

The west fork of Embarras river rises close to the southeastern corner of township 48, range 21. From Coalspur it has a northeasterly direction across the first ridge and is here followed by the railway which extends into the coal areas south and west of Coalspur.

With few exceptions the major streams are transverse and are not subsequent to the structure for any considerable distance. The Pembina in the southwest part of township 46, range 18, is flowing parallel to the first ridge. Blackstone river in the eastern part of township 42, range 18 has a direction depending upon structure. A few of the minor streams are subsequent as shown by the little Pembina in township 46, range 19, and by Dummy creek which joins the Embarras at Coalspur. These two streams flow along the west slope of the first ridge.

FLORA AND FAUNA.

Flora.—There are three forms of vegetation represented in this area: forest, mat-herbage, and grassland.

Most of the foothills belt shown on the accompanying map is or has been forested, but in recent years large areas have been laid waste by forest fires. In most parts the forest extends right up to the eastern escarpment of the mountains. No part of the area rises above the timber-line, which in the mountains occurs about 7,000 feet above sea-level.

An almost green forest of pine and spruce extends along the inner foothills belt from the head of Haven creek to the Brazeau, especially in the vicinity of Wapiabi and Blackstone rivers (Plate I). Farther north and in the outer foothills large areas have been burnt over and are represented by a tangled brule or partly covered by a regrowth of jack pine.

At least two species of pinus occur. The more widely distributed is *Pinus contorta* Murrayana, but in the lower uplands and along certain valley floors, *Pinus albicaulis* Engelmann is common. In the spruce forests, *Picea Canadensis* is very common, and in the lowlands is associated with willows, sedges, and in the swamps with tamarack (*Larix lyallii*). *Picea Engelmannii* and *Abies lasiocarpa* occur interspersed with other forest types. The largest spruce are about 24 inches in diameter.

A very small quantity of the dead timber and some green timber is utilized for mine props. It is necessary to obtain permits from the Forestry Branch to utilize the timber since all of this area lies within the Clearwater and Brazeau forest reserves. Poplar growth is confined largely to the valley of the North Saskatchewan and to the outer foothills. The top of some of the higher ridges are wind-swept and void of forest growth with the exception of dwarfed spruce or juniper.

The other two types of vegetation, mat-herbage and grassland, are limited in their distribution and are not always easily differentiated. The mat-herbage type is confined to lowlands in broad valleys and it is characterized by the presence of herbaceous perennials and occasional grasses (Plate II). This type approaches a muskeg in many places. One of the largest areas of this type occurs at the head of Lookout and Shunda creeks. Smaller areas of swamp are common and all are troublesome where the pack trail crosses them, especially during a wet season such as that of 1923. *Lysichiton kamtschatcense* (Skunk cabbage) is common, and grows to a height of three and sometimes four feet in wet marshy places. Clumps of willows, sometimes ten feet in diameter and 20 or 30 feet high, are common with this type of vegetation. Outside of the area mapped mention should be made of the extensive areas of mat-herbage west of the Bighorn range. Some of these open stretches are three to five miles in length and up to two miles in width.

Open grasslands are confined to the broad lowlands along streams or about the low divides in the drainage system. Other patches of grassland occur on terraces along the sides of valleys, and furnish excellent feeding grounds for game. Some of these are a mile in length and up to a mile in width. The beauty and profusion of small flowering plants are worthy of mention.

Fauna.—Large fauna, such as deer and moose, are very abundant throughout the foothills area. Elk, which are rather scarce in the Alberta foothills, are plentiful in one small area that lies between the north and main Brazeau, near their confluence. One herd of eleven, as well as several individuals, were observed during our traverses¹. This district, which is open and heavily covered with glacial drift, appears to afford a suitable habitat. Black and grizzly bear, lynx and smaller fur-bearing animals are known to occur in this region.

¹This herd is shown in Plate VI, B., crossing the gravel on the Brazeau.

CHAPTER V.

DESCRIPTIVE GEOLOGY.

General Statement.—The part of the foothills discussed in this report is limited on the west by the Paleozoic formations in Bighorn range and Nikanassin outlier, so that a description of rocks older than Mesozoic is not included. Triassic and Jurassic rocks are not exposed in this area, and this chapter will include only a description of Cretaceous and younger strata.

The lithological character of the Cretaceous formations has been described previously¹ so that these details are not repeated, but several changes in the previous description are necessary as a result of the field investigations of 1923.

CRETACEOUS FORMATIONS.

	FORMATION	MEMBER	DESCRIPTION
Montana	Saunders	Upper member	Continental deposits; sandstones, conglomerates, clay shales, coal seams in the northern part of the area.
		Lower member	Continental deposits; sandstones, conglomeratic sandstones, clay shales, coal seams.
Colorado	Wapiabi		Black marine shales. Numerous nodules and many fossils.
	Bighorn		Hard, fine grained massive sandstones interbedded with black shales.
	Blackstone		Black marine shales of uniform character; lower part has interbedded sandstones.
Kootenay	Kootenay	McLeod member	Continental deposits; conglomerates, sandstones and clay shales. Few thin coal bands.
		Coal bearing member	Continental deposits; conglomerates, sandstones, clay shales, carbonaceous shales and coal seams.

¹Allan, J. A., and Rutherford, R. L., op. cit., 1922, p. 30.

KOOTENAY GROUP.

Definition.—On account of the somewhat ambiguous use of the word "Kootenay," it is necessary to define what strata are included in this name. The term "Kootenay" as used here denotes a group name similar to the Colorado and Montana, and the rocks deposited within this time make up the *Kootenay formation*. This formation includes all the strata of lower Cretaceous age from the top of the Jurassic up to a lithological or faunal break which in this part of the foothills is at the base of the Colorado marine strata.

In this district the Kootenay strata have been divided into two members, namely, the *Coal-bearing member* below, and the *McLeod member* above.

The beds making up these members are all of continental deposition, so that there is no field nor scientific reason for dividing this series of beds into two formations. The term "Dakota" has been used by various workers in the foothills belt of Alberta for those beds included in the McLeod member of the Kootenay. The writers are strongly in favor of discontinuing the application of the name Dakota in Alberta for the series of beds of continental origin overlying the coal measures of similar origin, when no break occurs between them. "Dakota" refers to a particular series of beds in central United States with which the beds of corresponding stratigraphic position in central Alberta have not been correlated.

In the foothills in southern Alberta the name "Blairmore" has been applied to a series of beds of continental origin above the coal measures. This formation has been grouped as Dakota in age and placed in the upper Cretaceous, but there is no evidence for such a formational division in central Alberta.

The practice of giving a new name to an uncorrelated series of beds is desirable instead of adopting a name already in use. For this reason the strata of continental origin above the coal-bearing beds have been called the *McLeod member* of the Kootenay formation. In the following discussion when the term *Kootenay* is used it implies both members, but when only the coal-bearing member is referred to, it will be so designated.

Distribution.—The Kootenay formation occupies a relatively small part of this map-area. A belt of these rocks in township 40, range 15, shown on Map No. 2, accompanying the report on Saunders creek and Nordegg coal areas extends westward as far as Black Canyon in township 39, range 15. This belt extends northwest along the upper drainage of Shunda creek. The Kootenay is shown farther west on map No. 5, than on Map No. 2. The field work of 1923 has led the authors to make this change although the exact boundary cannot be determined from the paucity of outcrops. This belt extends north to the end of Brazeau range as shown in map No. 2.

A small belt of Kootenay between Tepee creek and Bighorn river represents a south-eastern continuation of the Kootenay beds as mapped by Malloch in Bighorn basin. All the exposures along Blackstone river east of Bighorn range show beds of Colorado and younger ages.

A narrow belt of Kootenay (coal-bearing) crosses the main Brazeau in section 26, township 44, range 20 (Plate III.B). The southern termination of this belt was not determined. These beds extend northwest, forming a high ridge east of Medicine lake in section 5, township 45, range 20, and cross the north Brazeau near Grave creek cabin. The northern continuation of this belt is concealed by erosion and plant growth. This belt is not exposed on the headwaters of Pembina river, but may occur beneath at some depth. The absence of Kootenay rocks on the Pembina may be due to the fact that Pembina river is a small stream near its head, and has not eroded as deeply as the north or main Brazeau rivers.

Another belt of Kootenay crosses the main Brazeau at the mouth of Ruby creek in section 11, township 45, range 21. This belt appears to be split to the north by the southern end of Nikanassin outlier, and one portion of the Kootenay extends northwest along the front of this outlier. These beds, however, do not outcrop at the surface on the Pembina but probably occur beneath the river level at considerable depth. It is believed that the Kootenay beds exposed at Cadomin and Luscar belong to this same belt, but have been exposed by the relatively deeper erosion of McLeod river and its tributaries. This belt extends southwards from the north Brazeau and crosses the main Brazeau in township 43, range 20, but these rocks have not been traced further south.

Lithological Character.—The Kootenay strata in this map-area are similar to those in the Nordegg area, and consist of alternating beds of conglomerate, sandstones, clay shales, carbonaceous shales and coal seams. The sandstones are lenticular and frequently grade into clay shales within short distances. It is impossible to give a detailed section from the exposures in this area since the beds are much folded and broken. The section given by Malloch¹ should apply in general for this area, since the Kootenay exposed in this part of the foothills lies within 10 miles east of the exposures in the Bighorn basin.

Petrography.—Since the publication of the fourth annual report some petrographical studies have been made on the Cretaceous sandstones from the Saunders creek and Nordegg areas which lie to the southeast and borders the area shown on the map accompanying this report. It is believed from the lithological similarity that the general composition of the beds of the same age in both fields is similar, and the conclusions arrived at from the petrographical study will apply to both areas as far as general results are concerned, although lateral variations in sedimentation may show many minor differences.

In the Saunders creek and Nordegg areas the base of the Kootenay was placed at the top of a conglomerate. A considerable thickness of sandstones occurs below this conglomerate which grade downward into black marine shales of Fernie age. The petrographical study was made on these transition strata from marine to continental deposition and is included in the following discussion of the Kootenay.

¹op. cit., p. 31.

These studies of the upper Fernie beds show that the dominant material present is silica, chiefly in the form of quartz and chert. Even the finer grained argillaceous sandstones are made up largely of elastic quartz and chert. It is noteworthy that many of the sandstone bands carry very little other mineral material. With stratigraphic rise there is an increase in the proportion of chert grains with respect to quartz, which culminates in a conglomerate at the top of the Fernie formation. A microscopic examination of the pebbles of the conglomerate shows them to be made up of very finely crystalline quartz. In most cases they are traversed by a series of small fractures that were filled with vein quartz previous to their deposition as clastics in their present associations. Many of the pebbles have a dark color which tends to make them opaque in thin section. Smaller fragments of this colored chert give rise to the grey color in many of the finer grained sandstones.

There is also a noticeable increase in size of the essential mineral grains with stratigraphic rise. This likewise has its culmination in the conglomerate at the top of the formation.

Change in shape caused by solutions subsequent to deposition makes it difficult to determine what shape of the elastic grains were at the time of deposition. This change has apparently been brought about by circulating ground waters which have taken into solution parts of the grains. A redeposition of silica leaves most of the quartz grains with an irregular outline. The chert pebbles have suffered less from this agent and retain their elastic outline to a better degree. These show a fairly well-rounded outline while the quartz fragments are, as a rule, more angular and irregular.

Accessory minerals are not found in sufficient quantities nor in a sufficient number of rock specimens to allow any generalizations.

Regrowth of quartz crystals is the prevailing method of cementation. This has produced well-cemented sandstones with angular grains tightly interlocked. Occasionally some specimens show a thin coating of iron oxide around the original quartz fragments, but in most cases the old outline has been largely destroyed. In some of the fine grained beds calcite becomes plentiful as a cementing material. It is doubtful whether any of the calcite was deposited as a elastic mineral, but a large part of the calcium carbonate may have been chemically precipitated at the same time as the elastic material was being laid down.

In addition to minerals these transition beds show plant fragments which are small and too finely broken up for paleobotanical determination. Such fragments, however, are often the cause of dark colors in some of the sandstone bands.

The marked uniformity in material, composition and texture of individual beds indicate that the materials were well-sorted before final deposition. Some of this uniformity may be due to post-depositional changes. The outlines of the greater number of quartz grains cannot be interpreted as due to mechanical action. The change from the elastic shape has in all probability been carried out by solution action since deposition, and new materials might have been introduced into the sediments or some materials removed by

such solutions. This study indicates that nothing new was introduced unless it was silica, or in a few cases calcite. The absence of any mineral material other than quartz in several beds is noticeable.

These upper Fernie beds also indicate a change relative to the source of material. The increasing coarseness could be brought about by two factors. A marked change in climatic conditions might have caused the Fernie seas to become more powerful distributing agents, thus carrying coarser material farther from its source and depositing it above the lower shale members. Secondly, the terrane from which the material was derived may have been closer to the site of deposition in upper Fernie time. The latter explanation seems to meet the conditions better than the first, since the upper sandstone beds carry plant remains which are occasionally sufficiently intact for paleobotanical identification. This would indicate that the source of material for the upper sandstone beds was closer than that for the lower shale beds, due probably to an uplift to the west. Such an uplift would tend to lessen the depth of water in the Fernie seas, and the increase in supply of material would tend to fill up such bodies of water as remained. Field evidence shows that the combination of forces and agents acting in late Fernie time succeeded in the termination of marine conditions in this part of the foothills area. These conditions were supplanted by those suitable for the deposition of the continental Kootenay deposits. No angular unconformity was observed at the top of the formation.

The Kootenay sediments show a recurrence of similar beds within the formation. The most outstanding change from the Fernie is shown by the prevalence of feldspar grains in many of the beds of coarser material. This mineral with quartz and chert make up the greater portion of the sandstones. In some cases the feldspar content is sufficiently high to make the rock an arkose. With a rise, stratigraphically, there seems to be a slight decrease in the ratio of chert grains to the other elastic minerals. Chert is more abundant in the conglomerate at the top of the Fernie and decreases as an essential constituent both upward and downward from this bed.

The rock specimens studied were chiefly from the coarser and arenaceous beds. Associated with these are many beds of what may be termed clay shales which differ quite markedly from the marine Fernie shales. They are not of marine deposition, and do not show fine lamination, but break into angular irregular fragments. These shales are frequently arenaceous and carbonaceous and occur in lenses. Under microscopic examination the larger grains in the harder phases are essentially of the same material as the coarser sandstones.

There is no regular change in size of grain with stratigraphic rise. The sizes vary from submicroscopic up to about .5 mm. in diameter.

The angularity of the quartz grains is marked. The basal Kootenay rocks contain grains with irregular outlines. This marks a gradation from the Fernie type, but the greater number of beds examined show quartz grains that have suffered very little rounding

action in transportation or change by solution action after deposition. The feldspar and chert grains on the whole show more rounding than the quartz grains, but frequently the feldspar grains have very sharp corners.

The feldspar grains are often highly sericitized, but frequently within the same rock section there are many grains that show no sign of alteration. Although a gradation from very fresh to highly altered grains may occur in the same bed, there seems to be a prevalence of either the very fresh or very much altered feldspar fragments in the individual specimens.

Among the accessory minerals hornblende and chlorite, or hornblende altering to chlorite, are quite common in the upper Kootenay beds.

The dominant cementing materials are clay, calcite, and frequently carbonaceous matter. In some cases the calcite forms the greater part of the rock. Some of the calcite may be of clastic origin as an essential or accessory mineral in the rock. It is difficult to determine what proportion is primary or contemporaneous with the other clastic material, and what part has been later introduced as a cement. The presence of rounded isolated grains, seen in thin section, suggests that it is in part a primary clastic.

On the whole the materials in the Kootenay are not as well-sorted as those in the Fernie formation. This is shown by the greater variety of materials and textures in individual specimens. Besides these types of sediments the Kootenay formation includes several coal seams and many scattered bands rich in plant remains.

Deductions and Conclusions.—Field and microscopical studies of the Kootenay beds show a change from the type of sedimentation prevalent in the upper Fernie. The most marked change is the appearance of feldspar as an essential mineral in the sediments. This mineral appears to be most prevalent in the beds above the coal seams. This indicates a more rapid transportation of material to the site of deposition after the coal beds were laid down than during or prior to their formation. The regular occurrence of shales and clays as the footwall of coal seams also substantiates this idea. Sandstone bands frequently occur between coal seams, but they are more abundant and of greater thickness above the coal. It seems that big increases in supply of clastic material were unfavorable to the growth of coal-forming materials at or near the sites of deposition.

The prevailing angularity of the clastic grains indicates a relatively rapid disintegration of the material at the source, slight action during transportation, and also that post-depositional changes have not had much effect in changing the shape of the fragments. The presence of angular fresh grains of feldspar in close association with highly altered grains of the same mineral indicates that the alteration of the feldspar took place for the most part prior to deposition. It does not seem possible that these two phases of the same mineral could remain in such an association if post-depositional action of ground solutions were the cause of the alteration.

In the lower part of the formation there are indications of the upper Fernie type of sediment. This, however, was soon replaced by materials which were more rapidly accumulated. Pauses in this

rapid accumulation are marked by the clay shale beds and coal seams. These in turn are followed by the deposition of thick masses of arenaceous material. The lithic units on the whole do not persist laterally for any great distance, but are lensed in nature. This feature accompanied by cross-bedding, and a frequent intermixing of shale and sandstone bands, indicates a shallow-water deposition.

The upper Fernie beds indicate a shallowing of the water over the sites of deposition. This shallowing continued until the sediments were deposited in waters that appear to have been non-marine. These conditions continued into the lower Kootenay time, but the sediments became finer prior to the accumulation of the coal material. This indicates that the rate of supply of material had somewhat lessened. Shallow waters and slow supply of sediments prevailed during accumulation of the coal, but these conditions were followed by an increase in material which seems to have stopped the formation of the coal beds.

Depression of the basins of deposition would permit a rapid accumulation of the sediments, but the changes in type of material deposited indicate that changes at the source were perhaps more influential. Both igneous and sedimentary rocks apparently were the source of the clastics, and these were rapidly broken down and carried to their present position.

The main source of supply was apparently from the west. In this direction the formation shows a rapid thickening. As far as known there are no igneous rocks associated with the later Paleozoic strata in the Rocky Mountains to the west. It should be noted, however, that igneous action is known to have occurred near the close of Kootenay (Dakota) time, in the southwestern part of Alberta¹.

In the Crowsnest region this is represented by a series of tuffs and agglomerates, that show gradational sedimentary relations to the Dakota below and the Colorado above. The most northerly known occurrence of these beds is on Oldman river which lies south of the Highwood coal area².

Thickness.—In Bighorn basin the Kootenay strata have a measured thickness of 3,600 feet, and the Dakota an additional 1,800 feet. Since only partial and much folded sections of the Kootenay rocks are exposed in this area it is not possible to determine the thickness of these members. The lower Cretaceous formations are known to thin rapidly to the east along the foothills belt, so that the Kootenay in this area is believed to be somewhat thinner than in Bighorn basin.

COLORADO GROUP.

General Statement.—The strata of this group were divided in order to age into Blackstone shales, Bighorn sandstones and Wapiabi shales in the Bighorn coal basin, where the structural relations are relatively simple and it is possible to map these divisions separately.

¹Mackenzie, J. D., "The Crowsnest volcanics"; Geol. Surv., Can., Mus. Bull. No. 4, 1914.

²Rose, Bruce, Highwood Coal area: Geol. Surv. Can., Sum. Rept. Pt. C., 1919, p. 16.

In the area east and north of the Bighorn range the Colorado beds are in most places much folded and broken, so that it is impossible to map the formations separately. For this reason the Colorado formations are mapped as a group.

Distribution.—The strata in the Colorado group form the underlying rocks over a large part of this area. The most easterly exposure is that at the mouth of Brown creek on Blackstone river. Here the Colorado shales outcrop in the river bottom but are not exposed for any great distance to the northwest.

An extensive belt extends from Blackstone to Pembina rivers, lying between *Chungo fault* and the contact with the Saunders formation to the west. This belt is known to extend north across the Pembina for some distance, but the relations of these beds to the section on McLeod river have not been determined.

Another well defined belt extends from the Blackstone river to the Pembina, and is bounded on the east by the *Blackstone fault*. The west side of this belt is more poorly defined. On the Blackstone it is in contact with the Saunders formation near Bighorn range. On both the main and the north Brazeau rivers the western boundary shows faulted relations with the Kootenay beds, while on Pembina river these Colorado beds extend up to the limestones of Nikanassin outlier. The continuation of this belt across the Pembina has not been determined, but in all probability it is represented by some of the Colorado beds which cross McLeod river northeast of Cadomin.

This same belt continues south of Blackstone river and in all probability extends across the North Saskatchewan river, since the exposure from Black Canyon to the Bighorn mountains indicates that the entire area is underlain by Colorado beds.

The wide belt of Colorado strata between Black Canyon and the Bighorn range is split to the north by two belts of the Saunders formation which cross Blackstone river. One part makes a rather abrupt turn to the northeast around the north end of the Brazeau range and forms a part of the belt of Colorado that crosses the Blackstone below the mouth of Lookout creek. *Black mountain* in township 41, range 16, is made up of the Colorado beds that form this eastern band that crosses Lookout creek, striking N. 45° E., in the northwest corner of township 41, range 16.

Another part of this broad belt exposed on the North Saskatchewan follows along the front of the Bighorn range, and is shown to cross Blackstone river as a narrow belt immediately east of the Palaeozoic rocks.

Colorado beds separate two belts of Kootenay rocks that are exposed on north Brazeau river. These extend north, join the other belt of Colorado to the east and cross the Pembina beneath a capping of Saunders beds along the front of Nikanassin outlier.

Lithological Character.—The Colorado strata are mostly black marine shales. The threefold division made by Malloch in the Bighorn basin can be recognized at several localities in this area.

The lower formation (Blackstone) is composed of black marine shales uniform in character. Malloch¹ records a thickness of 1,050 feet for an incomplete section. The basal part of Blackstone formation is not exposed in the Bighorn coal basin, therefore, the Blackstone or lowest member of the Colorado group is somewhat thicker than the above figure. The change from continental conditions of the Kootenay to marine conditions of deposition of the Colorado is represented by an alternating series of shales and conglomeratic sandstones.

Since all exposures of Colorado beds in the area mapped are much folded and broken, it is impossible to give their thickness or to arrive at the total thickness of the *Blackstone formation*. Furthermore, it is difficult to ascertain the exact position of the base of the Colorado. These basal beds are exposed on Blackstone and Brazeau rivers on the west side of the *Chungo fault*. Future work may prove that some of these beds belong to the McLeod member, but, tentatively, they are not separated from the Colorado. Most of this lower formation consists of black marine shales that are on the whole free from sandstone bands or nodules and contain few fossils.

The lower black shale is followed by a formation which consists of massive fine grained sandstones, 25 to 75 feet thick, alternating with black marine shales (Plate IV, A.). This has been named the *Bighorn formation* in the Bighorn basin and measured 390 feet in thickness.

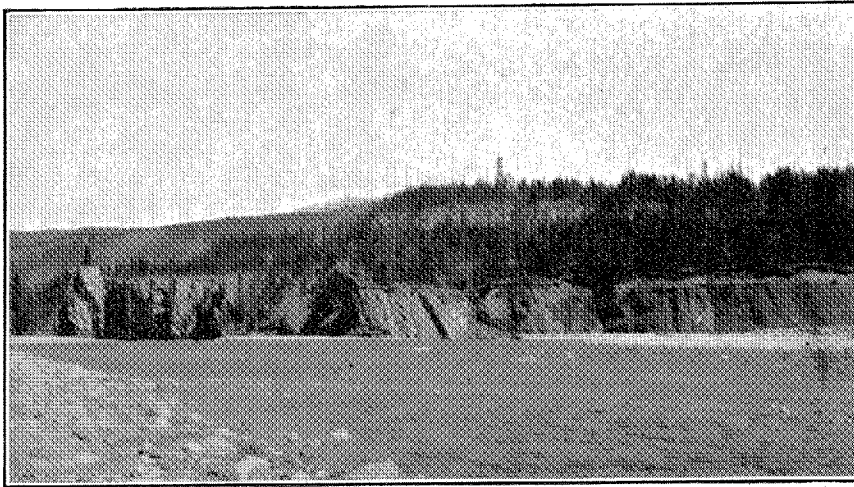
The massive sandstones in this formation are very hard, and in many cases conglomeratic. These give rise to many physiographical prominences in the areas mapped as Colorado between the main Brazeau and Pembina rivers. One of the hard members of this formation caps Black mountain, and several other ridges in the southern part of this area are due to these hard bands.

The upper Colorado strata or Wapiabi shales are similar in many respects to the black shales of the Blackstone formation (Plate IV, B). In contrast, however, the upper shales carry numerous nodules and concretions, many of which are fossiliferous.

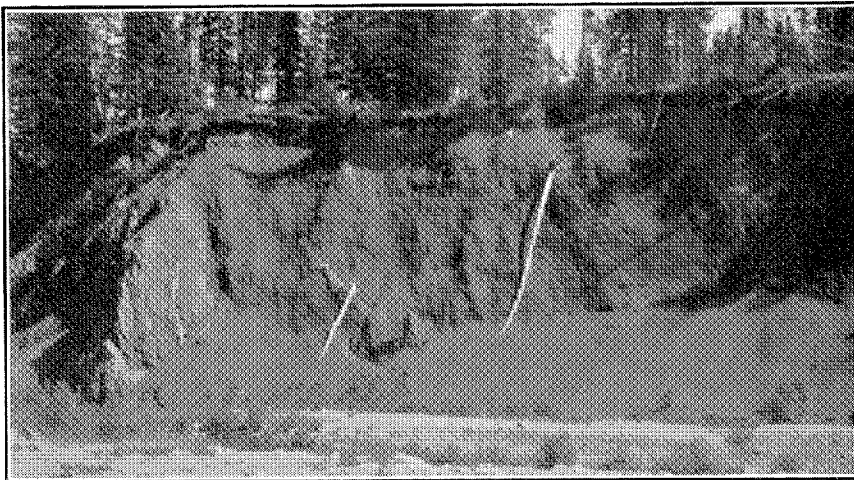
The change from marine to continental conditions at the top of this upper shale formation is very abrupt. This abrupt change is exposed at well separated points on Blackstone, Brazeau and Pembina rivers.

A good section of the Wapiabi formation is exposed on Blackstone river below the mouth of Lookout creek. This section is as follows:

¹op. cit., p. 23.



A. Colorado formations on the Blackstone near the mouth of Lookout creek
Bighorn formation on the left and Wapiabi on the right.



B. Wapiabi shales on the Blackstone river near Lookout creek.

SECTION ACROSS WAPIABI FORMATION ON BLACKSTONE RIVER
BELOW LOOKOUT CREEK.

Shale, black, calcareous, with nodules up to one foot in diameter	103 feet
Concealed, presumably soft shale.....	350 "
Shale, dark grey, fissile, weathers reddish, occasional thin sandstone lenses	99 "
Shale, dark grey, calcareous.....	30 "
Limestone, hard arenaceous.....	2 "
Shale, black, with hard grey calcareous bands near the top (Fossils No. 38).....	42 "
Shale, black, fissile.....	261 "
Shale, black, fissile, (Fossils No. 37)	9 "
Shale, black, fissile, with evenly spaced bands of concretions.....	81 "
Shale, soft, black fissile.....	108 "
Shale, black, fissile, with a few large concretions up to 14 inches in diameter.....	45 "
Shale, dark, breaks into angular fragments.....	45 "
Shale, soft, black, very fissile.....	27 "
Shale, black, with ironstone bands and scattered concretions.....	45 "
Shale, black, with numerous concretions.....	54 "
Shale, black, few concretions, (Fossils No. 36)	45 "
Shale, black.....	99 "
Concealed, presumably soft shale.....	288 "
Shale, black.....	18 "
Shale, black, few concretions, (Fossils No. 35)	18 "
Shales, black.....	36 "
Shales, ferruginous.....	16 "
Shales, black.....	79 "

Total thickness.... 1,900 "

Note.—Fossil numbers refer to specimens not yet determined.

Petrography.—A petrographical study of some of the hard sandstone bands shows that there is considerable similarity between the coarser materials in the Colorado formations and those in the Kootenay and Fernie. The feldspars, though frequently present, do not represent as large a percentage of the elastics as is frequently the case in the Kootenay beds. Quartz and chert fragments are the main minerals present in the coarser grained beds. Calcite forms a high percentage in many of the argillaceous rocks. Where calcite is the dominant cementing material the clastic grains show a high degree of angularity. This would indicate that the calcite to a large extent was deposited contemporaneously with the clastic grains, rather than introduced later by circulating ground waters which would tend to change the angular outline of the quartz and chert grains. Conglomeratic sandstones are very common. These are made up chiefly of chert pebbles with sand grains as the matrix.

The lowest Colorado beds examined show a high proportion of quartz grains with irregular outline and cemented together by regrowth of the quartz crystals.

The size of grain varies from submicroscopic in the shales, up to well rounded pebbles which average 2 cm. in diameter in the conglomerate beds.

Conditions of Sedimentation.—Field and petrographical investigations show that during lower Colorado time there was a return to marine conditions in this area. These conditions prevailed for sufficient time to permit the accumulation of at least 800 feet of beds that are dominantly marine shales with a marked absence of coarse material. Such conditions, following upper Kootenay time when material was rapidly transported and deposited, indicate a depression at the site of deposition to allow marine waters to occupy the areas previously covered by fresh waters. The lack of coarse material seems to indicate that the shoreline was a considerable distance from this area, and that only the finer material was carried out by current action. The source of the coarse material for the upper Kootenay may have been eroded down near to base-level and stream action reduced considerably. Field evidence indicates depression as the cause for change in sedimentation, since it is known that marine conditions prevailed for a considerable distance to the west during lower Colorado time.

After the deposition of these lower shales there was a return to conditions similar to those that prevailed in the upper Fernie seas. These conditions produced massive sandstone members composed chiefly of small quartz grains. The sandstone beds are associated with marine shales which apparently have diverted circulating ground waters into the sandstones. This has resulted in producing beds that are cemented by the regrowth of the quartz grains. Rising stratigraphically the sediments become coarser and sandstone bands are more numerous. The presence of much feldspar, both fresh and altered, and the marked angularity of grains indicate a partial return to conditions somewhat similar to those in Kootenay time. The presence of pebbly sandstone indicates poor sorting, and the angularity of the particles means a rapid transportation to the site of deposition. Furthermore, some beds contain carbonaceous bands which indicate near-shore conditions where the waters were much more shallow than in lower Colorado time. These carbonaceous bands are not of sufficient magnitude to be classed as small coal seams, but are made up of fragments of coal and coaly material that are mixed in with the other sediments. These beds may represent continental conditions, but the associated sandstones and shale members are of greater lateral persistence than are the beds of the Kootenay or of the Montana formations.

These carbonaceous shale bands are exposed along the north Brazeau and McLeod rivers. On the north Brazeau in the southwest quarter section 17, township 45, range 20, just below the mouth of Grave creek, one of these bands is exposed. It has an appearance similar to an impure coal band in the Kootenay coal measures. A similar band in the Colorado has been prospected on McLeod river in the southwest quarter section 30, township 47, range 22.

While the Colorado as a whole carries many sandstones and conglomerate bands, there does not appear to have been any time

when conditions were other than marine. Close approach to continental conditions may have existed part of the time, but definite evidence for such has not been observed. The lithic units are of greater lateral persistence than those of the Kootenay, and the sandstone beds almost always show relatively sharp contacts with the associated shale beds. Near-shore conditions perhaps existed during middle Colorado time, since the Bighorn formation shows a larger amount of coarser material in the Bighorn basin to the west. This shallowing of the seas in middle Colorado time was temporary and was followed by distinct marine conditions which permitted the accumulation of almost 3,000 feet of shales.

MONTANA GROUP.

SAUNDERS FORMATION.

Definition.—In the fourth annual report all the strata above the marine beds of the Colorado group were named the Upper and Lower Saunders formations, separated by the Saunders coal series.

In this report strata of this age are mapped as one unit since the number of coal-horizons increases to the north, and it is difficult to separate these Montana strata into two formations. There is, however, some distinct lithological differences between some of the upper and lower strata as shown by petrographical examination. These are discussed in a later paragraph.

Distribution.—The Saunders formation has a wide distribution in this map-area. Practically the entire area east of *Chungo fault* is underlain by either the lower or the upper members. The upper member lies mainly to the east of the *Lovett fault*. This belt of Saunders extends from south of Blackstone river northwest to McLeod river. It becomes much broader to the north and extends as far west as the mouth of MacKenzie creek on McLeod river.

Another well defined belt of Saunders extends from the Blackstone to the Pembina, between the *Blackstone fault* on the west and the contact with the Colorado on the east.

To the south this belt extends across the Blackstone almost to Black mountain. It may have extended much farther to the south, but it has been removed by erosion, leaving Colorado beds as the underlying rock. This belt of Saunders also extends northwest across the Pembina, but its continuation beyond this point has not yet been determined.

The beds in this belt belong largely to the lower member of the Saunders, and are stratigraphically below the coal seams in the Saunders creek area.

A third area of Saunders beds with synclinal structure is exposed on the Blackstone just east of Bighorn range. This belt extends south of the Blackstone and probably crosses Wapiabi creek. To the northwest it is probably represented at the headwaters of Brown and Chungo creeks, but does not cross the main and north Brazeau rivers. It is represented by the beds which cap the Colorado at the head of Pembina river. These exposures appear to represent the isolated remains of a once continuous belt along the front of the Paleozoic rocks, which has been dissected by the deeper channels of the major streams.

Lithological Character.—The general description of these strata in the Saunders creek and Nordegg basins applies equally well to this region¹. The lower and upper members both consist of continental deposits represented by sandstone, clay shales and coal seams.

The most outstanding lithological difference, shown in the lower member in different parts of the area, is the increase in thickness and number of coal seams towards the north. Between North Saskatchewan river and the Blackstone only one coal horizon with seams of commercial thickness was observed, and this horizon occurs over 5,000 feet above the base of the formation.

This conclusion was reached in 1922 from an examination of the section shown along Blackstone river between the mouths of Chungo and Brown creeks. Another section of lower Saunders beds is exposed on Blackstone river between the mouth of Lookout creek and the Wapiabi. This section also shows that the lower 3,200 feet of the Saunders formation do not carry coal in this part of the area. The coal seams exposed near the mouth of Chungo creek have been traced northwest across Brown creek, and are exposed on the main Brazeau less than one-half mile below the mouth of the north Brazeau. The strata between Chungo and Lovett faults on the Brazeau are the stratigraphical equivalents of those between Chungo and Brown creeks on the Blackstone. On the Brazeau, however, the succession shows three coal horizons in addition to the one mentioned above. These three coal horizons are definitely in lower positions, stratigraphically, than the coal in the Saunders creek area, and are separated from each other by considerable thicknesses of sediments.

The external lithological appearance of the upper member of the Saunders formation is similar to that of the lower member. The petrographical examination, however, shows some difference.

The Saunders formation is, on the whole, poor in fossil animal remains. This is especially true of the lower two-thirds of the formation. The upper part has several lenses that carry fresh-water fossils such as *Unio* and *Viviparus*.

Petrography.—Petrographical studies have been made on the sandstones in the lower member of the Saunders formation in the southern part of the area.

These studies show that the dominant clastic materials of the lower Saunders strata are quartz, chert and feldspar. Fragments of shale or clay, and carbonaceous matter are present with the elastics and are prevalent in some beds. Sometimes the shale fragments range from one to two inches in diameter, and are cemented with sand grains to form a conglomerate-like mass. These are most commonly associated with highly cross-bedded sandstones. Furthermore, there appears to be a larger percentage of feldspars in the upper than in the lower beds.

The average size of grain is about the same throughout. The upper strata, however, do not show as uniform a size of grain as do the lower ones.

¹Allan, J. A., and Rutherford, R. L., op. cit., p. 52.

On the whole the clastic grains are angular, especially the quartz and fresh feldspar grains. The quartz grains are often much fractured, especially in the upper beds. The fracturing appears to have been pre-depositional as the beds carrying such grains are in many cases only slightly deformed. The only generalization that can be made regarding alteration is that it is common to find very fresh and highly altered feldspars in the same rock section. Some specimens show a dominance of one type over the other, but this appears to be due to chance sections, as two rock sections from the same bed will show the reverse conditions. Biotite and epidote occurring as accessories are as a rule highly altered. These two minerals were not observed in the microscopical study of sandstones from the Kootenay and Colorado.

Clay and carbonaceous matter are the dominant cementing materials, while some of the beds are high in calcite. These materials are usually so intermixed that it is difficult to determine the approximate proportion of each present.

Sandstones from the upper member of the Saunders formation show the following characteristics when studied microscopically: The dominant clastic materials of this member are similar in many respects to those of the lower Saunders. This is especially true in the case of the basal members which are essentially composed of quartz, chert, and feldspar grains. About 500 to 1,000 feet from the base there is, however, one outstanding characteristic in the mineral composition of many of the beds. This is the presence of clastic grains of calcite which sometimes form at least 30 per cent. of the rock. Calcite is noted in lower strata, but it is questionable in most cases whether it occurs as a portion of the cement or as clastic grains. In the upper Saunders member clastic calcite has been identified at four localities which are quite widely separated. It may be safely stated then that clastic calcite is typical of this horizon and does not represent an isolated or chance deposit in one locality.

The upper part of this member shows a reversal to the lower Saunders type in having quartz, chert and feldspar as the essential clastic minerals. Throughout the formation many of the beds show fragments of coal as clastic grains. In many cases the quartz grains are highly fractured. This fracturing appears to have been pre-depositional as such grains do not show strained effects in thin section.

The grains vary in shape from angular to subangular, apparently depending largely on the hardness of the different minerals. Thus quartz is usually the most angular mineral present, while chert, feldspar and calcite show some degree of rounding.

The average size of grain ranges from about .5mm. in diameter, to submicroscopic. In many cases, however, there are rows of quartzite and chert pebbles that are as much as 6 inches in diameter.

Biotite is a common accessory mineral in addition to the minerals already mentioned and is usually considerably altered. Both much altered and very fresh feldspar grains frequently occur in the same specimen.

The prevailing cementing material is a mixture of clay, calcite and carbonaceous matter. Many of the sandstone members are very porous and poorly cemented. The most uniform sizes of grain are present in the beds that have an appreciable quantity of elastic calcite. The other beds consist of particles of various dimensions mixed in with the clay.

The observations noted above have been made on sandstone specimens but much of the formation is made up of clay shales. The nature of this shale can be studied where it occurs as hard pellets in the sandstone beds. These pellets consist of fine grains of the normal elastics with a considerable amount of clay material.

Deductions and Conclusions.—The lower Saunders beds represent a transition from the marine Colorado beds to the continental deposits of the Saunders. This transition to a continental type of deposit is shown in the basal strata of the formation. These strata are more uniform in texture and of greater lateral persistence than the beds that follow. A microscopical examination of basal Saunders sandstones shows that the material is better sorted than in the overlying beds.

Continental deposition prevailed from near the beginning of lower Saunders time. Mud-crack impressions seem to indicate that shallow water deposition was common. Sorting of material was poor as shown by various sizes of clastics mixed with clay material. This indicates that either the supply of material was increased, or that the water at the sites of deposition had become more shallow than at the beginning of the deposition of this member. The observations favor a decrease in water depth since there is no marked increase in coarseness of material but less sorting.

The presence of epidote, considerable biotite, some vein quartz, in addition to the essential elastics in the upper strata indicates poorer sorting and more rapid transportation of material from its source to sites of deposition. Further evidence of rapid transit of material is the presence of fresh angular grains of feldspar.

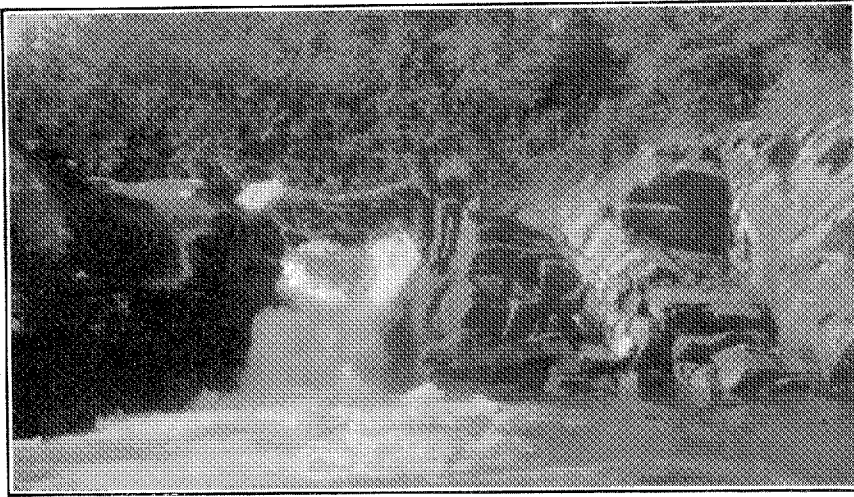
As this member is over 6,000 feet thick, deposition must have been accompanied by subsidence, since the upper Colorado beds do not indicate very deep waters preceding lower Saunders time. The accumulation of material apparently was slightly more rapid than the rate of subsidence, as the upper strata indicate that the water was more shallow than when the basal beds were deposited.

On the whole, the strata are more uniform than those of Kootenay time. This fact, together with the thickness of beds, seem to indicate a relatively long time of stable conditions at the sites of deposition, at the source of supply, and in the rate of transportation of material.

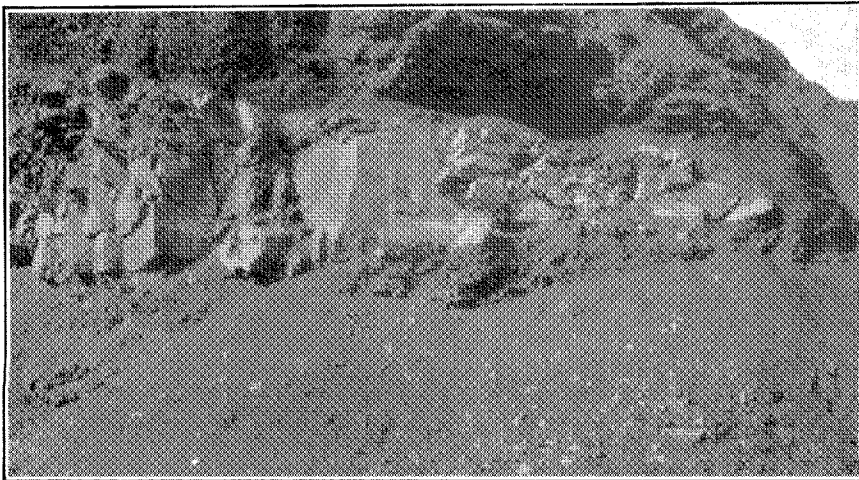
The general characteristics of the lower members in the Saunders seem to indicate a source of material similar to that for the Colorado and Kootenay formations.

A study of some of the sandstone bands between the coal seams, shows that the elastic materials are essentially the same as those in other parts of the formation. In some cases beds are sufficiently high in calcareous material to be classed as limestones. Fragments of coal

PLATE V.



A. Falls on the Pembina river made by basal Saunders beds.



B. Lens of sandstone in coal seam at mile 53.5 Alberta Coal Branch.

are frequently present and the cement is often largely composed of clay. On the whole, the sorting of the material is very poor and each bed consists of a mixture of different sized grains. A large proportion of the quartz grains are highly fractured. Bedding is not very good and cementation is usually poor. The field and microscopic evidence indicate shallow water deposition of these beds.

The field and microscopic study of the upper member of the Saunders formation lead to the conclusion that the strata were also deposited in shallow water. The relative softness of the rocks as compared with those in the lower formations is due largely to the fact that they have not been buried so deeply. They were deposited similarly to the beds in the lower member of the Saunders formation and represent a continuation of lower Saunders conditions. The presence of clastic calcite in appreciable amounts in the lower part of the upper member indicates that limestones were present at the source of material. Such rocks may have been present at the source of the supply for the earlier strata, but, if such were the case, the calcite underwent almost complete solution before reaching the site of deposition. The sediments of the upper Saunders do not appear to have been more rapidly transported than those of the lower part, and the sorting and sizing is about the same in both cases.

Summary of Montana Group.—Certain general characteristics of the whole Montana group are apparent in this area. The formation is made up essentially of continental deposits, and a rather marked repetition of similar conditions of deposition is shown in both the upper and lower members. On the whole, the lower beds are better cemented, due perhaps to the greater weight of the overlying formation. Both, however, begin with thick sandstone members averaging up to 75 feet. These are interbedded with clay shale beds averaging 30 to 40 feet in thickness (Plate V,A).

Rising stratigraphically in both the lower and upper members the relative quantity of clay shale increases, and the sandstone beds become finer grained, more argillaceous and decrease in thickness. The upper beds in both members frequently contain large lenses of coarser sandstone (Plate V,B), with smaller lenses of conglomerate, clay pellets, and plant remains. The top of the Saunders formation has not been defined since it has been eroded away from this part of the foothills.

The formations in southern Alberta that correspond in part to the Saunders formation have been studied microscopically by Stewart¹. The results tabulated for this area show many similarities to those given for the Saunders formation. Quartz and feldspar are the essential clastics, while calcite is the prevailing cementing material. The grains are dominantly angular and the sizes are about the same as those in the Saunders formation.

Although the area described by Stewart is 250 miles to the southeast of the Saunders creek area, there appears to be a somewhat marked similarity in the sediments deposited in late Cretaceous time. Future investigation will show whether or not this similarity of sediments exists in the area that intervenes.

¹Stewart, J. S., *Geology of the Disturbed Belt of Southwestern Alberta*: Geol. Surv. Can., Mem. 112, 1919, pp. 41-42.

QUATERNARY.

PLEISTOCENE AND RECENT.

The unconsolidated rocks consist of boulders, gravel, sand and clay of glacial and fluvial origin. The two ice sheets that effected this region were the *Cordilleran* from the west, and the *Keewatin* from the northeast. The glacial deposits in the foothills have been derived from the former, but the distribution of these deposits in the outer foothills and in the western edge of the plains was influenced by the latter.

The mountains and the foothills were formed long before the advance of the ice sheets into this region, possibly as early as middle Tertiary time. Valleys such as the North Saskatchewan, Brazeau, McLeod, and possibly the Blackstone and north Brazeau were eroded across the foothills by the drainage from the uplifted region to the west. The foothills were invaded from the mountains by glaciers which moved down the valleys, deepening and widening them. The amount of glacial erosion in the valleys depended upon the volume of ice advancing and on the character of the rock in which the valley was formed. This accounts for some of the valleys in the foothills being broader and deeper than others. For example, the North Saskatchewan and Brazeau valleys in the inner foothills are larger than the McLeod and Blackstone valleys.

When the ice had filled the valleys it flowed over the intervening ridges, and formed a piedmont glacier along the base of the mountains, covering even the highest ridges in the foothills.

When the glacier melted the enclosed debris was left in scattered morainal ridges throughout the foothills, or filled up lakes formed by interrupted drainage to the east. The Saskatchewan valley in townships 39 and 40, between Bighorn river and the gap through Brazeau range contains such a deposit. Glacial-lake silts and gravels occur along the north side of the valley in ranges 15 and 16 and almost to the headwaters of Haven creek.

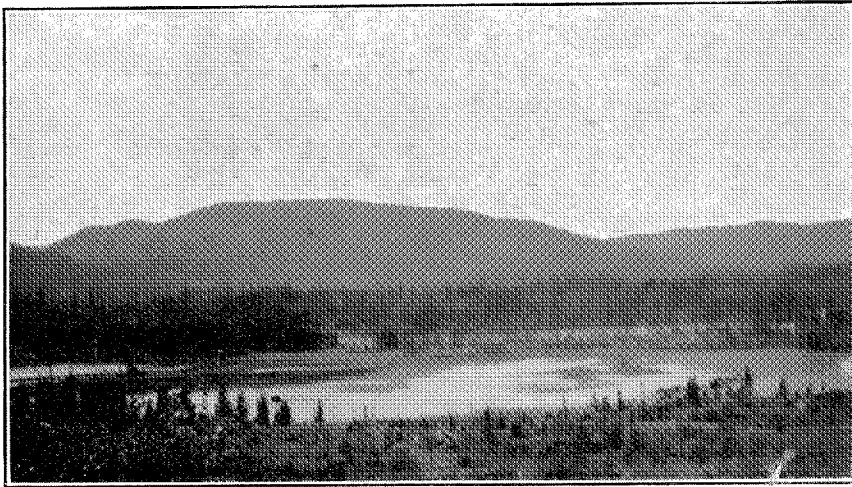
Much of the broad depression between the Bighorn and Nakanassin ranges, occupied in part by the valley of Brazeau and north Brazeau rivers, has been partly formed by glacial erosion. This part of the area is underlain by soft rocks of Cretaceous age.

Glacial deposits are quite extensive along Brazeau valley in range 19 as drift and as morainal ridges. Some of these gravel ridges are 50 feet high and extend along the valley in an east-west direction for a mile. Several small ponds a quarter of a mile in diameter, without surface outlets, occurs in these gravels between these ridges and the side of the valleys. (Plate VI.A.) The water in these shallow ponds is apparently derived from seasonal precipitation.

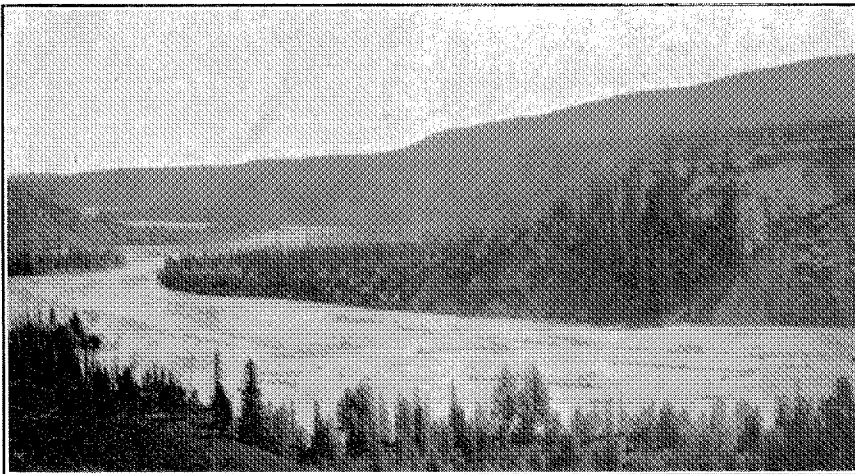
The finer sand and silt from this morainal material were deposited to the east over an area extending for three miles above the confluence of Brazeau and north Brazeau rivers.

Limestone boulders, as much as three feet in diameter, perched in the side of a hill north of the junction of these two rivers, is further evidence of the glacial action in this valley. These boulders occur about 800 to 1,000 feet above the present water-level in the Brazeau, and about 600 feet above the top of the post-glacial valley.

PLATE VI.



A. Ponds in glacial moraine in the Brazeau valley.



B. Post-glacial valley of the Brazeau, cut through the Colorado shale ;
section 6, township 45, range 18.

There are several distinct gravel terraces along the valleys of the north Brazeau in township 45, range 20, and at several places along the Blackstone and smaller streams.

Post-glacial valleys have been cut below the glacial valleys along several of the major streams. These are represented by narrow steep-sided valleys, in some places superimposed along the side of the old glacial valley. On Brazeau river west of the outermost ridge of the foothills the post-glacial valley ranges from 200 to 500 feet in depth (Plate VI,B.) At several places the valley has the form of a canyon with nearly perpendicular walls, and almost free from recent river deposits (Plate III,B).

East of the outermost ridge in the foothills the post-glacial valley is not distinct, and at many places flat gravel terraces of fluvial origin occur along the sides of the valley. Such recent river terraces are prominent along the Brazeau in township 45, range 17.

CHAPTER VI.

ECONOMIC GEOLOGY.

General Statement.—The presence of coal in commercial quantities in this area makes geological information concerning the coal seams of economic importance. Two coal-bearing formations are present, namely, the *Kootenay* and the *Saunders*. The chief object of investigation from the economic standpoint has been to trace these coal-bearing strata from the North Saskatchewan to the McLeod along the foothills, and to connect up structurally the mining districts in the Saunders creek and Nordegg areas with those to the north along the Alberta Coal Branch of the Canadian National Railway.

Since the Kootenay and Saunders coal-bearing beds are separated by at least 3,000 feet of strata, and the character of the coal is different, they are discussed separately.

KOOTENAY COAL.

The general character and distribution of the Kootenay coal-bearing strata are given on pages 36 to 48.

The coal-bearing beds that are developed by the Brazeau Collieries at Nordegg extend northwest, but are not exposed on Blackstone river. The seams mined by the Brazeau Collieries in township 40, range 15, cannot be correlated with seams mined by other companies in this map-area.

The forces causing the uplift of Bighorn range and Nikanassin outlier brought Kootenay rocks to the surface. The Bighorn coal basin lies west of the range by the same name, and Mountain Park coal basin lies west of Nikanassin outlier. Both of these basins contain Kootenay coal measures. Disconnected belts of folded and broken Kootenay coal-bearing strata are exposed along the inner foothills.

Kootenay beds are exposed by deep erosion of the Saskatchewan valley in township 39, range 16, at the southern end of Bighorn range, but these have been overridden by the Paleozoic rocks of Bighorn range within three miles to the north.

The belt of Kootenay beds which crosses the Brazeau in section 26, township 44, range 20, should continue southeast for some distance to the east of Bighorn range, but these rocks were not observed. Between the Brazeau and Saskatchewan rivers the elevations along the front of the Bighorn range are relatively much higher than the levels of these two rivers where Kootenay rocks outcrop. This would indicate that in the intervening area between these two rivers the Kootenay is overlain by younger Cretaceous sediments, so that no

immediate commercial importance may be attached to the possibility of productive measures underlying most of this interstream area.

The exposures on the Saskatchewan show a few thin impure coal seams which are closely folded and of no commercial importance. The exposures on the Brazeau in section 26 (approximately), township 44, range 20, show one coal seam which is at least 10 feet thick. This seam has been prospected on the north bank of Brazeau river, but erosion since the date of prospecting has concealed most of the evidence of such activity.

This same belt extends northwest along the east side of Medicine lake in section 5 (approximately), township 45, range 20, and crosses the north Brazeau in section 18, township 45, range 20, and in section 13, township 45, range 21.

The measures have been prospected along the outlet of Medicine lake in section 8 (approximately), township 45, range 20, and on the north Brazeau in section 18 (approximately), township 45, range 20. At the present time one 4-foot seam and two thinner seams are exposed at the above position on the north Brazeau. Erosion, subsequent to prospecting on the outlet of Medicine lake, has concealed the coal seams so that the thickness could not be ascertained. Since our traverse was made renewed activity has taken place in this district. The coal seams have been prospected by diamond drilling, and a location survey of a projected railway has been made.

Coal seams in the vicinity of Medicine lake can be mined more economically than those on the main Brazeau or on the north Brazeau. This is due to the fact that the surface where the Kootenay beds are exposed on these two rivers is of low relief and there is not sufficient elevation to allow mining up the pitch. Especially is this true of the area along the north Brazeau. In the vicinity of Medicine lake, however, the strata are steeply dipping and these form a high hill along the east side of the lake. This physiographical condition would permit the removal of coal by means of gravity.

No seams of commercial thickness are exposed on the north Brazeau where another belt of Kootenay rocks crosses in the vicinity of the mouth of Ruby creek in township 45, range 21.

The Paleozoic rocks in Nikanassin outlier break through the Kootenay and later Cretaceous beds within 2 or 3 miles northwest of the mouth of Ruby creek, and only Colorado and younger Cretaceous beds are exposed along the east side of the outlier. The Kootenay formation is not exposed at the head of Pembina river.

McLeod river east of Cadomin gap through Nikanassin outlier exposes Kootenay beds which are mined by the Cadomin Coal Co. in section 31, township 46, range 23. The Luscar Collieries are operating on the northwest continuation of this belt in section 23, township 47, range 24. The structural details of the coal seams at these two mining centres have not yet been worked out.

The Bighorn coal basin between Bighorn range and the front range of the Rocky mountains is known to contain an extensive deposit of coal in Blackstone valley west of the gap and on George creek, and also on the headwaters of Wapiabi creek. A railway has

been located and the right-of-way cut out from Nordegg to the eastern end of the gap. The construction of this line was interrupted when the coal seams were discovered at Nordegg, where they are being mined by the Brazeau Collieries.

Considerable prospecting and drilling has been done by the British Collieries in township 43, range 20, near the main Brazeau. The coal seams at this locality are presumably the northward extension of those exposed in the Bighorn basin.

SAUNDERS COAL.

The Saunders formation of late Cretaceous age carries coal seams of commercial thickness at several horizons in this area. In the Saunders creek area only one coal horizon was recognized that carried seams of commercial thickness, and this horizon was taken as the division between the upper and lower Saunders formations in the fourth annual report¹. The study of the Saunders strata to the north shows an increase in the number of coal horizons, especially in the lower member of the Saunders formation. The coal is sub-bituminous in quality, similar to that in the Saunders creek coal basin².

The coal seams prospected on the Blackstone in section 18, township 43, range 16, and exposed on Chungo creek in section 13, township 43, range 17, are also exposed on Brown creek in township 44, range 17, and on the Brazeau river in section 8, township 45, range 18. A gentle open fold in these Saunders beds exposed this coal horizon farther to the east on the Brazeau in the southwest quarter section 16, township 45, range 18. This horizon is believed to be the one in which the mines in the Saunders creek area are located.

On Blackstone river the complete section of the lower Saunders beds below this horizon is exposed eastwards from Chungo creek, and no coal seams of commercial thickness are present. The Brazeau section of the same strata contains three other coal horizons in addition to the one mentioned above. These are exposed in the steep banks of the deep valley of the Brazeau in township 45, range 18. These four horizons are in the westward dipping Saunders beds which lie west of the *Lovett fault*, and are discussed in order of age.

The lowest of these four coal horizons is exposed on the Brazeau at the water-level in legal subdivision 16, section 13. There are two seams over 3 feet thick at this horizon. As these are exposed on the south side of the Brazeau they were inaccessible and a section was not obtained.

¹op. cit., p. 51. Note.—The distribution of the Saunders Coal series as shown on Map No. 5 was mapped as accurately as possible from available data. The authors did not make surveys of the rivers. It is now known that parts of Lawrence and Ruth creeks as shown on Map No. 5, accompanying the fourth annual report are not correct.

²In the fourth Annual Report, page 58, fifth line, "*semi-bituminous*" should read "*sub-bituminous*."

The second coal horizon exposed in legal subdivision 2, section 22, and separated from the lower horizon by about 4,500 feet of strata, shows the following approximate section:

	FEET
Sandstone, massive, hard, lensed.....	50
Coal.....	1
Shales, arenaceous clay, lensed, not over.....	10
Coal.....	2
Shales, arenaceous clay.....	20
Coal.....	1
Bentonitic clay (about 2 inches).	
Coal, clean.....	4

A coal horizon about 1,000 feet stratigraphically above the second is exposed in the N.E. and S.W. quarters section 21. An approximate section is:

	FEET
Sandstone, massive, grey lensed.....	100
Coal.....	6
Shale, arenaceous clay.....	20
Sandstone, massive, grey, lensed.....	25

Inaccessibility prevented a measurement of the section in the fourth coal horizon exposed on the Brazeau in section 8, township 45, range 18. About 2,000 feet of sediments separate this from the third horizon.

A section across the fourth coal horizon, measured on Chungo creek near its mouth, is as follows:

	FEET
Sandstone, massive, hard, conglomeratic.....	40
Shales, arenaceous, coal lenses, sandstone bands.....	25
Shales, arenaceous.....	10
Sandstone.....	1
Shales, soft clay.....	4
Coal, with few thin clay partings.....	5
Shales, clay.....	20
Coal, with many clay partings.....	3
Shales, with small coal bands.....	5
Shales, grey, clay.....	15
Shales, brown.....	4
Shales, nodular.....	4
Sandstone, massive.....	80
Coal, with shale partings, at top.....	4

The lower four-foot seam of coal in the above section is the same seam as the one prospected in section 18, township 43, range 16. A section of this seam taken from a prospect tunnel 20 feet from the entrance is as follows:

	FEET	INCHES
Shale, clay.....	10	0
Clay (roof) bentonitic.....	0	3
Coal.....	0	4
Shale, black, hard.....	0	3
Coal.....	0	4

Shale parting.....	0	1
Coal, soft.....	1	3
Coal, hard.....	1	3
Coal, with thin partings.....	1	6

A channel of coal taken from this seam at the entrance of the tunnel and analysed at the Fuel Laboratory in the University of Alberta gave the following results:

Loss on air drying.....	3.1	
	Air-dried	As Received
Moisture.....	5.1%	7.0%
Ash.....	10.5%	10.2%
Volatile Matter.....	31.7%	31.4%
Fixed Carbon.....	52.7%	51.4%
Calorific Value (Air-dried) B.T.U. per lb.....		11,780
Fuel Ratio (F.C./V.M.).....		1.65

The same series measured on Brown creek is as follows:

	FEET
Coal.....	5
Shale, arenaceous.....	15
Coal, blocky.....	6
Shales, arenaceous.....	6
Nodular band.....	1
Shales, arenaceous.....	6
Coal.....	3
Shale, arenaceous.....	5
Coal.....	1
Sandstone and clay shales.....	100
Coal and sandy shale (base not exposed).....	5

The lowest coal in this section corresponds to the lowest coal seam in Chungo section.

There are two coal horizons exposed in the Saunders beds east of the Lovett fault on Brazeau river.

The lower horizon is exposed in sections 17 and 18, township 45, range 17. In section 18 the beds stand almost perpendicular, while in section 17 they have a steep dip to the northeast. The coal seams in this horizon are believed to be the same as those exposed in the southwest quarter section 28, township 43, range 16, at the base of the Saunders strata exposed on the east side of Lovett fault. It is difficult to correlate these seams with the coal in any of the four horizons exposed on the Brazeau west of Lovett fault. We are of the opinion that they correlate with the 4th horizon if the structural interpretations made on the Blackstone are correct. This horizon east of the fault in section 18, exposed 3 seams of coal within about 100 feet of sediments. The upper seam is about 5 feet thick and the lower ones 2 feet thick. It was impossible to measure these seams since they are exposed on the south side of the Brazeau in sections 18 and 17, and it was not possible to cross the river at this point.

A stratigraphically higher coal horizon is exposed on the Brazeau in section 10, township 45, range 17. This contains a 5-foot seam of clean coal overlain by a 50-foot bed of massive, lensey sand-

stone. The lensed nature of this roof is very apparent in that the exposure of the same seam on the south side of the river is not overlain by sandstone.

These two coal horizons east of the Lovett fault are separated by about 5,000 feet of sediments.

From the exposures on the Brazeau in township 45, it appears that the Saunders formation has five horizons which carry coal seams of commercial thickness.

The increase in the number of coal horizons between Blackstone and Brazeau rivers illustrates the varying nature of the Saunders formation. This is shown to a greater degree in the sedimentary beds which have a marked lateral variation. The massive sandstones which frequently occur above the coal seams show lensing, and a bed as much as 100 feet thick often lenses out to a thin band in less than half a mile. It is possible that these coal horizons on the Brazeau were represented by coal deposition at the same time on the Blackstone, but many of these seams may have been removed by erosion before the sediments which cover them were deposited. For this reason it is difficult to predict the possibility of any appreciable lateral extent of the coal seams exposed.

The synclinal basin of lower Saunders beds lying east of *Blackstone fault* does not show coal seams on Blackstone, Brazeau, or Pembina rivers. The absence of coal in this syncline on the Blackstone confirms the conclusion that the lower 3,200 feet of the Saunders do not carry coal in this part of the area. The absence of coal in this syncline on the north and main Brazeau shows to a further degree the rapid lateral variation of the formations and of the contained coal seams.

Saunders coal is mined extensively to the north of Brazeau river by the numerous mines situated along the Alberta Coal Branch of the Canadian National Railway. The seams mined are on the average much thicker than any exposed on Brazeau river. The seams which were mined at Lovett are exposed on the Pembina in section 23, township 46, range 19. These are correlated with the third coal horizon on the Brazeau in section 21, township 45, range 18.

On account of lateral variation in thickness of the coal seams and also the partings, it is difficult with the data at hand to suggest a suitable naming of the seams mined and prospected along the Alberta Coal Branch. A preliminary survey of this district was made in 1920¹. The chief object of the past summer's work was to establish the major structural relations of the area. It is the present intention to continue the survey in order to obtain greater detail regarding the coal seams in this important part of the area.

The Pacific Pass Collieries which operated at Lovett mined two seams known as the Mynheer (lower), and the Silkstone (upper), separated by about 200 feet of sediments and thin coal seams. These seams have been traced northwest by prospects to Embarras river in the vicinity of Coalspur. A thick seam is exposed in legal sub-

¹Allan, J. A., "Coalspur-Lovett Area," 2nd Ann. Rept., Min. Res., Alta., 1920, p. 50.

division 14, section 33, township 48, range 21. This may be the equivalent of the Silkstone to the south. The record of the prospect in section 33 gives over 40 feet of coal with many partings.

It is the present belief that the open pit mines of the Sterling Collieries, and the Coal Valley Mining Co. are in this seam. This seam also outcrops in the railway cut in section 15, township 49, range 21, near the Balkan mine.

Most of the other mines along the Coal Branch are in some part of this seam, with the exception of the Foothill Collieries. This mine is operating in a still higher seam known as the Val d'Or seam. The general character of the seam now mined at Minehead and Mercol, and which was mined at Coalspur and to the northwest in section 6, township 49, range 21, by the Yellowhead Coal Co., are correlated with the seam now mined by the Foothills Collieries. The sections of the seam at these various locations are as follows:

FOOTHILLS COLLIERIES.

	FEET	INCHES	
Coal.....	1	3	
Shale.....	1	3	
Coal.....	3	0	} No. 1
Clay.....	0	4	
Coal.....	2	9	
Sandstone.....	3	3	
Coal.....	2	0	
Clay.....	0	7	
Coal.....	2	0	
Clay.....	0	6	
Coal.....	6	0	} No. 2
Clay and hard shale.....	1	0	
Coal.....	3	6	

The upper part mined is locally known as No. 1 seam and the lower part mined as No. 2 seam. The entire section constitutes the Val d'Or seam. Most of the mining by this company has been carried on in No. 2 seam, but recent operations have been extended into No. 1.

YELLOWHEAD COAL CO., COALSPUR.

(Mine abandoned)

	FEET	INCHES	
Coal.....	4	1	} No. 1 (local name)
Clay.....	0	7	
Coal.....	1	6	
Sandstone.....	4	0	
Coal.....	3	2	
Clay.....	1	4	
Coal.....	1	8	
Clay.....	0	6	
Shale.....	1	0	
Coal.....	5	3	} No. 2 (local name)
Clay.....	0	6	
Coal.....	6	3	

This section is correlated with the section representing the Val d'Or section at Foothills Collieries.

BALKAN COAL CO., MINEHEAD.

	FEET	INCHES	
Coal.....	2	5	} No. 1 (Not mined)
Clay and hard shale.....	0	1	
Coal.....	2	5	
Shales sandstone about.....	10	0	} No. 2 (Mined)
Coal.....	3	7	
Clay and hard shale.....	0	8	
Coal.....	4	6	

This section is correlated with the above Val d'Or sections.

A section of the same seams at Mercol mined by the McLeod River Hard Coal Co., is as follows:

	FEET	INCHES	
Coal.....	3	6	} No. 1 seam
Clay.....	0	6	
Coal.....	3	8	
Sandstone.....	1	0	
Coal, bone and clay.....	1	4	} No. 2 seam
Coal.....	1	10	
Shale and clay.....	1	1	
Coal.....	1	5	
Clay and shale.....	1	4	
Coal.....	6	0	
Clay.....	0	8	
Coal.....	4	0	

Most of the mining has been done in No. 2 seam, but recent operations have been extended into No. 1.

The lateral variation in the number and thickness of the seams, together with a change in structure from a monoclinical succession on Brazeau river to a synclinal on the Embarras, makes correlation difficult since in the intervening area continuous exposures are wanting and numerous minor folds and faults have disturbed the normal sequence.

It appears that all the seams mined along the Alberta Coal Branch belong to one horizon, and that the first, second, fourth and fifth horizons as exposed on Brazeau river are not mined to the northwest of this stream.

The coal horizon mined carries at least three seams that are of commercial thickness. These seams have many partings, which in some places are of sufficient thickness to warrant the division of a seam into two. These partings thicken and thin laterally (Plate V,B). This horizon is approximately 400 feet thick and carries many thin bands and seams of coal in addition to those thick enough to be mined.

Local folding has thickened the coal in such places as Sterco, where the coal is removed by open pit methods after a mantle of loose sediments has been stripped off.

TABLE OF COAL HORIZONS

The present data obtained on the Saunders coal horizons may be summarized as follows:

	Sediments (thickness not determined).....	
No. 5.	<i>Coal</i> horizon.....	
	Sediments.....	5,000 feet
No. 4.	<i>Coal</i> horizon. Mined at Saunders creek.....	
	Sediments.....	2,000 feet
No. 3.	<i>Coal</i> horizon. Mined along the Alberta Coal Branch	
	Sediments.....	1,000 feet
No. 2.	<i>Coal</i> horizon.....	
	Sediments.....	4,500 feet
No. 1.	<i>Coal</i> horizon.....	
	Sediments (thickness not determined)	

INDEX

A

	Page
Abies lasiocarpa	20
Acknowledgements	4
Alberta Coal Branch	2, 20, 40, 45
Allan, J. A.	1, 4, 33, 45
Allison formation	7
Analyses (Chungo creek coal)	44
Arctic ocean	19
Athabaska river	1, 19
Atlantic ocean	19

B

Balkan Coal Company section	47
mine	46
Beak, W. P.	5
Bearpaw formation	7
shales	7
Beaverdam creek	20
Belly river beds	7
Benton formation	7
Bentonitic clay	43
Bickerdike	2
Bighorn basin	1, 19, 29, 33
coal basin	28, 40, 41
formation	7, 30
range	2, 3, 9, 22, 29, 33, 38, 40
sandstones	28
thrust fault	11
Black Canyon creek	18, 19, 29
Black mountain	18, 29
Blackstone fault	10, 13, 14, 18, 29, 33, 45
formation	7, 30
river	2, 17, 19
section	12
shales	28
Blairmore formation	7
Brazeau Collieries	2, 4, 40, 42
forest reserve	3, 21
range	9, 29
river	2, 18, 19
sandstone	7
section	13
station	2
British Collieries	14, 42
Brown Creek	3, 17, 19, 42
section	44

C

Cadomin	2, 24
Coal Company	41
coal field	4
gap	20, 41
Cairns, D. D.	7
Canadian Forestry Branch	2
National Railway	2, 45
Cenozoic era	7
Chungo creek	3, 19, 42
creek section	43
fault	10, 12, 14, 15, 29, 33
Claggett shales	7

	Page
Clay pellets	37
Clearwater forest reserve	3, 21
Coal horizons	48
production	1
Valley Mining Company	46
Coalspur	2, 4, 17, 45, 46
coal field	4
Lovett area	45
Colorado	7
fossils	31
distribution	29
general statement	28
lithological character	29
petrography	31
Wapiabi on Blackstone river	31
Continental deposits	37
Cordilleran ice sheet	38
Cretaceous	7
formations	22
Crowsnest volcanics	7
D	
Dakota	7
deMille, W. E.	2
Dominion Land Surveys Branch	3
Topographical Surveys Branch	4
Dowling, D. B.	2, 4
ford	3, 19
Drainage	18
Duggan, Wm.	5
Dummy creek	20
E	
Edmonton formation	7
Elk	21
Embarras river	2, 20, 47
F	
Fauna	20, 21
Fernie formation	7
shales	26
Field work	2
Fifth coal horizon	44, 48
First coal horizon	42, 48
Flora	20
Foothills Collieries	46
Collieries section	46
Forest	20
Forestry Branch	3, 21
Fossils, fresh water	34
Fourth Annual Report, correction	42
Fourth coal horizon	43, 48
Fuel laboratory	44
G	
Geographic position	1
Geology, general	6
descriptive	22
structural	9
Glacial valleys	39
Grave creek cabin	24
Grass mountain	12, 14, 17
Grassland	20
H	
Hammond, F. L.	5
Haven creek	18, 19

INDEX

51

	Page
Haworth, Geo. C.	2
Hetherington, W. B.	5
Horne, Thomas	5
Hudson Bay	19

I

Investigation, object of	1
--------------------------------	---

J

Jewitt, W. G.	2
Jurassic	7
rocks	22

K

Keewatin ice sheet	38
Kootenay coal	40
coal-bearing member	7, 40
coal measures	40
definition of	8, 23
distribution of	23
formation	7, 28
group	7, 23
lithological character	24
petrography	24
rocks	40
thickness	28

L

Larix lyalli	20
Lookout creek	13, 18, 19, 34
Lovett	2, 4, 45
fault	9, 12, 13, 14, 15, 16, 17, 33, 42, 44
Luscar	24
Collieries	41
Lysichiton kamtschaticense	21

M

MacKenzie creek	10, 16, 33
D.M.	5
J.D.	28
river	18, 19
Main fault	10, 12
Malloch, G. S.	1, 4, 7, 8, 24, 30
Map No. 2	2, 23
No. 5	1, 23
No. 5 correction	42
Bighorn coal basin	11
Mat-herbage	20, 21
McDonald, J. R.	5
McEvoy, J.	4
McLeod member	7, 8, 23, 30
river	7, 8, 23, 30
River Hard Coal Company section.....	47
section	16
McMillan, J.	5
McMurray	3
Medicine Lake	24, 41
Mercol	47
Mesozoic	7
Minehead	2, 16, 17, 46
Montana group	7, 33
summary	37
Morainal ridges	38
Mountain Park	2

	Page
coal basin	40
coal branch	2
Coal Company	2
Mud crack impressions	36
Mynheer	45

N

Nelson cabin	12
Nikanassin outlier	19, 20, 22, 24, 29, 40, 41
range	2, 9, 38
Niobrara formation	7
Nordegg	2, 3, 4
coal basin	1
North Brazeau river	19
section	14
North Saskatchewan river	1, 2, 18, 19
section	11

O

Onions, W.	5
Origin of Blackstone valley	38
Brazeau valley	38
McLeod valley	38
North Saskatchewan valley	38

P

Pacific Pass Collieries	4, 45
Paleozoic era	7
rocks	41
Pembina river	1, 9, 18, 19, 41
section	15
Physiography	17
Picea Canadensis	20
Engelmannii	20
Pinus albicaulis Engelmann	20
contorta Murrayana	20
Plant remains	37
Pleistocene	38
Porcupine hills formation	7
Post-glacial valley	39
Preparation of map	2
Previous work	4
Piedmont glacier	38

Q

Quaternary	7, 38
------------------	-------

R

Red Deer	2
Rocky Mountain House	2, 19
Rose, Bruce	7, 28
Ruby creek	15, 24, 41
Rutherford, R. L.	1, 33

S

Saskatchewan river section	11
Saunders coal basins	1, 42
coal horizons	48
coal series	33
definition of	33
distribution of	33
formation	7, 12, 33, 42, 45
lithological character	34
Lower	8

	Page
petrography	34
Upper	8, 12
Scientific and Industrial Research Council of Alta.	3
Scott, J. G.	5
Second coal horizon	43, 48
fault	9
Sections—	
Balkan Coal Company	47
Brown creek	44
Colorado, Wapiabi formation	31
Chungo creek	43
Foothills Collieries	46
fourth coal horizon, Chungo creek.....	43
McLeod River Hard Coal Company	47
second coal horizon	43
structure along:	
Blackstone river section No. 1.....	12
Brazeau river section No. 2.....	13
McLeod river section No. 5.....	16
North Brazeau river section No. 3.....	14
Pembina river section No. 4.....	15
Saskatchewan river section	11
third coal horizon	43
Yellowhead Coal Company	46, 48
Semi-bituminous	42
Shankland, W.	5
Sub-bituminous	42

T

Table of—	
coal horizons	48
correlation of formations	7
cretaceous formations	42
Tepee creek	23
Tertiary	7, 8
Third coal horizon	45, 48
Third fault	10
Topography	17
Triassic	7
Rocks	22

U

Unio	34
Upper Banff shales	7

V

Val d'Or seam	46
Viviparus	34

W

Wapiabi formation	7, 31
creek	13, 19, 33, 41
shales	28, 30
Waterways	2
Willow creek formation	7

Y

Yellowhead Coal Company	46
section	46
Yellowhead Pass route	4

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