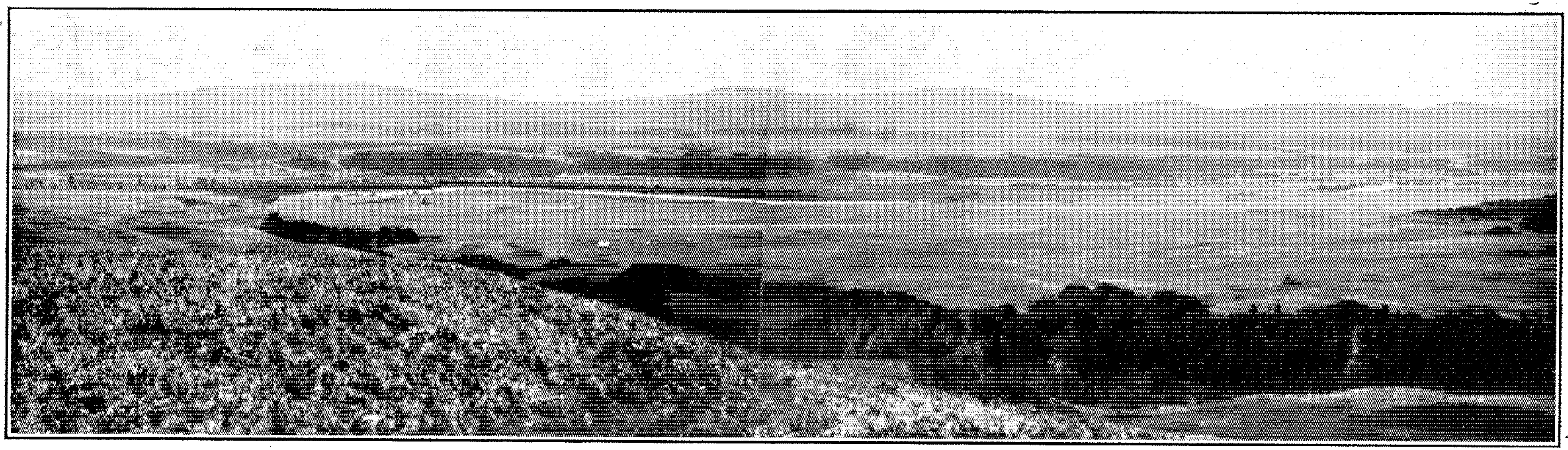

Panoramic view, looking south to southwest across Bow valley from hillside in river lot 1, Morleyville settlement. Indian agency and mission school at Morley on extreme right. Reserve well can be seen to the east of these buildings. Extensive terraces on south side of Bow between Chiniki and Morley railway stations show up in lower background. Jacob creek in foreground. (Frontispiece.)

PROVINCE OF ALBERTA

Scientific and Industrial Research Council. *Report No.* 17

University of Alberta, Edmonton, Alberta.

GEOLOGICAL SURVEY DIVISION

JOHN A. ALLAN, Director.

Geology along the Bow River

BETWEEN

Cochrane and Kananaskis

Alberta

BY

RALPH L. RUTHERFORD

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ORGANIZATION

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

The personnel of the Council at the present time is as follows:

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

HONOURABLE J. E. BROWNLEE,

Premier of Alberta,

Chairman, Scientific & Industrial Research Council of Alberta.

Edmonton, Alberta.

SIR:—I have the honour to transmit herewith a report of the Alberta Geological Survey Division entitled "*Geology along the Bow River between Cochrane and Kananaskis, Alberta,*" prepared from field observation by Dr. Ralph L. Rutherford in 1926. This is Report No. 17 of the publications of the Scientific and Industrial Research Council of Alberta.

This report contains the results of a geological survey of a belt about ten miles wide across the entire width of the foothills along Bow River. The area mapped geologically and discussed in the report is approximately 250 square miles and represents a belt about eight miles wide and thirty-two miles long, extending from Cochrane west to the front of the Rocky Mountains. A geological map in nine colours and three geological structure sections, all on a scale of one inch to one mile, accompany this report.

The object of this survey was to determine the thickness and character of the various formations, and to work out the geological structure. This has been accomplished in a satisfactory manner by the author of this report. Previous geological data on this belt across the foothills are now quite out of date as no field work has been done in this part of Alberta since 1906, when geological interpretations were based on less complete data regarding certain formations. Increased activity in the search for petroleum within the foothills of Alberta also warranted the survey.

In order to facilitate the field survey I obtained from the Topographical Survey of Canada aerial photographs taken along the Bow river, and I wish to record the valuable use that we were able to make of these photographs. It was possible to locate geological boundaries on these photographs so that data are shown more accurately on the map than would have been otherwise possible.

This report will be most useful to companies and individuals in their endeavour to develop the petroleum resources within the foothills of Alberta.

All of which is respectfully submitted.

Yours truly,

JOHN A. ALLAN.

Department of Geology,

University of Alberta,

Edmonton, March 30th, 1927.

TABLE OF CONTENTS

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

CHAPTER V.

MAPS AND ILLUSTRATIONS

Geology along the Bow River
BETWEEN
Cochrane and Kananaskis, Alberta

By

RALPH L. RUTHERFORD

CHAPTER I.

INTRODUCTION.

General Statement.—The Geological Survey Division of the Scientific and Industrial Research Council of Alberta has carried on surveys in several of the coal areas of the Province since 1921. During part of the field season of 1926 the writer continued this work in the coal areas west of Edmonton. The continued search for oil in the Province of Alberta received fresh impetus in the latter part of 1925 and the survey division decided to devote a part of the 1926 field season to work in the foothills of Southern Alberta. Consequently, the writer spent about five weeks during June and the first part of July, 1926, in examining the area along Bow River between Cochrane and Kananaskis.

The chief purpose of this work was to obtain data regarding the lithology and thickness of the Cretaceous formations in this part of the foothills and to map the structural and areal geology of the area examined.

Geographical Position and Accessibility.—The area discussed in this report and shown on the accompanying map (No. 12) is situand within the foothills belt of Alberta between 114°15′ and 115°15′ west longitude. It includes all or portions of townships 25 and 26, ranges 4 to 8, west of the Fifth Meridian. Most of the western part of the area lies within the Stoney Indian Reserve (numbers 142, 143, and 144). The extreme western part is within the Rocky Mountains Park. A part of the area on the north side of the Bow, between Ghost river and Jacob creek, is subdivided into river lots and is known as Morleyville Settlement. A small, irregularly shaped area on the west side of Jacob creek forms the Methodist Mission Reserve.

The main line of the Canadian Pacific Railway, which follows Bow river, crosses the area. The Calgary to Banff highway, which follows along the north side of the Bow, makes most of the area readily accessible by automobile. In the eastern part of the area several graded roads branch off to the north from this highway. The area along the south side of the Bow may be reached by way of traffic bridges, which cross the Bow at Cochrane and Morley. There are some graded roads east of the Indian Reserve, but none within the Reserve on the south side of the river. The country, however, is open and most places are easily accessible by automobile, excepting during wet seasons. (Plates 1, 2B, 3A, 5A.)

The Bow may also be crossed on the dam at the upper power plant by special permission from the Calgary Power Company.

Culture.—All the area lying east of the Stoney Indian Reserve is settled and utilized chiefly as grazing lands by ranchers. Ranching is also the chief occupation of the Indians within the Reserve. The government Agency bulding and the Indian school operated by the United Church of Canada are situated at Morley. The hydro-electric plants of the Calgary Power Company are situated in the western part of the area and a number of the officials and employees reside in the vicinity of the plants. A shale pit and limestone quarry are operated in the western part of the area by the Company which manufactures cement at Exshaw. There are no towns within the area, and Cochrane is the only railway station around which a village has built up.

Field Work and Preparation of Map.—This report is based largely on information obtained in the field between May 27th and July 10th, 1926. Traverses were made along both sides of Bow river and along the hills to the south and north of the area. It was necessary to cover an area considerably larger than shown on the map in order to determine some of the structure within the area.

Two central camps were used during the work, one at Cochrane and a second in the Morleyville settlement. L. S. Russell rendered very satisfactory service as assistant in the field and has prepared the notes on the vertebrate remains which were collected. G. C. Haworth ably assisted the party as cook and chauffeur.

The base for the accompanying geological map has been prepared from the sectional maps number 114 and 164 issued by the Topographical Survey of Canada. These sheets are printed on a scale of one inch to three miles and 100-foot contour intervals. While it is recognized that enlarging a map is not good practice, it was necessary to do so in order to show much of the geological detail. A map with a smaller contour interval would have been much more valuable for this work. During the summer of 1926 the topographical branch of the Geological Survey of Canada was preparing a map which included the eastern part of this area.

It was often difficult to locate the position of certain geological contacts and structural lines, especially in the unsurveyed portions within the Indian Reserve. In locating outcrops in unsurveyed areas considerable use was made of aerial photographs of the Bow taken by the Royal Canadian Air Board, which were obtained from the Topographical Survey of Canada.

Acknowledgements.—The writer wishes to acknowledge the favours and courtesies given the party during the field season by settlers within the area traversed. The party is especially grateful to Mr. D. McDougall, who kindly permitted the party to occupy his house at Morleyville for three weeks.

Dr. J. A. Allan[1], who has made traverses over many parts of this and adjacent areas, has given appreciable assistance in the preparation of this report and map. Dr. P. S. Warren[2] has kindly

[1]Professor of Geology, University of Alberta, Edmonton, Alta.
[2]Associate Professor of Geology, University of Alberta, Edmonton, Alta.

determined the fossils collected in the field and has given valuable suggestions regarding the stratigraphical significance of several of the species.

Previous Work.—Many of the early explorers and travellers through western Canada used the Bow valley as a route to the mountains. The records of their travels contain some of the earliest observations on the geology of the foothills in this locality. Dr. James Hector, who was a member of the expedition conducted by Captain Palliser through the west in 1859, makes mention of the strata occurring at several points along the Bow. His reports are included with those of Palliser[3].

The first report which gives an appreciable amount of detail regarding the geology of this area is that of Dawson[4], who in 1881 traversed the Bow river from the mountains eastward to the plains as part of his work in southern Alberta. The records of his observations in this area are clear and precise, a characteristic for which this pioneer in western Canadian geology has been so often eulogized by later workers. Dawson's observations were, of necessity, very general in this area, since it constituted only a small portion of the larger field he was examining, and it remained for later workers to give more detail of the geology in this particular area.

The geology of a part of the foothills extending south from the Bow has been mapped by Cairnes[5] who, in 1905, examined the general area including and surrounding Moose Mountain. Cairnes devoted most of his attention to the Kootenay coal-bearing beds in the vicinity of Moose Mountain, and consequently there are many inaccuracies in his mapping of the Upper Cretaceous beds along Bow river, especially in the part between the mouth of Ghost river and Cochrane. It must be remembered, however, that a lot of geological work has been done on the Cretaceous rocks of Alberta since 1905, and consequently some of the correlations made by Cairnes have to be changed in the light of present day knowledge. The structure along the Bow between Morley and Kananaskis is closely related to that of the Moose Mountain area, and by examining Cairnes' report one may obtain a better understanding of the structure existing along the Bow, which is described below.

Following Cairnes, other geologists have examined different parts of the area along Bow river at different times, but have not reported in detail on this district. This area has not received the attention from government surveys that most of the foothills to the southeast have received, probably because it has not been an important coal producer. However, with the increased activity in the search for oil within the past few years, the area along Bow river and the adjacent territory are at present receiving the attention of many geologists in the employ of private companies.

3Capt. J. Palliser, The Journals, Detailed Reports and Observations, etc., 1860.
4Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1882-83-84, pp. 29-31C and 80-82C.
5Cairnes, D. D., Moose Mountain District, Southern Alberta, Geol. Surv. Can., Mem. 61, Second Edition, 1914.

CHAPTER II.

GENERAL CHARACTER OF THE AREA.

Geological Succession.—The rocks underlying this area belong chiefly to the Cretaceous ~~epoch~~ period. The general character of the formations and the names assigned to them are as follows:

CENOZOIC	Quaternary	Glacial and river deposits of gravel, sands and silts.
	Tertiary	*Paskapoo* Alternating sandstones and shales of fresh-water deposition. (Plate 7B.)
MESOZOIC	Cretaceous	*Edmonton* Alternating sandstone and shales of fresh-water deposition. (Plate 7A.)
		Belly River Alternating sandstone and shales of fresh-water deposition.
		Upper Benton Dark to black shales of marine deposition. (Plates 5B, 6A.)
		Cardium Alternating sandstone and shales of marine deposition. (Plate 4.)
		Lower Benton Black fissile shales of marine deposition.
		Blairmore Alternating sandstone and shales of fresh-water deposition. (Plate 3B.)

The table indicates that several of the formations are lithologically similar, but the older formations having been subjected to deeper burial contain relatively much harder rocks than the younger formations of similar lithological composition. This tabular statement of the formations also indicates that the Cretaceous and early Tertiary strata in this area consist of two series of beds of fresh-water deposition, separated by a series of beds of marine deposition.

Drainage.—Bow river and its tributaries drain the area. Ghost river is the largest tributary stream that joins the Bow from the north in the area, and Kananaskis river is the largest tributary from the south. These two streams, however, drain a small part of the area only. Several large creeks join the Bow from the north, such as Bighill, Horse, and Grand Valley creeks, while two large creeks, namely Jumpingpound and Chiniki, join the Bow from the south. Jumpingpound is the largest of all these creeks. Most of the larger creeks join the Bow in the eastern part of the area.

Most of the streams have a relatively steep gradient and are fast-flowing. Bow river drops about 500 feet between the mouth of the Kananaskis river and Cochrane, the swiftest part being above the mouth of Oldfort creek. Possibly the swiftness of the Bow above Oldfort creek was prohibitive to river navigation by early explorers, and it may have been partly for this reason that Bow Fort was established at the mouth of Oldfort creek. The hydro-electric plants of the Calgary Power Company are situated at places where waterfalls occurred in this swift flowing portion of the Bow.

Several small lakes are shown within the map-area, many of which are merely undrained ponds. Chiniki lake in the western part of the area is the largest body of water and Cochrane lake in the northeast corner is the second largest.

Physiography.—The area lies within the foothills of Alberta and consequently has a relief which is intermediate between that of the plains to the east and the Rocky Mountains to the west. There are several major streams in Alberta which rise in the mountains and flow eastward through the front ranges of the Rocky Mountains, thence across the foothills and plains. Bow river is one of these streams and consequently the foothill physiography of this area has been modified by Bow river which has eroded a broad valley across the foothills. (Plate 1.)

The elevation of Bow river at Cochrane is about 3,700 feet above sea-level, and the hills which form the top of the valley here rise to an elevation of 4,300 feet. This difference of 600 feet expresses the relative relief at the eastern side of the area. The difference in elevation between valley top and river level increases to the west, reaching a maximum where Paleozoic formations override the Cretaceous, giving differences in elevation of over 2,000 feet between the river level and the adjacent high areas along the valley. Bow valley is open and practically free from forest growths excepting along the higher parts of the valley in the western part of the area. (Plate 1.)

Glacial action during Pleistocene time exerted considerable influence on the drainage of the area along Bow river, and the present contour of the valley is in part a result of this glacial activity.

The underlying strata have been faulted and folded into a series of parallel belts with a north-west trend. This structure and the difference in lithological character of the deformed strata have to some extent determined the present surface features of the area.

In general, the present relief is composed of three elements. One of these is the higher areas forming the upper part of the valley of the Bow. These are dissected into several ridges which frequently extend for considerable distance northwest or southeast from the respective sides of the Bow valley. Broad river or river-lake terraces in the lower part of the valley constitute a second physiographic feature of the area. (Plate 3A.) The present river channel, which has been eroded through these terrace deposits and deeper into the underlying formations, represents the third feature. (Plate 4.)

The ridges which occur along the top of the river valley have in general resulted from differential erosion on a series of tilted strata, and are more pronounced in the western half of the area where the highest points are usually underlain by the hardest beds. This feature is illustrated to some extent by the relation of the areal distribution of the formations to the contour of the uplands. Greater uplift in the western part of the area has also aided differential erosion in forming more pronounced ridges than occur in the eastern part. In the eastern part of the area the slopes are gentle and the surface of the upland areas are usually free from peaks or sharp ridges. The hills immediately northeast of Cochrane village, which rise about 600 feet above the river level, have been formed by erosion on flat-lying beds, as this locality is east of that part of the area which is underlain by deformed strata. This hill near Cochrane is the western edge of a broad, flat-topped upland which extends for several miles east and includes the hills about three miles north of the City of Calgary. Another flat-topped upland occurring southeast of this map-area and situated in township 24, range 2, south of the Bow and west of Calgary, is a remnant of this upland which extends from Calgary to Cochrane on the north side of the Bow.

The extensive terraces in the lower part of the Bow valley are a pronounced physiographic feature. (Plate 1, 3A.) They probably were formed when Bow river was dammed up at various stages during early post-glacial time. Isolated masses of morainal material, averaging 25 feet to 50 feet in height, occur as numerous islands upon the terraces. (Plate 3A.) One of the most pronounced of these terraces extends along both sides of the Bow from Kananaskis river east to within two miles of Morley station. It is best developed as a long flat area around Ozada station. (Plate 3A.) Post-glacial erosion has modified this terrace along the north side of the Bow between Kananaskis and Morley, and consequently the surface is more irregular than on the south side of the river.

A series of terraces extend along both sides of the river from Morley east to Radnor station. The lower ones are narrow and appear to be the result of river work, rather than of laking of the stream, which is believed to have formed the large terrace at Ozada. The higher terraces are broader and the railway between Chiniki and Morley stations follows along the north face of an upper terrace which is about a mile wide. River terraces are well developed in Morleyville settlement and occur between the Banff highway and the river.

From Radnor to Cochrane the terraces are not so well developed as they are to the west, although they are prevalent at several points along the north side of the Bow. The village of Cochrane is situated on a river terrace. There appear to have been pronounced terraces at some time in the past between Cochrane and Ghost river, but these have been modified considerably by a number of large creeks which enter the Bow between these points.

Several small creeks draining the upper parts of the valley disappear beneath the surface on reaching the terraces owing to the porous nature of the deposits. This water emerges at lower levels as numerous springs in the lower part of the valley.

The present channel of the Bow is the third physiographic feature of the area. This channel lies within a narrow valley that has been developed since glacial times. It has been cut through the terraces exposed along the sides of the channel throughout the greater part of the area. This channel is more pronounced in the area between Morley and the mouth of the Kananaskis river, where it has an average depth of 100 feet below the upper terrace levels. (Plate 4, 5B.) From Morley to Cochrane it is more shallow and seldom over fifty feet deep, while in many places the terraces extend down to the river level. In such places, however, the lower terraces are of recent formation, and occur on one side of the stream, whereas on the opposite side the underlying formations are frequently exposed. The channels of the creeks which are tributary to the Bow all join it at grade, but some of these channels are very deep and narrow near the mouths of the creeks. This feature is well developed on the lower part of Oldfort creek.

Changes in Drainage.—Bow river has probably occupied the same valley since glacial times, although the position of the stream channel within the valley has probably changed several times as the valley became deepened. The Kananaskis and Ghost rivers, however, show clear evidence of having occupied different positions than those occupied by their present channels and valleys.

The Kananaskis, undoubtedly, at one time flowed through the valley now occupied in part by Chiniki lake and had its confluence with the Bow somewhere east of Morley station. A low, open valley extends west from Chiniki lake and joins the present Kananaskis valley in section 14, township 24, range 8. (Plate 2A.) This old valley has not been occupied by Kananaskis river, however, since the formation of the higher terraces which occur east of Morley station. This seems to indicate that it was a pre-glacial valley or perhaps existed during glacial times. It is possible that Bow river drained through this old valley, as the present terraced valley at the Bow is very broad and flat in the vicinity of Chilver lake in section 28, township 24, range 8, and has about the same elevation as the valley occupied by Chiniki lake.

Ghost river, like the Kananaskis, at one time had its confluence with the Bow farther east than its present position. The valley of that part of the Ghost shown on the accompanying map is narrow and deep and is clearly of recent origin and perhaps entirely of post-glacial development. The valley occupied by the stream to the north of this area is older and was outlined either in glacial or pre-glacial time. This old valley extends east from the present valley of the Ghost in section 33, township 26, range 6, and follows almost along the correction line at the north boundary of sections 34, 35 and 36, township 26, range 6. (Plate 2B.) Thence it turns southeast through the southeast quarter of section 31, township 26, range 5. From here to the Bow it is difficult to determine the outline of the old Ghost valley. Spencer creek may be occupying part of the old valley, yet Beaupre lake in section 18, township 26, range 5, appears to be lying in the old valley also. Post-glacial erosion has so modified the valley here that it is difficult to determine the position of the older Ghost valley. It was, however, as far east as Spencer creek and perhaps as far as Beaupre creek.

It would require a study of a large part of the areas adjacent to this to work out all the history of the drainage in this area during and following glacial times. Ghost river undoubtedly carried a much larger volume of water at some time in the past than it carries today.

The surface appearance of the area presents a lot of interesting physiographical detail that would require special study to interpret, and in the above discussion only the major features have been mentioned. The outcrops of the underlying formations are in most parts of the area confined to the stream channels or the upper parts of the valley. The terrace deposits have concealed the formations between these two positions, and consequently it is difficult to determine the position of the geological contacts and structural lines in these parts covered by the recent materials which form the terraces.

CHAPTER III.

STRUCTURAL GEOLOGY.

General Structure.—In mapping the structure of this area an attempt was made to select and indicate the major structural features. Consequently it will be realized that a closer examination of any particular part of the area would probably reveal much more structural detail than has been indicated. The structural lines on the map are indicated as *observed* and *assumed.* Observations were made beyond the limits of this area in order to project the structure to its present boundaries, and these observations indicate that structural conditions change very rapidly within short distances. Consequently it is not safe to project these structural lines beyond the area shown until field data have been obtained.

This area along the Bow extends across the foothills from east to west and consequently exhibits structure that is characteristic of the foothills. This structure consists of a series of folds and faults with a northwest trend which is parallel to that of the Rocky Mountains. Deformation increases from east to west across the area. In the eastern part the folds are open and there is less displacement along fault planes than in the western part where Paleozoic rocks have been thrust over the upper Cretaceous.

This parallelism of structure is considerably modified in the western part of the area, as is indicated by the areal distribution of the formations. The front range of the Rocky Mountains, striking northwest, crosses the Bow at the western edge of the area, but to the southeast the Paleozoic formations are brought to the surface east of this range and form an elevated area known as Moose Mountain[6], which is situated in townships 22 and 23, ranges 6 and 7. The effects of the Moose Mountain uplift extend northwest across the Bow. The Paleozoic beds which form the central part of Moose Mountain are surrounded by Mesozoic strata, the lowest formations being adjacent or close to Moose Mountain and the later Mesozoic or Cretaceous formations outcrop roughly in concentric arrangement around the Moose Mountain structure. Bow river cuts across these Cretaceous beds in the western part of the area.

From an examination of districts adjacent to this area it appears that Bow river crosses the foothills in a part of the area that has not been so highly elevated as have the corresponding foothill areas occurring to the northwest or southeast of the Bow. Evidence for this is the fact that lower beds are exposed further east on Jumpingpound creek than on the Bow. A narrow belt of Benton beds occurs on Bow river in section 15, township 26, range 5, whereas a broad belt of Benton occupies a higher area along Jumpingpound creek in sections 6 and 7, township 25, range 4, and sections 12, 13 and 24, township 25, range 5. Similarly it is believed from general field observations that Benton beds occur at or near the surface in the north end of the Wildcat hills in the northwest corner of township 27, range 5, which is to the north of

[6]Geol. Surv., Can., Memoir 61—Map Accompanying, 1914.

the area shown on the accompanying map. This structural feature is significant and perhaps is one reason for the position of the Bow valley; that is, the major stream traverses the foothills where the uplift has been relatively less.

This feature is not local, but has been observed by the writer in other parts of the foothills in areas adjacent to other major streams. For example, in the foothill areas south of Athabaska river[7] the Benton beds occur at the surface further east than on the river at the corresponding strike positions. The same is true in the foothills north of North Saskatchewan river.[8]

A full discussion of the significance of this relation of drainage to foothill structure will not be given here other than to mention that the valleys of major streams which cross the foothills frequently occupy positions that have been relatively less uplifted than the adjacent foothill areas.

Local Structure.—The more pronounced folds and faults of the area are here described in some detail. This structural detail is described from east to west across the area.

The position of Cochrane may be taken as the eastern edge of foothill structure. East from here the beds are practically flat-lying, and although small angles of dip may occur locally these are not considered as due to dynamical deformation. Careful levelling over long distances might show a regional dip in these beds, but such information would be difficult to obtain as the strata are lenticular and frequently show local initial dips of over 5 degrees. Local undulations sometimes occur, but these may be interpreted as due to unequal settling of the sediments during consolidation. Dawson[9] refers to a synclinal structure occurring on Bow river about 3 miles east of Jumpingpound creek. He records west dips of 5 to 10 degrees at a point on Bow river which appears to be in the east half of section 36, township 25, range 4. Our observations at this locality do not agree with those of Dawson. The beds are flat-lying, or nearly so, at all exposures along the Bow from the traffic bridge at Cochrane east to Glenbow, where our traverse ended. General observations made at several points between Glenbow and Calgary indicate that the beds are practically flat from Cochrane east to Calgary, and if the strata in this distance have a regional dip it is probably to the east. The general level of the upland between Cochrane and Calgary slopes to the east, being about 300 feet lower north of Calgary than at Cochrane. This difference in elevation may be due entirely to erosion, but probably is in part due to a slight inclination of the strata. The beds exposed just above the water level on the south side of the Bow in the southeast quarter of section 34, township 25, range 4, dip about 2 degrees to the northeast. These are the most easterly beds showing deformational dips and consequently this point may be taken as the beginning of the foothill structure in this area. Westward the dip increases rapidly. At the mouth of Jumpingpound creek it averages 8 degrees to the northeast and increases to about 30 degrees at the mouth of Grand Valley creek.[10] The average strike is north

7Sci. Ind. Res. Coun., Alta., Rept. No. 11, Map No. 7, 1925.
8Sci. Ind. Res. Coun., Alta., Repts. 6 & 9, Maps No. 2 & 5, 1923, 1924.
9Geol. Surv., Can., Rept. of Progress, 1882-84, p. 81C.
10Some reports refer to this as "Coal Creek."

20 degrees west. The succession is regular from Grand Valley creek east with no duplication of strata. The same regular succession is exposed along Jumpingpound creek from its mouth up to L.S.D. 14, section 20, township 25, range 4. These east dipping beds from Grand Valley creek to Cochrane have been mapped as the Edmonton-Paskapoo formation.

Grand Valley creek enters the Bow at the most easterly break in the area. This is shown as a fault extending northwest up the creek valley and southeast towards Jumpingpound creek, which it crosses in L.S.D. 14, section 20, township 25, range 4, outside the area shown on the accompanying map. Dawson and Cairnes referred to this break as representing the eastern edge of the disturbed belt.

The succession to the east of this break is regular, but the beds to the west of it are much faulted and folded. This broken zone extends west past Mitford station as far as L.S.D. 3, section 13, township 26, range 5. The dip of the beds in this broken zone varies from flat-lying up to 90 degrees with an average dip direction to the northeast. In general the dip is steep. Numerous small folds and faults occur, none of which appear to have a regional significance. This broken zone extends northwest along the west side of the Grand Valley creek, and to the southeast it crosses Jumpingpound creek in section 20, township 25, range 4. The broken zone is interpreted as representing part of the east limb of an anticlinal structure which is faulted to the south of the area and more regular to the northeast. Apparently Bow river has cut across the faulted anticline at a point about half-way between the distinct faulted structure and the more regular anticline. The axis of the anticlinal structure is shown to cross Bow river in L.S.D. 3, section 14, township 26, range 5. On Bow river this axis is represented by a series of drag folds and small faults extending across legal subdivisions 2 and 3, section 14, and south of this area on Jumpingpound creek there is evidence of faulting since a broad belt of Benton beds is brought to the surface on the west side of the axis. These Benton beds are well exposed on Jumpingpound creek in sections 13 and 24, township 25, range 5. North from Bow river this axis becomes more definitely anticlinal and passes along the west face of the Wildcat hills, which occur in the western part of township 27, range 5, north of the area shown on the map.

Thus the eastern limb of the anticlinal structure is much broken on the Bow as far as Grand Valley creek, where a fault has been mapped. There does not seem to be any evidence of much displacement along this fault and in fact the displacement may be shared by all the minor structures occurring between the anticlinal axis and the fault. The regular succession occurring to the east of Grand Valley creek is part of the east limb of the anticlinal structure also.

The structure is more regular on Bow river immediately west of this anticlinal axis and is represented by a regular succession of west dipping Belly River beds which form the west limb of the anticlinal structure referred to above. This west limb extends northwest from the river and forms the west side of Wildcat Hills. It extends south from the Bow to the boundary of the map-area, but further south the corresponding strike position along the west side of Jumping pound creek in sections 13 and 24, township 25, range 5, is occupied by Benton rocks. This may mean that the strata have been more highly elevated here and consequently the Belly River beds have been eroded away.

It is believed that the uppermost Benton rocks may occur within 300 feet below Bow river level at the point where this axis is shown to cross. It is also possible that Benton rocks occur along the west side of this structure in the southwest corner of section 36, township 25, range 5, since the area to the southeast, along Jumpingpound creek, is mostly underlain by Benton beds.

Along Bow river the dip near the axis is about 20 degrees to the southwest. This dip gradually increases to the west and is about 35 degrees where the Belly River beds are cut off by a fault which crosses the Bow in L.S.D. 4, section 15, township 26, range 5. The displacement at this fault is at least 2,000 feet and consequently uppermost Benton beds are brought to the surface at the west side of it. The fault is shown to extend northwest from the river for about three miles. North of this the structure appears to synclinal, and there is no definite surface evidence of faulting. If this fault continues further north than indicated on the map it very probably follows the valley of Beaupre creek. Recent deposits and vegetation conceal the strata in this valley so that it is difficult to obtain structural data. Beaupre creek, however, appears to be lying in an unbroken syncline in the southwest corner of township 27, range 5.

This fault extends southeast from Bow river beyond the boundary of this map, separating Belly River beds on the east from Benton on the west. The Benton beds on the west side of the fault dip southwest from 25 to 35 degrees. These grade up regularly into the Belly River beds with the contact between the two formations crossing Bow river practically on the line between sections 15 and 16. About 200 feet of Benton beds are exposed between this contact and the fault to the east. This constitutes the most easterly exposure of Benton beds in the area. They are not shown on any previous geological map and apparently were not observed by Cairnes, who probably would have mapped them as *Bearpaw* since these beds are similar in lithology and carry the same fossils as do three other belts of Benton occurring to the west which he mapped as *Bearpaw*. This belt of Benton would not be noticed unless close observation is made along the Bow channel, since it is a narrow belt and is not exposed either north or south of the Bow channel in this area.

The distance between the Belly River-Benton contact and the fault is shown to narrow to the north of the river since the displacement is believed to lessen in this direction, permitting lower Belly River beds on the west to be in contact with higher beds of the same formation on the east. South of the river the Benton belt widens out considerably since the fault strike is more to the northwest than that of the strata. The belt of Benton extends south beyond this area and forms part of a broad belt of Benton beds which occur along the west side of Jumpingpound creek, in township 25, range 5.

In view of the recent drilling tests for oil on Jumpingpound creek to the south of the area, this structure on the Bow is significant in that it indicates much greater uplift to the south where a considerable thickness of Benton is brought to the surface, whereas on the Bow, at a lower elevation, only about 200 feet of these beds occur.

Westward laong the Bow through legal subdivisions 1, 2, and 3, of section 16, a regular succession of southwest dipping Belly River beds is exposed. The dip averages 25 degrees. In L.S.D. 4, section 16, the structure is more complex and even in the short distance of the width of the Bow it is difficult to connect the structure exposed on the south side of the stream with that on the north. On the south side of the Belly River beds are faulted off and are in contact with Benton to the west. The Belly River strata dip on the average 70 degrees to the southwest at this fault. The same beds on the north side are considerably broken and appear to form a small syncline in L.S.D. 4. The west limb of this syncline extends west into L.S.D. 1 of section 17, where it is bent over into an open anticline that is exposed along the north side of the Bow channel up to the mouth of Spencer creek. (Plate 6B.) These are basal Belly River beds, and the uppermost Benton is exposed below this contact as shown on the map from the mouth of Spencer creek to the east side of section 17. West from the mouth of Spencer creek the strata dip west 40 to 45 degrees in regular succession, passing from Upper Benton into Belly River in the western half of section 17. Thus the difference in structure on the two sides of the river brings to the surface a much broader belt of Benton on the south side of the river than on the north. This broader belt extends south beyond the map-area. The narrower belt extends northwest beyond the limits of this area and is bordered on the east by a sharp anticline of Belly River rocks. (Structure Section E-F.) The strata underlying the northern part of sections 31, 32, and 33, township 26, range 5, show synclinal structure. The axis of this syncline would be approximately coincident with the position of Beaupre creek in section 32, and as mentioned above there may be some faulting along this axis. The west limb of this syncline dips more gently than does the east limb.

These details concerning some of the local structure illustrate the rapid changes that may occur within short distances along the strike. The structure that is exposed along the opposite sides of Bow river in section 17 is especially illustrative of this point. Furthermore, the dip of the strata on Bow river in section 16 is in the opposite direction to that in section 31, which is in strike alignment with section 16.

Belly River beds dipping west 40 to 45 degrees extend west from the Belly River-Benton contact in section 17 to about the centre of section 18, near Radnor station, where they are again faulted off. This belt of Belly River extends northwest and southeast from the river and apparently has the same structure at the boundaries of the area as it has on the Bow.

Benton beds are again brought to the surface by the fault which cuts off the Belly River near Radnor. These have a southwest dip which averages 30 degrees, and they extend west across the range line into the northeast quarter of section 13, township 26, range 6, where they are in formational contact with Belly River. This belt of Benton extends northwest and southeast from the river as a belt parallel to the Belly River to the east and having the same general structure throughout as exposed on the river.

Southwest dipping Belly River beds are exposed along the river from the contact with the Benton in L.S.D. 16, section 13, west to the mouth of Ghost river. They dip 20 to 25 degrees to the southwest and are faulted off a short distance west of the mouth of the Ghost. They form another belt which extends across the area parallel to the others to the east.

The fault that bounds this belt on the west side brings Benton beds to the surface again, which are represented by small exposures on the Bow, but are well exposed on the Ghost in the northeast quarter of section 23. These Benton beds dip southwest about 45 degrees, extend across the area parallel to the belts to the east and grade regularly into another belt of Belly River to the west.

Belly River beds with synclinal structure occur along the Ghost from the contact with Benton in section 23, northwest beyond this area. The axis of the syncline crosses the Ghost in section 27. Evidence of synclinal structure to the south is exposed along the railway grade in the Indian reserve south of river lot 9. On Ghost river the east limb of this syncline dips 40 to 45 degrees to the southwest, whereas the dip of the west limb increases from 45 degrees near the axis to 90 degrees at the west side. The asymmetrical character of this syncline is also exposed south of the Bow along the railway grade, where the beds in the west limb are vertical and those in the east limb dip 50 to 60 degrees to the southwest. The west limb of this syncline is faulted off in the hills to the south of the railway and the east limb extends south beyond the boundary of the area. North of Bow river the synclinal structure continues across the Ghost and beyond into township 27, range 6. The west limb is in formational contact with Upper Benton beds. This contact is well exposed in the creek valley in L.S.D. 4, section 34, township 26, range 6.

There are no exposures of strata along Bow river in river lot 9 or the eastern part of river lot 8 (Morleyville settlement), and the structure as indicated on the map was interpreted from exposures in hills to the north and to the south of the river.

Upper Benton beds are well exposed on the Bow in the western part of river lot 8. These have an average dip of 50 to 90 degrees to the southwest and represent a broad belt of Benton that extends across the area from south to north. These beds are considerably deformed and consequently numerous folds, faults, and repetitions occur. The minor structures, however, cannot be traced for any distance from outcrops. The same beds show a similar structure on Ghost river north of this area, where they are well exposed. The same belt of Benton extends south of the Bow beyond this area and across the north branch of Jumpingpound creek.

A narrow belt of Belly River crosses the Bow in river lot 7. This is represented by a small exposure on the river flat in river lot 7, and appears to be faulted off south of Banff highway. This narrow belt extends south from the river to the boundary of the area, dipping about 60 degrees to the southwest and is faulted off at the west side. Benton beds occur to the west of this narrow belt of Belly River on Bow river. These extend south for a short distance beyond the boundary of the area, and to the north of Bow river they join the broader belt of Benton to the east.

A well defined asymmetrical syncline of Belly River rocks underlies river lot 6 and parts of lots 5 and 7 north of the Banff highway. The east limb dips more steeply than the west limb and the axis of the syncline appears to have a small dip to the northwest. Considerable change in structure takes place here between the automobile highway and Bow river, since only the east limb of the syncline crosses the stream, the west limb having been faulted off. This fault extends to the south boundary of the area. The east limb extends southeast and apparently is in formational contact with the norrow belt of Benton to the east that is faulted off in section 24, township 25, range 6, just south of the boundary of this area. The fault which cuts off the west limb of the syncline at the river is believed to extend northwest along the west limb. The strata are considerably broken along this fault line in river lot 5, just north of the automobile highway.

From Chiniki station west to Morley most of the area is underlain by Benton beds. The structure within this part of the area is very difficult to determine since it is underlain by a relatively broad belt of strata that are largely shales, which when deformed tend to fold and fault into a series of minor structures. Furthermore, the exposures of bed rock are relatively small and discontinuous. (Plate 1.)

The Cardium formation which contains several hard sandstone bands is brought to the surface in a number of places within this part of the area as is indicated on the map. The outcropping of these sandstones reveals some of the structure, but much of the detail is concealed. The deciphering of the structure here is also made difficult by the fact that recent deposits conceal most of the strata in the lower part of the valley. Furthermore, the structure changes rapidly along the strike, and that exposed at the top of the valley does not coincide with the projection of the structure as revealed by the river channel outcrops.

Four belts of Cardium are shown to cross Bow river between Chiniki station and Morley, two of which are exposed in the Bow channel. One of these crosses the Bow in river lot 2 and the other crosses it just east of the traffic bridge over the Bow at Morley. (Plate 5A.) All four belts outcrop in the hills north of the highway.

Cardium beds occur in river lot 3 about a mile north of the highway, but these do not outcrop along the river. South of the Bow river, in the Indian Reserve, there are a few scattered outcrops of Cardium beds in low hills just east of where the main road turns south, about a mile west of Chiniki station. These outcrops have been interpreted as belonging to the same belt that occurs in river lot 3, and hence are mapped as crossing the Bow. The Cardium in river lot 2 is shown to extend to the southern boundary of the area.

The outcrop evidence for this was rather poor, and further field evidence might necessitate a change in the mapping of these beds.

Cardium beds dipping southwest 40 to 50 degrees are well exposed along Jacob creek in river lot 1. This belt of Cardium can be traced northwest into section 24, township 26, range 7, and has a strike approximately parallel to the Cardium beds in river lot 2, which are also traceable to the north boundary of the area. The Cardium exposed on Jacob creek does not outcrop on the Bow, but its position on the river flats in the Methodist Mission Reserve is represented by low ridges of harder beds projecting slightly above the level of the river terraces. The entire absence of outcrops of these beds along the river substantiates to some degree the possibility of the Cardium in river lot 3 crossing the Bow, although not outcropping along it.

One outcrop of Cardium in the hillsides about two and a half miles south of the river has been taken as evidence that the Jacob creek belt extends as far southeast as mapped. This outcrop is approximately in strike alignment with the Jacob creek occurrence.

Cardium beds dipping 70 to 75 degrees southwest cross the Bow just below Morley bridge. (Plate 5A.) Like the eastern belts this one can be traced northwest into the hills for about 2 miles. South of the Bow there are no exposures of Cardium, but the structure of the district warrants a projection of these beds for some distance southeast of the river.

None of the faults shown with assumed position between the Morley bridge and Chiniki station are actually exposed and undoubtedly the structure is much more complex than indicated on the map or structure sections. The possibility of some of these Cardium beds being overturned has been considered, but sedimentary evidence was observed on three of these belts which indicated that they were not overturned. No confirmatory evidence was seen on the most easterly belt of Cardium in river lot 3.

A traverse was made along Ghost river about three miles to the northwest of this district, but the structure had changed so much in this distance that no interpolation of the intervening structure could be made wih any degree of accuracy.

Belly River beds form the only outcrops of strata that occur along the southern boundary of this area in the distance corresponding to that between Morley and Chiniki station. These outcrops occur mainly in sections 15 and 22, township 25, range 6. They form the north end of a synclinal structure which is better developed to the south of the area on the north branch of Jumpingpound creek. This syncline pitches to the south, and there appears to be considerable faulting along the axis, especially at the northern end of the structure just along the boundary of this arêa. It is possible that the fault shown near the west side of these Belly River beds should be extended further south than indicated.

The structure within the area between Chiniki and Morley is one of the most difficult parts to decipher in the field and was given considerable attention during our period of field work because of the fact that the Reserve well was being drilled in testing the area as a possible oil producer. Although the faults as shown were not observed on the Bow, their approximate positions were determined to some extent by lithological and palaeontological evidence obtained from disconnected exposures and in one instance from the core of the Reserve well.

Upper Benton beds are exposed at several places along the Bow west from the bridge for about one half mile. These dip 70 to 90 degrees to the southwest near the bridge, and about 45 degrees further west where they are in formational contact with the Belly River beds. This narrow belt of Benton extends northwest, having approximately the same structure as on the Bow. Southeast from the river it is interpreted to extend as mapped, although no outcrops were observed. The Belly River beds in contact to the west form a very narrow belt crossing the Bow. This is faulted off on the west side and Upper Benton is again brought to the surface. This belt of Belly River is believed to broaden to the southeast since the outcrops of this formation, dipping southwest about 35 degrees, occur in the hilltops in L.S.D. 1, section 17, township 25, range 6. This belt can be traced north of the river for over a mile, and is believed to extend to the north boundary, approximately as mapped.

The Upper Benton beds on the Bow to the west of the fault dip 45 degrees to the southwest, and are in formational contact with Belly River beds about a quarter of a mile west of the fault. These Benton beds form a narrow belt which is believed to be faulted off before the south boundary of the area is reached. They can be traced north of the river for about two miles, and the structure of the harder beds of the Belly River to the east and west indicates that these Benton beds extend north for some distance further. Basal Belly River beds occur west of the contact with the Benton. These dip southwest 40 to 45 degrees and should cross beneath the railway just east of Morley station. They are believed to extend southeast to form the ridges occurring in the northeast quarter of section 7 and the northwest quarter of section 8, township 25, range 6.

A belt of Belly River beds about 3 miles wide extends from north to south across the area west of Morley. This is folded in general into open synclines and anticlines as indicated by the positions of the axes and dips of the strata on the map. In some places the beds are much more broken and folded than indicated by the structure section or map. These general structures can be traced north of the river for over three miles and apparently continue to the north boundary of the area. South of the Bow the exposures are too few to permit projecting the structural lines any appreciable distance. Widely separated outcrops occur along the southern boundary of the area, but general structures cannot be readily determined from these. Chiniki peak is underlain by steep-dipping beds which form the west limb of a syncline, the axis of which is shown to cross the southern boundary about a half-mile to the east of the peak. This syncline crosses the Bow, although the west limb is not exposed on the river. This limb, however, is exposed north of the river near the automobile highway.

Structurally the area may be considered in two parts. The first includes the eastern part that has been thus far described and the second part is that to the west of the last mentioned broad belt of Belly River. This second part shows clearly the effects of the Moose Mountain uplift mentioned above.

Benton beds outcrop along the river west of the broad belt of Belly River. These are Upper Benton and are mapped as being overturned. The evidence of this structure is both palaeontological and lithological. These Upper Benton beds extend up the Bow for over two miles and exposures indicate considerable duplication of strata by folding and faulting. None of these faults, however, can be traced for any distance from the river exposures and most of the beds are dipping steeply. (Plate 5B.)

Cardium beds cross the Bow about two miles east of Ozada station. These are very much broken, and outcrop almost continuously along the river channel from this point west to the mouth of Oldfort creek. They are much more faulted and folded than can be indicated on a map of this scale. In general the structure is anticlinal, the west limb dipping gently to the west and the east limb almost vertical. Cardium beds are shown to extend south across Chiniki lake. They are exposed in the hills between the river and the lake and in the hills to the south of the lake. This belt of Cardium may be broader than indicated on the map.

From the mouth of Oldfort creek to the mouth of Kananaskis river the Cardium beds are exposed continuously either along the river channel or in the terraces. They cross the Bow four times in this distance and have an average dip of 15 to 25 degrees with strikes varying from eastwest to northsouth. At two of the crossings they dip downstream and at the other two upstream. These upstream crossings produce waterfalls on the Bow and the downstream crossings produce rapids. (Plate 4.) The falls have been utilized by the Calgary Power Company as sites for their dams. The Cardium consists of alternating beds of sandstone and shale, and both dams are built on the same member, which is the second sandstone from the top of the formation. The upper sandstone member crosses the river above each dam. At the upper dam it crosses at the west side of the mouth of Kananaskis river, where the Cardium beds turn to the south and extend approximately parallel to the mountains to the west. They cross the Kananaskis south of this area in the southeast quarter of section 15, township 24, range 8, just above the mouth of Lusk creek. The influence of the Moose Mountain uplift then is evident along the Bow from Kananaskis river east to the Cardium belt which crosses Chiniki lake. The general strike direction of the Cardium along the Bow in this part of the area being east and west, is an expression of the tendency of the formations to be arranged concentrically around Moose Mountain to the south. The numerous twists and breaks in these same beds express the effect of the Rocky Mountains to the west which tended to make the foothill structure parallel to them.

The Upper Benton and Belly River beds occurring stratigraphically above the Cardium occupy most of the area north of the Bow from a point about three miles east of Oldfort creek west to Kananaskis station. The structure is in general parallel to that of the Cardium as described above. Upper Benton beds, dipping to the north, are exposed on Oldfort creek from its mouth up to the contact with the Belly River which occurs about three-quarters of a mile north of where Banff highway crosses the creek. (Plate 6A.) These Benton beds form a long belt, with a general east trend parallel to the Cardium on the Bow. To the east they join other Upper Benton beds and turn north towards the Ghost, while to the west they turn south and cross the Bow above the mouth of Kananaskis river and extend southeast, parallel to the front ranges of the Rocky Mountains.

Belly River beds occurring above the Upper Benton have a structure parallel to the Benton and Cardium in this part of the area. They dip north and underlie the hills to the north of the highway, from a point north of Ozada west across Oldfort creek. Here they turn south with a west dip and cross the Bow in the vicinity of Kananaskis station, thence extending south, parallel to the Rocky Mountains.

The Paleozoic beds forming the front range of the Rocky Mountains are overthrust upon the Belly River beds along the west side of this area. This overthrusting is well exposed in the steep hillsides to the north of the Banff highway at the western boundary of the Stoney Indian reserve.

Lower Benton and Blairmore rocks are mapped in the southwest part of the area. These form part of the series of belts of Cretaceous beds that are arranged concentrically around Moose Mountain. Strata belonging to these formations are exposed on the Kananaskis river in sections 14, 15 and 23, township 24, range 8, and in some of the ridges northwest of Chiniki lake. Some of the Lower Benton is also exposed along the Bow beneath the Cardium beds. On the whole, however, the exposures of Lower Benton and Blairmore are too few to reveal much structure. The general structure is believed to be roughly parallel to that of the Cardium and younger strata in this part of the area. The Blairmore and Lower Benton beds are probably much more broken than has been indicated on the map and structure sections, since their position is close to both Moose Mountain and the front range of the Rocky Mountains.

The above discussion is believed to include a brief description of the most important structures occurring within the area. More structural detail has been given than will probably be of general interest but, on the other hand, those wishing to make use of this information in the field will find that the above description is general. The detailed structure of any particular part of the area is much more complex than can be shown on a map with a scale of one inch to one mile, or even a scale considerably larger.

CHAPTER IV.

DESCRIPTIVE GEOLOGY.

The area shown on the accompanying map is underlain mainly by strata of Cretaceous age. Rocks of Paleozoic age, occurring along the west side, were not examined, but are shown on the map to indicate the western edge of the foothills in this district. Some beds of Tertiary age occur in the eastern part of the area, but these are included with the uppermost Cretaceous beds in the mapping. Jurassic and Triassic strata which occur stratigraphically beneath the Cretaceous are not brought to the surface in any part of the area. A tabular list of the formations occurring in the area is given on page four and a table of the Cretaceous and later formations that have been mapped or described in reports on different parts of the foothills of Alberta is given below. The formations in this area are most readily correlated with those of other areas in southern Alberta. The names assigned to the formations occurring in the foothills of central Alberta are included in the table since some reference is made to them in the descriptions and correlations of the different formations within this area. The area along the south side of the Bow was included in the Moose Mountain district by Cairnes, but subsequent work in the foothills has afforded new data and information which necessitate some changes in correlation. Consequently, some of the formational names given by Cairnes have been omitted or changed in this report.

Correlation Table of Formations in the Foothills Belt, Alberta.

(SOUTHWESTERN ALBERTA) (WEST CENTRAL ALBERTA)

		Bow River (This Report)	(1) Moose Mountain	(2) Sheep River	(3) Southwest-ern Alberta	(4) Highwood Coal Area	(5) Bighorn Coal Basin	(6) Saskatche-wan to Atha-baska Rivers	(7) Smoky, Hay and Berland Rivers
CENOZOIC		Formations		Formations	Formations			Formations	
	QUATERNARY	Glacial and river deposits			Alluvium glacial drift	Superficial deposits	River Drift Glacial Drift	Fluviatile and Glacial	Recent and Pleistocene
	TERTIARY	Paskapoo-		Paskapoo	Porcupine Hills				
					Willow Creek				
MESOZOIC	CRETACEOUS	Edmonton	Edmonton formation	Edmonton	St. Mary River	St. Mary River (?)			
			Bearpaw Shales	Bearpaw	Bearpaw				
		Belly River	Belly River beds	Belly River	Belly River	Allison	Brazeau ss.	Saunders	Upper Sandstone and Shale
		Upper Benton	Claggett Shales				Wapiabi Shale	Wapiabi	
		Cardium	Niobrara-Benton	Benton	Benton	Benton	Bighorn ss.	Bighorn	
		Lower Benton				*	Blackstone Shale	Blackstone	Berland Shale
		Blairmore	Dakota Beds	Dakota	Blairmore	Blairmore	Dakota ss. and Shale		Sunset Sandstone
		Kootenay	Kootenay formation	Kootenay	Kootenay	Kootenay	Kootenay	Kootenay	Kootenay formation

(1) Cairnes, D. D., Geol. Surv., Can., Mem. 61, 1914.
(2) Slipper, S. E., Geol. Surv., Can., Mem. 122, 1921.
(3) Stewart, J. S., Geol. Surv., Can., Mem. 112, 1919.
(4) Rose, B., Geol. Surv., Can., Sum. Rept., 1919, Pt. c, p. 15.
(*) In the Crowsnest coal fields the Crowsnest volcanics occur between the Benton and Blairmore formations.

(5) Malloch, G. S., Geol. Surv., Can., Memoir 9E, 1911.
(6) Allan, J. A., and Rutherford, R. L., Sci. & Ind. Res. Coun., Alta., Repts. Nos. 6, 9, and 11, 1923-25.
(7) MacVicar, J., Geol. Surv., Can., Sum. Rept., 1923, Pt. B, p. 21.

Blairmore formation.—The lowest Cretaceous rocks which underlie a part of this area have been mapped as the *Blairmore* formation. This name has been used by several workers in the southwestern foothills of Alberta for the beds of fresh-water deposition which overlie the Kootenay coal-bearing formation and which underlie the Benton beds of marine deposition. Only the upper part of the *Blairmore* formation is exposed in this area and consequently its total thickness was not determined. These beds are exposed on Kananaskis river in the southwest part of the area and here they are folded and faulted into a series of minor structures. (Plate 3B.)

The names *Blairmore* and *Dakota* have been used somewhat synonymously by different workers as is indicated in the correlation table above. It is the opinion of the writer that the term *Dakota* should not be used for these beds in Alberta since *Dakota* refers to a formation occurring in the western United States, and the *Blairmore* formation of Alberta has not been definitely correlated with these beds. Some early workers in Alberta introduced the term *Dakota* while attempting to make broad correlations, but later Rose and Stewart, realizing the danger of too broad a correlation based on insufficient data, avoided the term Dakota and used the name *Blairmore* instead. Unfortunately, the name *Dakota* was used again in the report on the Sheep River area[11] which includes the Turner Valley oil field, and the term *Dakota* appears today in many press reports concerning the different oil wells.

Part of the Blairmore formation exposed on Kananaskis river consists of alternating beds of shales, arenaceous shales, shaly sandstones and sandstones. All the beds are quite hard, due in part to the deformation they have suffered and to the burial beneath the later Cretaceous beds. The shales are rather distinctly colored with various shades of green, brown, red and black. This coloration is characteristic of the shales in the Blairmore formation over most of southwestern Alberta. The sandstones are usually fine grained and light greenish grey in color. The lithological character of these beds indicates that they were deposited in fresh water.

Various workers in different parts of the southern foothills have found that the thickness of the Blairmore increases rapidly from east to west. Stewart[12] records 1,000 feet of Blairmore beds near Burmis, while Rose[13] gives the Blairmore formation a thickness of 2,000 to 3,000 feet in the Crowsnest coal field, and a thickness of 6,500 feet further west in the Flathead coal area.[14] Slipper[15] gives a thickness of 950 feet for the Blairmore in the Sheep River area. This thickness was determined from oil well borings since the whole of the Blairmore formation is not exposed in this area. Cairnes[16] gives a thickness of 900 to 1,700 feet for this formation in the Moose Mountain district. The greater thickness was obtained in the western part of the area.

11Geol. Surv., Can., Mem. 122, 1921.
12Geol. Surv., Can., Mem. 112, p. 28, 1919.
13Geol. Surv., Can., Sum. Rept., 1916, p. 110.
14Geol. Surv., Can., Sum. Rept., 1917, Pt. C, p. 31C.
15Geol. Surv., Can., Mem. 122, p. 4, 1921.
16Geol. Surv., Can., Mem. 61, p. 30, 1914.

In the area along Bow river the Blairmore formation occurring at depth probably varies in thickness from east to west in about the same manner as it does between the Sheep River and the Moose Mountain areas, that is, from about 1,000 feet at the eastern side to almost 2,000 feet at the west.

The top of the Blairmore formation is readily determined when exposed within the foothills since the overlying formation is of marine deposition and has a lithological appearance different from that of the Blairmore beds. It does not follow, however, that the relative stratigraphical position of the top of this formation is the same at all places, and the position of the top of the formation may also vary from east to west since the thickness of the formation varies rapidly in this direction.

It is more difficult to determine the stratigraphical position of the base of the Blairmore formation since this formation is underlain by the Kootenay beds which were deposited under conditions similar to those of the Blairmore, and both formations have a lithological character which is similar in many respects. A conglomerate bed which can be traced for appreciable distances latererally has been taken as the basal member of the Blairmore in southwestern Alberta. This bed is well exposed in the western part of the foothills, and can be traced for 120 miles[17] along strike.

In the eastern part of the foothills, where the Blairmore formation is reached only by drilling, it is more difficult to determine the stratigraphical position of the base of this formation which conformably overlies the Kootenay. In the foothills of west central Alberta there is no conglomerate within the Kootenay-Blairmore series that can be used as a formational boundary, and in reports[18] on parts of this area the writer included in the Kootenay formation all the lower Cretaceous beds of fresh-water deposition.

The Kootenay and Blairmore beds carry plant remains which may ultimately serve as a means of dividing the series into formations and permit correlation of the formations occurring in widely separated areas. The information thus far obtained regarding these plant remains, however, is insufficient to be used satisfactorily as a field method of separating the formations.

COLORADO GROUP.

The Blairmore formation throughout most of the foothills is overlain by black shales of marine deposition. So far as known these shales are conformable with the Blairmore and are generally designated by the term Benton. Although the greater part of the Colorado group consists of dark shales there is usually present a series of sandstones which permit the separation of the group into three formations. The term *Colorado* is more appropriate when no division of the group is made since the original usage of the term *Benton* applied only to a portion of the group. In this area the writer has attempted to map the three divisions of the Colorado group separately. If either the Lower or Upper Benton can be definitely correlated with these beds at Fort Benton, Montana, to

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17Geol. Surv., Can., Mem. 112, p. 31, 1919.
18Sci. & Ind. Res. Coun., Alta., Repts. No. 9 and 11, 1924-25.

which the name Benton was first assigned, then it would be appropriate to assign a new name to those in this area which do not correlate.

Lower Benton formation.—The dark to black shales overlying the Blairmore beds constitute the lowest member of the Colorado group in this area, and are designated as *Lower Benton.* These beds underlie a relatively small portion of the area and the complete succession is not exposed at any one place. The largest area underlain by Lower Benton is that to the south of Bow river in the vicinity of Ozada. Here they occur as one of the Cretaceous formations, which surround the northern end of Moose Mountain. Narrow belts of this formation are brought to the surface in the area between Morley and Chiniki stations.

Being a shale formation, the outcrops of Lower Benton usually show many minor folds and faults. These cause repetition of the beds, making it difficult to determine the succession or thickness of the formation. Furthermore, the soft character of the beds permits them to be readily eroded, and the strata are concealed in most of the area shown to be underlain by Lower Benton.

The uppermost beds of this formation are exposed beneath the Cardium at three places along the Bow west of Morley, but each of these exposures shows less than 300 feet of the formation. The uppermost 400 feet of this formation are exposed on Kananaskis river just south of this area. Small exposures of Lower Benton occur adjacent to the belts of Cardium which cross the Bow east of Morley. The widths of these belts of Upper Benton shown east of Morley have to some extent been determined by structural, as well as palaeontological data.

The thickness of the Lower Benton formation could not be determined in this area, and since most reports on foothill areas give a thickness for the entire Colorado group it is difficult to determine or estimate the thickness for this member of the group in this area. Cairnes, however, assigns a thickness of 500 to 800 feet for the Benton occurring below the Cardium in the Moose Mountain area.

This formation being largely marine shales should not vary in thickness very rapidly in short distances laterally, as does the Blairmore formation. The writer has examined the stratigraphical equivalent of the Lower Benton at several places in the foothills between the Saskatchewan and Athabaska rivers, where it has a thickness which averages over 1,000 feet. These areas, however, are somewhat removed from Bow river. Lower Benton beds are exposed along Elbow river in the vicinity of the mouth of Bragg creek. There are several places above the mouth of this creek where 350 to 400 feet of black, fissile Lower Benton shales are exposed, but the deformed state of the beds makes it difficult to reconstruct the entire formation. From observations in different parts of the foothills the writer is of the opinion that the Lower Benton is at least 1,000 feet thick, and probably thicker in this area along the Bow. If it were much less than 1,000 feet thick the Blairmore beds would be brought to the surface in several places now occupied by broken or folded Lower Benton beds.

Dr. P. S. Warren[19] has kindly determined the fossil invertebrates collected from some of the outcrops of Lower Benton in this area. Most of the fossil localities are indicated on the accompanying map.

FOSSILS FROM THE LOWER BENTON.

Field Number		Locality.
42	*Prionotropis woolgari* Mantell	Bow river, ¼ mile below Upper Dam.
41	*Prionotropis woolgari* Mantell?	Bow river, about a mile below the Lower Dam.
44	*Inoceramus labiatus* Schlotheim *Ichthyodictes* (Fish Scale)	Bow river, south side, just above mouth of Jacob creek.

The *Prionotropis* were collected from beds within 200 feet of the base of the Cardium. Consequently in this area they occur stratigraphically high in the Lower Benton formation. *Prionotropis* and *Inoceramus* are mentioned by Stewart[20] as occurring at an horizon 350 feet above the base of the Benton in southwestern Alberta. Cairnes lists *Inoceramus problematicus* and *Prionocyclus woolgari* as occurring in the Benton in the Moose Mountain area.[21] These two species are synonymous with *I. labiatus* and *Prionotropis woolgari*, and Cairnes considered as Benton only those beds below the Cardium. In the report on the Sheep River area[22] a list of fossils from an horizon 700 feet above the base of the Benton is given. The text of this part of the report appears confused to the writer, and the fossils listed suggest very strongly that they were collected from the Upper and not Lower Benton beds.

Fossils have been collected by the writer from Colorado beds at several places in the foothills between the North Saskatchewan and Athabaska rivers, some of which have been mentioned in reports on those areas.[23] *I. labiatus* and *P. woolgari* have been collected from several localities in these areas and in all occurrences were found to be in beds below the Bighorn formation, which is correlated with the Cardium. The stratigraphical horizon of these fossils may be of particular value in working out well logs from core drilling records in the eastern foothills where the Benton is not brought to the surface. The Benton beds are usually much deformed in the foothills and fossil horizons are of considerable assistance when mapping the structural and areal geology.

Cardium formation.—The Lower Benton formation is overlain, apparently conformably, by a thin formation known as the *Cardium* which consists of alternating sandstones and shales which grade uniformly into each other. The sandstones are usually light colored on fresh surfaces, fine grained and well consolidated, and often carry beds of pebble conglomerate. These conglomerates are not persistent laterally, but occur more as lenses within the sandstone beds. The pebbles are usually small in size, having an average diameter of from one-quarter to one-half inch. Lenses of pebble conglomerates frequently occur within the shales of the Upper or the Lower Benton beds, and such occurrences are usually free from sandstone. The pebbles in the Cardium beds are usually well

19Associate Professor of Geology, University of Alberta.
20Geol. Surv., Can., Mem. 112, p. 33, 1919.
21Geol. Surv., Can., Mem. 61, p. 53.
22Geol. Surv., Can., Mem. 122, p. 8.
23Sci. & Ind. Res. Coun., Alta., Rept. No. 11, p. 40.

rounded fragments of chert or quartzite, showing such colours as black, brown, green and white.

These arenaceous phases of the Cardium express themselves in the topography and often underlie the higher parts of the areas occupied by the Colorado formations. (Plate 5A.) Pebble conglomerates appear to be more prevalent in the outcrops of Cardium east of Morley than in the numerous outcrops along the Bow in the vicinity of Oldfort creek and west, although in these more westerly occurrences there is a greater thickness of arenaceous beds in the formation. The distribution of these pebble phases may appear somewhat anomalous in view of the fact that the source of sediments is generally believed to have been to the west, but the Cardium beds, exposed east of Morley, indicate better sorting of the material than in the corresponding beds to the west. This would probably account for the concentration of the pebbles into lenses and the apparent localization of their deposition.

In most reports which deal with areas within the southern foothills, the Cardium beds have not been designated or mapped separately, but have been included in the Benton. Several reports mention that these arenaceous beds persist throughout the foothills for a considerable distance in the areas south of the Bow. The report of Stewart[24] on the disturbed belt of southwestern Alberta indicates that the arenaceous Cardium beds are not well represented along the eastern edge of the foothills in that area. Similarly in the Sheep River area[25], Slipper does not recognize the Cardium, although he mentions a sandstone horizon of irregular composition and distribution occurring about 700 feet above the base of the Benton. He designated these arenaceous beds as the *Lineham* member. Rose[26] records the occurrence of Cardium as far south as township 14 in the foothills and township 17 in the mountains. Cairnes describes the Cardium along the Bow and in the Moose Mountain area.

Sandstone beds in the Colorado shales are well developed in the foothills between the Saskatchewan and Athabaska rivers. Malloch[27] called these arenaceous beds the *Bighorn* formation in the Bighorn Coal Basin. The writer has noted the occurrence of this formation in other foothill areas[28] of west central Alberta.

The Bighorn formation and the Cardium are very similar lithologically and both occupy about the same stratigraphical position in the Colorado group. These beds have not been traced through the area lying between the Bow and the North Saskatchewan rivers, yet it appears to the writer that they may be correlated with the Cardium and are of the same geological age.

The fossils collected from the Cardium along the Bow have been identified by Dr. P. S. Warren as *Cardium pauperculum* Meek. These were collected from the following localities:

24Geol. Surv., Can., Mem. 112, p. 33.
25Geol. Surv., Can., Mem. 122, p. 8.
26Geol. Surv., Can., Sum. Rept., 1919, p. 17C.
27Geol. Surv., Can., Mem. 9E, p. 137, 1911.
28Sci. & Ind. Res. Coun., Alta., Repts. No. 9 & 11.

FIELD
NUMBER
39 River lot 3, Morleyville, hillside north of Banff highway.
27 River lot 2, north side of Bow river.
30 Cardium exposure near Indian agency, Morley.
37 South side Bow river, near Ozada.

No other fossils were found in the Cardium beds. *Cardium pauperculum* occurs localized in lenses of sandstone and is not present in most of the exposures of Cardium beds. *Cardium pauperculum* has been collected by the writer from the Bighorn formation at several localities in the foothills of west central Alberta. This formation, however, carries other invertebrates as well.[29]

The Cardium formation appears to thicken from east to west across the area. It is difficult to obtain the exact thickness of the formation from the different outcrops which usually expose only a part of the formation. The arenaceous beds which are used to differentiate this formation grade, very regularly, into the black marine shales of the Lower Benton below and the Upper Benton above. In the eastern part of the area the Cardium is represented best by the outcrops of conglomerate sandstones on the Bow at the south end of river lot 2. Here the Bow river flows southeast for over half a mile between two well defined conglomeratic sandstone beds, which dip steeply to the southwest and are about 100 feet apart stratigraphically. The lower conglomeratic bed outcrops on the northeast side of the river. It has a thickness of about 15 feet and carries several lensed bands of pebble conglomerate. The upper bed of similar lithology outcrops along the southwest side about 25 feet from the river. Most of the strata above and below these arenaceous beds are concealed and the total thickness of the formation cannot be obtained here, but the outcrops indicate a thickness of over 150 feet of beds which are mostly arenaceous. Some of the uppermost beds of the Lower Benton formation are frequently strongly cemented, and these often weather to ridges which are similar in appearance to those produced by the shaly members of the Cardium. This similarity of lithology frequently is confusing when mapping the Cardium.

The most continuous exposures of Cardium beds occur along the Bow between Oldfort creek and Kananaskis river. (Plate 4.) From these one is readily able to obtain data regarding the character of this formation, at least for this locality. Cairnes gives a generalized section of the Cardium on Bow River near Old Bow fort.[30] This section as given contains three sandstone or arenaceous horizons separated by shale horizons, with a total thickness of 220 feet for the formation. Almost the entire formation is exposed four times on Bow river within a distance of three miles between Oldfort creek and Kananaskis river. The lateral variation in the lithological character of the different members can be observed readily by examining these exposures which, while showing the same types of beds in each case, also show considerable difference in detail. Well defined sandstone beds up to fifteen

29Sci. & Ind. Res. Coun., Alta., Rept. No. 11, p. 42, 1925.
30Geol. Surv., Can., Mem. 61, p. 27, 1914.

feet thick occurring at one locality are found to be split by several feet of shales at another. The thickness of the Cardium formation at these outcrops was determined to be on the average between 135 and 150 feet. There appear to be four sandstone bands in the formation. These are fine-grained, in some cases quite argillaceous, and from one to fifteen feet thick. They are usually separated by shale members which average about the same thickness as the arenaceous beds. The transition from shale to sandstone is gradational and the upper and lower limits of the various members are indefinite. The dams of the Calgary Power Company are both built on the same sandstone member, which is the second one from the top of the formation. This member is overlain by about 40 feet of dark shales, above which occurs a sandstone bed 20 feet thick which is the uppermost member of the formation at this locality.

The Cardium formation has been emphasized in the discussion above, because the recognition of this horizon within the whole Colorado group is of considerable importance and assistance to anyone in working out the geology of this or adjacent areas. There is a big thickness of Colorado beds above the Cardium, and when the Cardium can be found in the field it is a valuable key formation, especially for those in oil work who desire to start drilling at as low a position, stratigraphically, as possible. The Cardium beds are the only ones within the Colorado group that can be readily differentiated from the rest of the group, which are almost entirely shales.

The Cardium is believed to correlate with the Bighorn formation which occurs 100 to 150 miles to the northwest of the Bow. The two formations carry a characteristic fossil, have a similar lithology and, as noted below, occur at about the same position stratigraphically with respect to the top of the Colorado group. Consequently, whenever it is important to know with some degree of certainty the stratigraphical horizon of a series of Colorado marine shales, the occurrence of Cardium beds in these southern foothills or the Bighorn beds in the more northerly districts will serve the field worker to great advantage.

Upper Benton formation.—The uppermost beds of those assigned to the Colorado group in this part of the foothills are designated as the *Upper Benton* formation in this report. Due to the thickness and stratigraphical position of this formation it frequently occupies the greater part of the areas within the foothills which are underlain by Colorado beds. In most of the foothills areas where the geology has been mapped this formation has been included with the Cardium and Lower Benton under the designation of *Benton* shales or *Benton* formation.

The Upper Benton formation is apparently conformable with the Cardium below and the Belly River formation above. The formation consists of a thick series of dark to black fissile shales of marine deposition. (Plate 5B.) Frequently there are zones that are ribboned with ironstone nodules. These zones do not appear to have a definite stratigraphical position for the whole area, but are more prevalent in the uppermost beds of the formation. These nodules have an average diameter of 6 to 12 inches and weather to a reddish brown color. Lithologically, the Upper and Lower Benton formations are very similar, and it is difficult to differentiate these formations from small outcrops. The Lower Benton shales are usually more fissile and freer from ironstone nodules than those of the Upper Benton.

The areal distribution of the Upper Benton is shown on the accompanying map. In the eastern part of the area it is represented by a series of narrow belts extending across the area from north to south, parallel to the general structure. These have been brought to the surface by the succession of faults and folds which characterize the structure of this part of the area. The map of the Moose Mountain area[31] by Cairnes shows five separate belts of Bearpaw beds occurring on the Bow between river lot 4, Morleyville Settlement, and the mouth of Spencer creek. He apparently missed a narrow band of marine shales which crosses the Bow about a mile east of Spencer creek. These six belts of shale are all Upper Benton and occur below the base of the Belly River formation.

In the western part of the area the Upper Benton occurs as one large belt, conforming to the structure of this part of the area and having in general a concentric arrangement in respect to the Moose Mountain uplift to the south.

The Upper Benton is the thickest member of the Colorado group in this area and being a shale formation it is usually much deformed and consequently no exposure reveals the entire formation in regular succession. The shale beds occurring west of the Cardium which crosses the Bow near the bridge at Morley are believed to represent the whole Upper Benton formation. Between this Cardium and the first exposure of Belly River to the west there is room for at least 2,350 feet of beds, taking the average dip as 70 degrees to the southwest. Some parts of the exposures occurring within this distance have a steeper dip, but 70 degrees is thought to be a good average. The exposures do not indicate any appreciable amount of duplication so that the thickness given for Upper Benton at this locality is believed to be a reasonable estimate. The most continuous exposure of Upper Benton occurs along Oldfort creek, where, at the mouth of the creek, the contact with the Cardium is exposed and the contact with the Belly River beds is exposed about three-quarters of a mile above the highway crossing on the creek. Benton beds are exposed in the narrow valley of the creek almost continuously between these two contacts. (Plate 6A.) These beds have not been intensely deformed, have an average dip to the north of 5 to 10 degrees, and are not duplicated by folding. The calculated thickness of Benton beds between these two contacts is 2,300 feet, assuming the average dip to be 7 degrees. This dip is believed to be about the minimum average since dips as much as 15 degrees occur at some places, and at no place is the dip less than 5 degrees. Using a dip of 5 degrees, which is below the average, the thickness would be 1,800 feet, whereas if the average dip were 10 degrees the thickness would be 2,800 feet. Seven degrees was recorded in the field as the best average and the thickness obtained from using this figure checks rather closely

[31]Geol. Surv., Can., Map No. 963, to accompany Mem. 61, 1914.

with that determined for the formation at Morley. A third estimate of the thickness was made by taking an average dip of 15 degrees which prevails west of Kananaskis river. It appears rather a coincidence that this estimate also comes out to 2,350 feet.

These are the only places within the area where estimates of the thickness of Upper Benton could be made which are believed to have a reasonable degree of accuracy. A thickness of 2,300 feet for the Upper Benton is considerably more than that reported by most of the other workers in the foothills. Cairnes[32] records an approximated thickness of 1,100 feet of shales above the Cardium. This includes some beds not assigned to the Benton by him, but which, however, belong to those designated as Upper Benton in this report.

Most of the estimates of thickness given for other parts of the southern foothills are for the entire Colorado group. Stewart[33] records 1,500 feet of Benton on the Oldman river in southwestern Alberta, and estimates the thickness to be 2,000 feet on Crowsnest river. Slipper gives a thickness of 1,850 to 2,000 feet for these beds in the Sheep River area.[34] These thicknesses indicate that the Colorado group as a whole is thinner in districts to the southeast of this area along the Bow, or that the estimates for these districts are too low. The writer is inclined to the latter view after having examined several sections of the Colorado beds exposed along the Elbow, Sheep and Highwood rivers in the foothills.

In the foothills of west central Alberta the Upper Benton is represented by the Wapiabi formation. The Wapiabi formation has a measured thickness of 1,900 feet on Blackstone[35] river, and the other members in the Colorado group occurring in these areas add at least 1,500 feet more to the thickness, which makes a total of 3,400 feet of Colorado beds in the foothills between the North Saskatchewan and Athabaska rivers. Our estimate for thickness of the Colorado group occurring along the Bow is as follows:

Upper Benton	2300 feet
Cardium	150 "
Lower Benton	1000 "
Total	3450 feet

It is perhaps a coincidence that the estimated thickness of this group should be so nearly equal in districts separated from each other by over 100 miles, but it is necessary to emphasize that there is yet much uncertainty regarding the thickness of the Lower Benton in this area and the Blackstone formation in the area to the north, since complete sections of these lower Colorado beds are seldom exposed.

The Upper Benton strata are not replete with fossil remains, but several horizons, when carefully examined, usually yield characteristic marine invertebrates. The following is a list of those

32Geol. Surv., Can., Mem. 61, p. 26, 1914.
33Geol. Surv., Can., Mem. 112, p. 32, 1919.
34Geol. Surv., Can., Mem. 122, p. 4, 1921.
(Note: In Geological Survey of Canada Summary Report, 1926, Part B, which appeared while this report was in print, Hume assigns a thickness of 2500 to 3000 feet to the "Benton" (Colorado) in the Turner Valley oil area, Alberta.)
35Sci. & Ind. Res. Coun., Alta., Rept. No. 9, p. 31, 1924.

collected from different localities in this area. Most of these fossil localities are indicated on the map, and for convenience the localities are listed in order from east to west. Dr. P. S. Warren has determined the following from the collections:

FOSSILS FROM THE UPPER BENTON.

FIELD NUMBER		LOCALITY.
15	*Baculites ovatus* Say Fish Vertebra	N. side Bow, L.S.D. 4, Sec. 15-26-5.
16	*Baculites ovatus* Say	S. side Bow, L.S.D. 4, Sec. 15-26-5.
17	*Baculites ovatus* Say	S. side Bow, L.S.D. 1, Sec. 17-26-5.
18	*Ostrea* sp. undet. *Anomia* cf. *subquadrata* Stanton *Baculites ovatus* Say	N. side Bow, L.S.D. 6, Sec. 17-26-5.
19	*Ostrea congesta* Conrad	C.P.R. grade, L.S.D. 2, Sec. 17-26-5.
23	*Ostrea congesta* Conrad *Anomia subquadrata* Stanton *Scaphites ventricosus* M. & H.	N. side Bow, L.S.D. 13, Sec. 18-26-5.
24	*Baculites ovatus* Say	Near (23).
40	*Baculites ovatus* Say	Ghost river, L.S.D. 4, Sec. 34-26-6.
25 26	*Baculites asper* Morton? *Ostrea* sp. nov. *Scaphites ventricosus* M. & H.	N. side Bow, river lot 8.
29	*Baculites asper* Morton? *Baculites* n.s.?	N. side of Bow, one-half mile E. of Morley bridge.
45	*Scaphites ventricosus* M. & H.	Reserve well core, depth 1877 feet.
31 32	*Ostrea* sp. undet. *Baculites ovatus* Say	N. side of Bow, one-quarter mile W. of Morley bridge.
34	*Baculites* cf. *ovatus* Say	S. side of Bow, one-half mile W. of Morley bridge.
35 36	*Baculites* cf. *ovatus* Say *Ostrea* sp. undet.	S. side of Bow, about three miles west of Morley.
33	*Inoceramus* sp. nov. *Scaphites vermiformis* M. & H. *Scaphites ventricosus* M. & H.	N. side of Bow, three and one-half miles west of Morley.
38	*Scaphites ventricosus* M. & H.? *Baculites asper* Morton?	S. side of Bow, about 4 miles W. of Morley.
43	*Inoceramus* sp. nov. *Scaphites vermiformis* M. & H. *Scaphites ventricosus* M. & H.	Shale pit at Seebe.

In addition the following were collected from the uppermost Upper Benton beds on Jumpingpound creek just north of the area mapped:

FIELD NUMBER		LOCALITY.
9	*Baculites ovatus* Say	L.S.D. 16, Sec. 24-25-5.
12	*Oxytoma nebrascana* E. & S. *Pteria* sp. nov. *Baculites ovatus* Say	L.S.D. 10, Sec. 24-25-5.

A notable feature illustrated in this list is the recurrence of some of the forms at several localities. This is more significant when stratigraphical relations are considered. For example, *Baculites ovatus* was found at practically every place where uppermost Benton beds outcropped. In this area it always occurs within the upper 200 feet of the Upper Benton shales, and was not found in any other part of the formation. Ostreas occur at several localities in an horizon close to the *Baculites ovatus* horizon, but always stratigraphically below the Baculites. It was this stratigraphical relation of fossils which indicated that the Benton strata are overturned on Bow river about three miles west of Morley. (Structure Section C-D.) This interpretation of structure was further augmented by the fact that fossils which occur still lower in the Upper Benton were found to the west at locality 33. Without fossil evidence the structure here would have been given an opposite interpretation.

It is of interest to note that the *Baculites ovatus*, or a very similar form, occurs very commonly in the uppermost shales of the Wapiabi formation in the foothills of west central Alberta. The writer has collected it at several localities[36] and it was never found excepting in the uppermost beds. The occurrence of this form within the same narrow horizon stratigraphically and in widely separated areas seems to indicate that the top of the Colorado group or base of the Belly River formation has a fairly definite position stratigraphically throughout the foothills. *Baculites ovatus* is a Pierre form and its presence in these beds indicates an intermingling of Pierre and Colorado fauna towards the close of marine conditions in the foothills. It seems to the writer that it was the occurrence of this Pierre fossil in the Upper Benton that confused Cairnes in his interpretation of the succession in the area along the Bow. He correlated[37] the upper 150 to 300 feet of these marine shales with the Claggett formation of the western United States, which is Pierre in age. He also assigned a Bearpaw (Upper Pierre) age to the narrow belts of Upper Benton occurring in the eastern part of the area, and his lists of fossils[38] from the Claggett and Bearpaw are identical. Cairnes records sandstone beds 50 to 150 feet thick occurring below the "Claggett" and he used these to separate the "Claggett" from the Benton. We did not observe this sandstone member in any exposure of the Upper Benton, which in places was exposed for as much as 500 feet stratigraphically below the contact with the Belly River formation. The description of the sandstone seems to indicate that he was referring to the Cardium beds as they are developed in the area east of Morley.

Dowling[39] used the formational terms of Cairnes in his report on the Sheep River gas and oil field, but Slipper,[40] in a later report on the same area, does not recognize the same divisions of the Colorado and lower Montana strata as used by Dowling.

Our field observations lead to the conclusion that the Upper Benton formation as described above includes all those beds which Cairnes assigned to the Bearpaw, Claggett and Benton occurring above the Cardium strata. The uppermost beds of the Upper Benton formation carry Pierre fauna, but they grade regularly down into beds which carry definite Coloradoan forms.

Scaphites ventricosus and *Scaphites vermiformis* are two Coloradoan forms which occur commonly in the Upper Benton beds.

36Sci. & Ind. Res. Coun., Alta., Rept. No. 11, p. 43, 1925.
37Geol. Surv., Can., Mem. 61, p. 26, 1914.
38Idem, p. 52.
39Geol. Surv., Can., Mem. 52, p. 5, 1914.
40Geol. Surv., Can., Mem. 112, 1921.

They seem to occur throughout a considerable vertical distance within this formation, being more abundant in the lower part, but were at no place found in the uppermost beds, which are characterized by the presence of *Baculites ovatus*. *Baculites asper* occurs frequently associated with the Scaphites.

Further detailed work in the foothills may yield palaeontological evidence of a stratigraphic break in the beds here classed as Upper Benton, which may be in part Colorado in age, and in part Pierre. It would be, however, very inconvenient to map separately the uppermost beds characterized by the presence of *Baculites ovatus*, since their lithological character is very similar to those of definite Colorado age below.

McLearn[41] has recently described several new species of Coloradoan fossils from the Lower Smoky and Peace rivers of northwestern Alberta. He also discusses the faunal zones of the Colorado in that area, and in addition correlates some of the strata occurring along the Peace and Smoky with those of southwestern Alberta, Montana and Wyoming. It is of interest to note that the upper 100 to 150 feet of shales in the Peace River district are characterized by *Baculites ovatus*.[42] These beds have practically the same thickness and stratigraphical position as those on Bow river, which are characterized by the presence of the same fossil. Since similar conditions exist in the foothills south of the Athabaska river,[43] which lies between the Peace and the Bow, it appears that this thin horizon characterized by *Baculites ovatus* and occurring at the top of the Colorado strata has a very wide and uniform distribution, at least in a northwest and southeast direction.

These Colorado beds have usually been grouped together in mapping because of difficulty in differentiating lower from upper beds. The recognition of key horizons is essential in attempting to map the divisions separately, and frequently these are concealed or absent. Fossil horizons or faunal zones are believed by the writer to be the most useful means to assist in this division. Micropalaeontology is suggested by some as a means of differentiation, but previous to resorting to this method it seems essential to first work out the zones and vertical distribution of the fossil remains having macroscopic dimensions.

Belly River formation.—The strata overlying the Benton marine shales in the foothills have been called the *Belly River* formation by different workers. In foothill geology Belly River is more inclusive than the strict usage of the term implies in the locality where strata were first given this name by Dawson.[44] All the Cretaceous beds occurring above the Colorado are sometimes referred to as the *Montana* group.

In the southern Alberta foothills the beds above the Benton have been designated as the *Allison* formation by Rose and others. The writer used the name *Saunders* formation for the same strata in the foothills between the North Saskatchewan and Athabaska rivers. In many parts of the foothills it is difficult to divide the

41McLearn, F. H., Geol. Surv., Can., Bull. 42, p. 117, 1926.
42McLearn, F. H., Idem, p. 120.
43Sci. & Ind. Res. Coun., Alta., Rept. No. 11, p. 43, 1925.
44Geol. Surv., Can., Rept. of Progress, 1882-83-84, p. 112C.

strata occurring above the Colorado into separate formations, and such terms as *Allison* and *Saunders* are more inclusive in one area than in another. In some places they refer to all the beds of Montana age and in others some early Tertiary beds are also included. The term *Belly River* is used in this report for the beds of fresh water deposition occurring above the Upper Benton and below the *Edmonton* beds of uppermost Cretaceous age.

The Belly River formation underlies a large portion of the eastern part of the area where it is represented by several anticlines, synclines and fault blocks which cross the area from north to south. A broad folded belt of these beds crosses the area just west of Morley and a third belt underlies the Paleozoic rocks of the Rocky Mountains at the western side of the area. In all they underlie over one-third of the entire area mapped. This formation frequently occurs on the higher parts of the area where the valleys are underlain by Benton shales. The sandstone bands frequently express themselves as parallel ridges along the hilltops.

The Belly River formation consists of a thick series of shales and sandstones of fresh water deposition. The lithological units vary rapidly both vertically and laterally, and detailed sections can only be correlated when the strata between such sections are also exposed. The sandstone beds vary in thickness from bands of a few inches up to as much as 30 feet, while 10 to 20 feet is a more common average thickness. Those attaining greater thickness usually carry lenses of shale. The same range of thicknesses is characteristic of the shale members, which are very irregular in composition and show regular gradation both laterally and vertically through arenaceous phases into sandstones. The thicker lithological units are more common in the lower part of the formation which is characterized by a preponderance of sandstone over shale. The sandstones are light to dark grey in colour, while the shales are usually darker, showing various shades of brown and dark grey. All the beds are poorly stratified, which makes Belly River shales readily distinguishable from those of the Benton.

The arenaceous beds are usually fine grained and coarse phases such as pebble conglomerates are uncommon. A microscopical examination of a few thin sections reveals the essential constituents to be angular to sub-angular grains of quartz, chert and feldspar, cemented together by carbonates and argillaceous material. The number of sections examined, however, was insufficient to be taken as representative of the whole formation.

Most of the Belly River beds are well consolidated, especially the lower strata. This state of aggregation is due to the weight of overlying beds and in part to deformation.

Thin seams of coal occur at different horizons in the Belly River. Some were observed in the basal beds, but they appear to be more prevalent in the upper part of the formation. None of those in the lower part are thick enough to be classed as commercial seams and furthermore they are usually interstratified with thin layers of shale. A thin seam occurs about 25 feet above the base of the formation in L.S.D. 6, section 17, township 26, range 5, and a similar seam occupies approximately the same stratigraphical horizon in L.S.D. 4, section 15, township 26, range 5.

Coal seams which are in some places of sufficient thickness to be mined occur in the strata which cross the Bow at the mouth of Grand Valley creek. These extend southeast and cross Jumpingpound creek in L.S.D. 13, section 20, township 25, range 4. These seams have been prospected at several points along Grand Valley and Jumpingpound creeks, and were at one time mined on the south side of the Bow in the southeast quarter of section 13, township 25, range 6, about half a mile east of Mitford station. The workings here have been abandoned and at present a small mine situated in L.S.D. 7, section 6, township 26, range 4, operates during the winter season. Most of these coal-bearing beds have been included in the Belly River formation in this report, and shown as such on the accompanying map.

In the southern foothills and the plains to the east, the top of the Belly River beds is usually fairly well marked by the presence of the marine beds of the Bearpaw formation (Upper Pierre), which occur immediately above it. In this area, however, the Bearpaw is not represented by marine beds; consequently it is difficult to determine where the top of the Belly River formation should be placed, since the succeeding formations have a similar lithology. Our field observations lead to the conclusion that the Bearpaw horizon in this area is approximately the same as the stratigraphical position of the coal beds at Grand Valley creek.

There are several places along the Bow in the eastern part of the area where considerable thicknesses of beds occur which may be definitely assigned to the Belly River, and from these it is possible to get an estimate of the thickness of the formation in this area.

A secton, from the base of the formation exposed near the east side of section 16, township 25, range 5, west to a point near the mouth of Spencer creek, contains at least 2,000 feet of beds. The upper beds of the formation are faulted off and this section does not represent the whole formation. Another section exposes the lower part of the formation near the centre of section 14, township 26, range 5, and a regular westerly dipping succession extends upstream to the island in the southwest quarter of section 15. This section contains at least 2,500 feet of Belly River beds, exclusive of some basal beds which are not brought to the surface and some uppermost beds which are faulted off. Approximately 2,500 feet of Belly River are contained in a section which exposes the base of the formation just west of the mouth of Spencer creek. None of these sections include the entire formation, and it is our belief that the Belly River formation in the eastern part of the area is at least 2,500 feet thick.

Fresh water deposits in the foothills usually thicken from east to west, but the exposures in the western part of this area are deformed to such an extent that it is not possible to obtain reasonably accurate estimates of the thickness. There are at least 1,500 feet of Belly River beds in the belt along the west side of the area, which is overridden by the Paleozoic strata. The Belly River formation may possibly have a thickness of over 3,000 feet in the western part of the area.

These thicknesses given above are somewhat greater than that given by Cairnes, who states that the maximum thickness of Belly River along the Bow is 1,025 feet[45] and only about 850 feet further south. Our estimates, however, were obtained from sections occurring in the eastern part of the area which were placed above the Bearpaw formation by Cairnes.

In the sheep river area[46] Slipper assigns a thickness of 1,850 feet to the Belly River formation and Stewart estimates the thickness to be 3,000[47] feet on Oldman river in the disturbed belt of southern Alberta. Rose[48] gives a thickness of 2,500 to 3,000 feet for the Allison formation in the Crowsnest coal field, and the greater part of this formation correlates with the Belly River.

The estimated thickness of 2,500 to 3,000 feet given for the Belly River along Bow river appears to be confirmed by most of the reported thicknesses in other foothill areas to the south. It is not possible to extend this comparison of thicknesses north to the foothills of west central Alberta, where the Belly River beds are represented by the Saunders formation, which is a thick series of fresh-water deposits that include strata younger in age than Belly River.

A few vertebrate remains were found in the uppermost Belly River beds on Bow river just west of Grand Valley creek, and on Jumpingpound creek south of the area shown on the map. These bones are not determinable. Some Unios were collected from the upper beds on Jumpingpound creek. In addition, a few fossil leaves were collected from the beds along the Bow. On the whole, the Belly River beds are remarkably free from either plant or animal remains. This feature appears to be characteristic of these beds throughout the foothills. In areas between the North Saskatchewan and Athabaska rivers the writer found very few fossil remains in that part of the Saunders formation which corresponds with the Belly River. The geological reports on different areas to the south of the Bow seems to substantiate the conclusion.

Bearpaw formation.—In southeastern Alberta a series of marine shales characterized by a Pierre fauna, and called the *Bearpaw* formation, occur above the Belly River beds. Here they separate the Belly River from a series of fresh-water deposits of uppermost Cretaceous age which are similar lithologically to the Belly River strata. The Bearpaw is best developed in the plains area of southern Alberta. It has been observed in the eastern foothills of southern Alberta,[49] but has not been definitely recognized north of Oldman river in township 10. Stewart mapped the Bearpaw as far north as Pekisko creek in township 17, but states that the marine character of the beds could not be detected this far north. The Bearpaw has not been recognized in the southern foothills to the west of the area mapped by Stewart. Further north, in the Sheep River area, Slipper[50] assigns a Bearpaw age to shale beds about 100 feet thick which lie above the coal horizon in the uppermost Belly River and below coal which occurs in the lower part

[45]Geol. Surv., Can., Mem. 61, p. 25, 1914.
[46]Geol. Surv., Can., Mem. 122, p. 9.
[47]Geol. Surv. Can., Mem. 122, p. 35, 1919.
[48]Geol. Surv., Can., Sum. Rept., 1916, p. 112.
[49]Geol. Surv., Can., Mem. 112, p. 36, 1919.
[50]Geol. Surv., Can., Mem. 122, p. 9, 1921.

of the Edmonton formation. He records a brackish water fauna from these shales, which are exposed on the Highwood river at the mouth of Bull creek in section 9, township 18, range 2. This is the most northerly reported occurrence of Bearpaw in the foothills, and is over 50 miles southeast of where strata, equivalent in age to the Bearpaw, would cross the Bow. In the area along the Bow, the Bearpaw horizon is represented by fresh-water deposits which cannot be differentiated from the Belly River below or Edmonton above. Consequently the Bearpaw formation has not been recognized in this area by the writer.

Cairnes[51] reported and mapped the occurrences of marine Bearpaw beds along the Bow, but, as stated above, all these shales which he assigned to the Bearpaw in reality underlie the Belly River. This error confused some of the later workers in other parts of the foothills, and McLearn has stated that the Upper Pierre sea (Bearpaw) extended further west in Alberta than did the Pierre sea of earlier Montanan time.[52] The palaeontological and lithological evidence at present, however, indicates a reverse conclusion. The occurrence of a Pierre fauna in the shales below the basal Belly River beds or their equivalent strata throughout the foothills in the western part of the province from Peace River south beyond the Bow, and the general absence of marine beds of Bearpaw age throughout the foothills from Athabaska river south beyond the Bow as far as the Crowsnest coal field, indicate that the western shoreline of the Pierre sea in Alberta was more restricted in Bearpaw time than at the time immediately preceding the deposition of the basal Belly River beds.

Edmonton-Paskapoo formation.—The uppermost consolidated rocks in this area consist of a series of beds of fresh-water deposition, apparently representing continuous sedimentation. In the plains area of eastern Alberta the Bearpaw marine beds are overlain usually conformably by a series of beds of uppermost Cretaceous age, referred to as the *Edmonton* formation. The Edmonton is in turn overlain by strata of similar lithology commonly known as the *Paskapoo* formation, to which is assigned an early Tertiary age.

In the plains area these formations are separated largely on lithological differences and in some districts there is evidence of a disconformity[53] between the Paskapoo and Edmonton beds. In some instances fossil remains assist in differentiating these formations. In the foothills the conditions of deposition in both Edmonton and later time were similar, and it is very difficult to determine even the approximate position of the top of the Edmonton or base of the Paskapoo. In the area along the Bow the writer was unable to determine the stratigraphical position of the top of the Edmonton formation; consequently, the Edmonton and Paskapoo beds were mapped as one formation and described as such.

The Edmonton-Paskapoo beds are confined to the eastern part of this area and are well exposed along the Bow from Grand Valley creek east to Cochrane. The lowest strata occur at Grand

[51] Geol. Surv., Can., Mem. 61, p. 24, 1914.
[52] McLearn, F. H., Geol. Surv., Can., Sum. Rept., 1914, p. 63.
[53] Allan, J. A. Oral communication.

Valley creek and the highest strata cap the hills to the northeast of Cochrane. These uppermost beds are as high stratigraphically as any that occur to the east as far as Calgary, and are higher stratigraphically than those exposed along the bow between Cochrane and Calgary.

The beds taken as the approximate base of the Edmonton are those exposed at the mouth of Grand Valley creek in section 13, township 26, range 5. The exposures on Jumpingpound creek in L.S.D. 13, section 20, township 25, range 4, are believed to represent the same horizon. From the discussion of the Bearpaw and Belly River given above it is evident that the position of the base of the Edmonton formation is indefinite. At the above localities the beds to the east dip in regular succession and are not intensely deformed, but at both localities the beds to the west are much broken and folded into numerous minor structures. Coal seams are reported[54] to occur in the uppermost Belly River beds and in the basal portion of the Edmonton in foothill areas to the southeast where there is more definite evidence of the presence of Bearpaw beds or their stratigraphical equivalents. Several coal seams occur in the broken strata just west of the mouth of Grand Valley creek. These have been included in the Belly River in this report. Thinner coal seams occur in the lowest easterly dipping strata along the east side of the creek, and these have been taken to represent the coal seams which occur in basal Edmonton beds to the southeast of the area.

The Edmonton-Paskapoo beds consist of interbedded light-coloured sandstones and shales. They are in general softer than the Belly River beds, due most likely to the fact that they have been less deeply buried and and are less deformed. They are well exposed along the Bow from Grand Valley east to Cochrane, and on the lower part of Jumpingpound creek. The lithological units are lenticular; consequently they vary laterally and vertically in composition and texture. Detailed sections could not be correlated over any distance. The lithological units vary in thickness from a few inches up to several feet and some of the sandstone beds are over 40 feet thick. The sandstones are fine-grained and usually buff to light grey in colour, whereas the shales are frequently darker. Cross-bedding is prevalent in the sandstones and the shales are not well stratified. The whole series is typical of fresh-water deposition. (Plate 7.)

The lower part of the Edmonton-Paskapoo strata is characterized by a dominance of sandstone beds (Plate 7A), which are exposed along the Bow from Grand Valley creek to the mouth of Bighill creek. Part of the same section is well exposed on the lower part of Jumpingpound creek. (Plate 7A.) In these sections the sandstone beds commonly have a thickness of 20 to 30 feet, and are usually separated by intercalated sandstone and shale beds.

From the mouth of Bighill creek east beyond Cochrane to the border of this map-area, the exposures along the river indicate that shale predominates over sandstone. The higher strata exposed along the hillsides east of Cochrane, however, contain more sandstones than shales. The prevalence of sandstones in these upper-

[54]Geol. Surv., Can., Mem. 122, p. 9, 1921, and Mem. 112, p. 36, 39, 1919.

most Edmonton-Paskapoo beds is believed to be responsible in part for the flat-topped hills which rise rapidly from the river at Cochrane and extend several miles east to the vicinity of Calgary. These upper sandstones have been quarried for building stone on the north side of the Bow valley near Glenbow, which is situated two miles east of the boundary of this area. Wherever these beds are exposed in the valley sides they are highly crossbedded and lenticular. They have about the same average thickness as those occurring lower in the series to the west and are interbedded with arenaceous shales.

In brief, Edmonton-Paskapoo may be said to consist of a lower part dominated by arenaceous beds, followed by more argillaceous beds, which are in turn overlain by a second group dominated by sandstones.

The approximate thickness of the Edmonton-Paskapoo in this area has been determined from the continuous easterly dipping succession occurring between Grand Valley creek and the hilltops east of Cochrane. This estimate has been obtained by using the average dip and distance across the strike. It is not possible to obtain very accurate results by direct measurement, since the dip is continually changing from east to west and the exposures are for considerable distances somewhat parallel to the strike, revealing only apparent dips.

The beds occurring between Grand Valley creek and the mouth of Jumpingpound creek have an estimated thickness of 2,600 feet. Using small differences in average dip, this value may be changed considerably. The minimum thickness, however, would be at least 2,300 feet and the maximum 3,000 feet. By the same method of calculation there is found to be 300 feet of beds between the mouth of Jumpingpound creek and the bridge across the Bow at Cochrane. The strata are approximately flat-lying at Cochrane, and the hilltops to the northeast of the valley are approximately 600 feet above the river level. Thus the estimated total thickness of Edmonton-Paskapoo beds occurring in this area is 3,500 feet. The lower beds, characterized by a predominance of sandstones, constitute about 2,800 feet. The overlying portion, characterized by shale, is about 150 to 200 feet thick, and the upper part, which is dominantly arenaceous, is from 500 to 550 feet thick. Dawson[55] estimates that the beds between Grand Valley creek (Coal creek) and the mouth of Jumpingpound creek had a minimum thickness of 3,300 feet. Our estimate of 2,600 feet for this section is perhaps too low, but after checking our results by splitting the section at several points it appears to us that 3,300 feet is too large.

The approximate thickness of 3,500 feet is valuable only as a minimum when correlating the Edmonton-Paskapoo with beds of the same age elsewhere, since in this area the upper part of the Paskapoo formation and any younger strata that may have been present have been eroded off. Thick fresh water deposits of approximately the same age as the Edmonton-Paskapoo have been noted in other foothill areas somewhat removed from the Bow. In the Sheep River area Slipper[56] estimates the thickness of the Ed-

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55Geol. Surv., Can., Rept. of Progress, 1882-83-84, p. 81C.
56Geol. Surv., Can., Mem. 122, p. 10, 1921.

monton to be 1,300 feet. An incomplete section of Paskapoo is 4,000 feet thick, making a total of 5,300 feet for an incomplete Edmonton-Paskapoo section. Still further to the southeast Stewart[57] assigns a thickness of approximately 6,000 feet to the beds which overlie the Bearpaw formation, and in the foothills south of Highwood river, Rose[58] records a thickness of 10,000 feet of strata occurring above the Allison formation, which is approximately the equivalent of the Belly River. These values indicate that this upper series of fresh water deposits is very thick in the foothills and the thickness obtained at different localities depends to some extent on how much of the uppermost beds have been eroded away.

One of the chief differences between the Belly River and the Paskapoo-Edmonton beds is the prevalence of fossil remains in the latter, and the notable absence of such in the Belly River. Those in the Edmonton-Paskapoo beds occur characteristically in lenses which are distributed fairly well throughout the whole series. These fossils consist chiefly of fresh water invertebrates, some plants, and fragmentary remains of vertebrates.

Dr. P. S. Warren has identified the following invertebrates from the material collected. The localities are arranged in stratigraphic order, those at the top of the list occurring in the lowest Edmonton-Paskapoo beds from which fossils were collected. Numbers 1 to 3 inclusive occur in the lower strata which are dominantly sandstone. Numbers 10 and 11 come from the shale zone which underlies the upper arenaceous beds.

LIST OF FOSSILS FROM THE EDMONTON-PASKAPOO.

FIELD NUMBER		LOCALITY.
3	*Unio* sp. nov.	North side Bow, east bank Grand Valley creek, L.S.D. 8, Sec. 13-26-5.
14	*Unio* sp. undet. *Viviparus* sp. undet. *Goniobasis tenuicarinata* M. & H. Vertebrate remains.	Railway grade, south side Bow, L.S.D. 4, Sec. 18-26-4.
2	*Unio senectus* White *Unio consuetus* Whiteaves *Viviparus cf. trochiformis* M. & H. *Campeloma producta* White *Thaumastus limnaeiformis* M.& H.	North side Bow, L.S.D. 2, Sec. 18-26-4.
6	*Unio senectus* White *Unio consuetus* Whiteaves *Unio* sp. undet. *Sphaerium formosum* M. & H. Vertebrate remains.	Jumpingpound creek, L.S.D. 15, Sec. 20-25-4.
5	*Unio senectus* White *Viviparus cf. trochiformis* M. & H. Fruits of *Ficus?*	Jumpingpound creek, L.S.D. 12, Sec. 33-25-4.
4	*Unio* sp. undet. *Viviparus* sp. undet. *Campeloma* sp. undet.	Jumpingpound creek, L.S.D. 11, Sec. 33-25-4.
1	*Unio priscus* *Unio senectus* White *Unio* sp. undet. *Sphaerium formosum* M. & H. *Viviparus cf. trochiformis* M. & H. *Valvata bicincta* Whiteaves Vertebrate remains.	North side Bow River, opposite mouth of Jumpingpound creek.

57Geol. Surv., Can., Mem. 112, p. 39, 1919.
58Geol. Surv., Can., Sum. Rept., 1918, pt. C, p. 15.

FIELD NUMBER		LOCALITY.
10	*Unio senectus* White	South side Bow, L.S.D. 2, Sec. 34-25-4.
	Unio sp. undet.	
	Physa copei White	
	Viviparus sp. undet.	
	Thaumastus limnaeiformis M.& H.	
11	*Unio senectus* White	Railway grade about 100 feet above Bow river, L.S.D. 4, Sec. 1-26-4.
	Unio danae	
	Viviparus cf. trochiformis M. & H.	
	Viviparus sp. undet.	
	Goniobasis tenuicarinata M. & H.	
	Thaumastus limnaeiformis M.& H.	
	Patula? sp. undet.	
	Gingko (plant remains).	
	Vertebrate remains.	

Vertebrate remains were found at several of the horizons from which the collections of invertebrates were made. The following determinations and notes on the vertebrates have been prepared by L. S. Russell.[59]

VERTEBRATES FROM THE EDMONTON-PASKAPOO.

FIELD NUMBER		LOCALITY.
14	Reptilia	Railway grade south side Bow river, L.S.D. 4, Sec. 18-36-4-W.5th.
	Saurischia	
	Dromaeosaurus? sp.	
	Pisces	
	Gen. et. sp. nov.	
6	Pisces	Jumpingpound creek, Sec. 20-25-4-W.5th M.
	Lepisosteus sp.	
1	Mammalia	N. side Bow river, opposite mouth of Jumpingpound creek, Sec. 4-26-4-W.5th M.
	Primates	
	Palaechthon, sp. nov.	
	Marsupialia	
	Thylacodon, sp. nov.	
	Ptilodus trovessartianus Cope?	
	Pisces	
	Gen, et sp. nov.	
11	Mammalia	Railway grade about 100 feet above Bow river, L.S.D. 4, Sec. 1-26-4-W.5th M.
	Ungulata	
	Meniscotherium, sp. nov.	
	Carnivora	
	Tricentes, sp. nov.	
	Insectivora	
	Mixodectes? sp.	
	Pisces	

The material listed under No. 14 consists of a single dinosaur tooth and a number of fish remains. The tooth is of the small deinodont type, and to suggest the general form is referred to *Dromaeosaurus*,[1] a Belly River genus. Similar isolated teeth, which cannot be definitely referred to a genus, occur in the Edmonton formation along Red Deer river. The fish remains are principally teeth, which represent an undescribed genus and species. Such teeth occur in the Lance formation of Wyoming and in the Paskapoo and Edmonton formations in Alberta, but they have not been reported from the Belly River series. The evidence of the dinosaur tooth and the fish remains, considered

59Assistant in Geology, University of Alberta.

1Matthew, W. D., and Brown, B., Bull. Amer. Mus. Nat. Hist., vol. 46, art. 6, p. 383, fig. 1, 1922.

together, indicates that the beds at this locality (No. 14) are of upper Cretaceous, and probably Edmonton, age.

The fish scales listed as No. 6, and referred to *Lepisosteus*, are of a type belonging to several widely separated groups of ganoid fish. These scales are known in Alberta from the Belly River and Edmonton formations, but Gilmore[2] has recognized them in the Paleocene of New Mexico.

The specimens listed as No. 1 consist of three mammalian teeth and some isolated fish teeth. *Palaechthon*, a lemuroid form, is apparently represented by a nearly complete upper molar. A similar tooth, associated with a Paleocene mammalian fauna[3] has been obtained at Calgary, 25 miles east of Cochrane. This genus was described by Gidley[4] from the Fort Union beds of Montana. *Thylacodon*[5] is an oppossum, originally described from the Puerco of New Mexico. In this collection it is represented by a fragment of a lower jaw, containing the last molar. *Ptilodus trovessartianus* was described by Cope[6] from the Torrejon of New Mexico. It is apparently represented here by a lower premolar, which is typical of the genus. Such multituberculate teeth are known from beds as low as the Belly River of Alberta and from the Torrejon formation of upper Paleocene age occurring in New Mexico. The fish teeth are of the same type as those listed under No. 14, and are not significant here, but the mammalian remains indicate a Paleocene age.

Meniscotherium,[7] listed under No. 11, is not known from strata older than Wasatch (lower Eocene). It is here represented by two specimens, a molar and a premolar, and both are typical of the genus. *Tricentes*[8] is a primitive creodont, which occurs in the Torrejon of New Mexico and in the Fort Union of Montana. The genus is represented in the present collection by a complete upper molar. A fragment of a jaw with two premolars is doubtfully referred to *Mixodectes*.[9] This is a genus of problematical relationships, which has been described from the Torrejon and reported from the Fort Union of Montana. A few indeterminate fish vertebrae are also included under No. 11. The presence of Paleocene and lower Eocene genera in the same stratum suggests that this stratum is probably uppermost Paleocene in age.

The invertebrates listed above occur commonly in the uppermost Cretaceous and lower Tertiary fresh water deposits of Alberta, but so far as known none of these forms can be used to distinguish Cretaceous from the lower Tertiary beds, since most of the forms are known to occur in strata of both these ages. The vertebrates indicate that the lower beds of the Edmonton-Paskapoo in this area were deposited in late Cretaceous time, and the uppermost beds in early Tertiary time. Very careful examination of the strata may reveal sedimentary characteristics which could be used to divide the Edmonton-Paskapoo, but it is doubtful if such criteria would be applicable in mapping the formations over a considerable area. The determining of the stratigraphical positions of the top of the Cretaceous in the foothills of Alberta is still a problem to be worked out, and much more palaeontological and lithological data must be obtained before this can be done. Early workers, such as Dawson,[60] who traversed a large part of southern Alberta, realized the difficulty of attempting to divide this series except locally, and

[2] Gilmore, C. W., U.S. Geol. Surv., Prof. Paper, 119, pp. 10, 68, 1919.
[3] Russell, L. S., Amer. Jour. Sci., vol. 12, p. 230, 1926.
[4] Gidley, J. W., Proc. U.S. Nat. Mus., vol. 63, art. 1, p. 6, 1923.
[5] Matthew, W. D., and Granger, W., Amer. Mus. Nat. Hist., Novitates, No. 13, p. 2, 1921.
[6] Cope, E. D., Amer. Naturalist, vol. 16, p. 686, 1882.
[7] Cope, E. D., Ann. Rept., U.S. Chief of Engineers, appendix FF, p. 596, 1874.
[8] Cope, E. D., Proc. Amer. Philos. Soc., vol. 21, p. 315, 1884.
[9] Cope, E. D., Proc. Amer. Philos. Soc., vol. 20, p. 558, 1883.
[60] Dawson, G. M., Geol. Surv., Can., Rept. of Prog., 1882-84, p. 112-114C.

consequently referred to them as the *Laramie* group. The work that has been done since the time of Dawson has not afforded satisfactory evidence for establishing formational boundaries within this group that can be used regionally. From observations made in several parts of the foothills from Athabaska river to the Highwood the writer is of the opinion that this series cannot be divided by any means that could be readily determined in the field and used in mapping the areal geology.

Recent Deposits.—A large part of the broad valley of the Bow is underlain by deposits of gravel, sand and silts of recent deposition. Most of these are unconsolidated materials of river and lake deposition. The most recent of these occur along the river channel as flood plain deposits. Deposits of an earlier date are extensively developed in parts of the valley, and occur now as broad flat terraces. These are believed to have been deposited during early post-glacial time, when there was considerable laking of the streams in this area. The distribution and topographical development of these deposits is discussed in previous chapters.

The terrace deposits are composed of gravel and sand mixed in varying proportions. At some places the gravel is composed of boulders which average 1 to 2 feet in diameter, but smaller dimensions prevail.

The time spent in the field by the writer was devoted more particularly to a study of the structure and lithology of the consolidated rocks and consequently very little data was obtained on the terrace deposits. These alone would require a lot of study and careful mapping in order to determine their relation to other similar deposits in southwestern Alberta. Dawson[61] has discussed these deposits in this area with respect to their relation to those of other parts of southern Alberta. Further information on these general relationships is contained in articles by Alden.[62]

61Dawson, G. M., Glacial Deposits of Southwestern Alberta, Bull. Geol. Soc., Am., vol. 7, p. 31, 1895.

62Alden, W. C., Pre-Wisconsin Glacial Drift in the Region of Glacier National Park, Montana, Bull. Geol. Soc., Am., vol. 23, p. 687, 1912; Bull. Geol. Soc., Am., vol. 24, p. 529, 1913.

CHAPTER FIVE.

ECONOMIC GEOLOGY.

Water Power.—The development of the area has been more in relation to agriculture in the form of ranching than to industries which have a direct geological bearing. The largest industry within the area is the hydro-electric plants of the Calgary Power Company, which are situated on the Bow near Seebe. The structure of the rocks at these locations and the lithological character of the Cardium beds which produced waterfalls in the Bow channel were the important factors which led to the selection of the sites for the dams. Most of the power generated here is transmitted to the city of Calgary.

Sandstone and Brick.—Paskapoo sandstones have been quarried near Cochrane and used to some extent in local buildings. Sandstone quarrying has been more extensively developed in the same beds at Glenbow, about five miles east of Cochrane. A description of some of these sandstones with respect to their physical properties is given by W. A. Parks[63] in a treatise on building stones in Canada. Silts and clays in the recent deposits near Cochrane were used in making bricks for some years, but at present this is not an active industry. The deposits of gravel, which extend along the valley sides of the Bow all the way across the area, have been utilized to some extent for railway ballast and highway surfacing. The Calgary to Banff automobile highway in this area is surfaced with this material. The reserve of gravel within the area is almost unlimited, and can be used as a source of supply for road construction in adjacent areas.

Shale and Limestone.—Shales used by cement plant at Exshaw are excavated annually from a pit near Seebe. These are from the Upper Benton formation and being of marine deposition are fairly uniform in composition. The same plant utilizes limestone from the Paleozoic beds which occur along the western side of the area. The limestone quarry is located close to Kananaskis station.

Coal.—Coal has been mined in the eastern part of the area for some years, although never on a very extensive scale. Seventy-one tons were produced in 1926 from a small mine situated in L.S.D. 7, section 6, township 26, range 4. A larger annual production was obtained for some years from a mine which operated in L.S.D. 1, section 13, township 26, range 5, near Mitford station. According to the reports of the Mines Branch of the Province of Alberta, this mine was opened in 1908 and abandoned in 1915. The old workings at this mine have caved in, and it was not possible to examine the seams.

The mine in section 6 was not operating during the summer, and no data on the thickness and character of the seams could be obtained in the field. Mr. W. McGlashing, who operates the mine,

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[63] Canada, Dept. of Mines, Mines Branch, Pub. No. 388, pp. 228-236, 1916.

stated that the coal and associated strata were much folded and faulted, and that the seam varied in thickness from 5 to 22 feet. The thicker parts are undoubtedly due to duplication of the beds through deformation.

The beds exposed along the Bow in section 13, township 26, range 5, near Mitford, are badly broken and folded. The exposures on the north side of the river and up the west side of Grand Valley creek as far as the automobile highway reveal a much broken series of beds and associated coal seams. One seam is about 4 feet thick with partings, and the other seams are thinner. There does not appear to be any thick seam in the succession at this locality, and it is not likely that mining operations will be resumed in the near future at Mitford.

The coal occurs in uppermost Belly River or basal Edmonton beds, and whereas there appear to be several thin seams within about 100 feet of beds none are of sufficient thickness to warrant extensive development. The same coal bearing horizon has been prospected on Jumpingpound creek in section 20, township 25, range 4, but the coal seams were found to be too thin to mine.

Thin coal seams occur at lower horizons in the Belly River, but all are too thin to develop. Consequently it appears that there is not likely to be any extensive coal mining in this area within the near future.

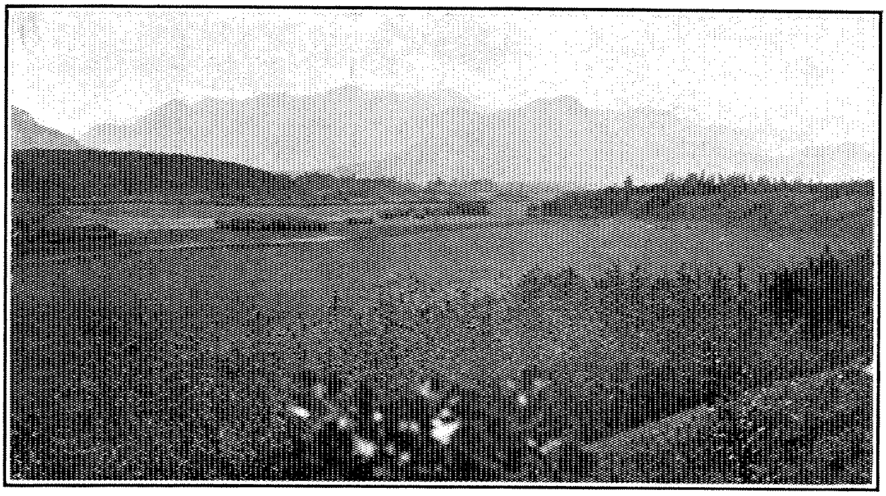
Oil Development.—The search for oil in the foothills, which centred around the Turner Valley district, was extended to this area along the Bow in 1926. The Reserve Oils, Ltd., were drilling on the river flat near Morley while we were examining the area. A diamond core bit was being used, since this was more in the nature of a test hole. Operations at this well were suspended, at least temporarily, in September, 1926, when a depth of approximately 1877 feet had been reached. Drilling was commenced and stopped in the Upper Benton formation.

Two other wells were started in this area late in the fall of 1926, one by the Gold Coin Oils, Ltd., and another by the Wabash Oil Company. The approximate location of these wells is shown on the map. These wells were commenced after we had completed our field work, and since they are situated in the unsurveyed territory of the Indian Reserve their exact positions cannot be stated. The writer is indebted to Mr. R. V. Heathcott, D.L.S., for information regarding the approximate position of these wells. The Gold Coin well is situated about 3 miles west of Morley station, and near the Railway. According to the writer's interpretation, they started drilling in Upper Benton beds, and it also very probable that the beds are overturned at this locality. The Wabash Oil Company well is situated about a mile west of the west end of Chiniki lake. They commenced drilling in the beds that are low in the Blairmore formation, and even possibly in the Kootenay formation.

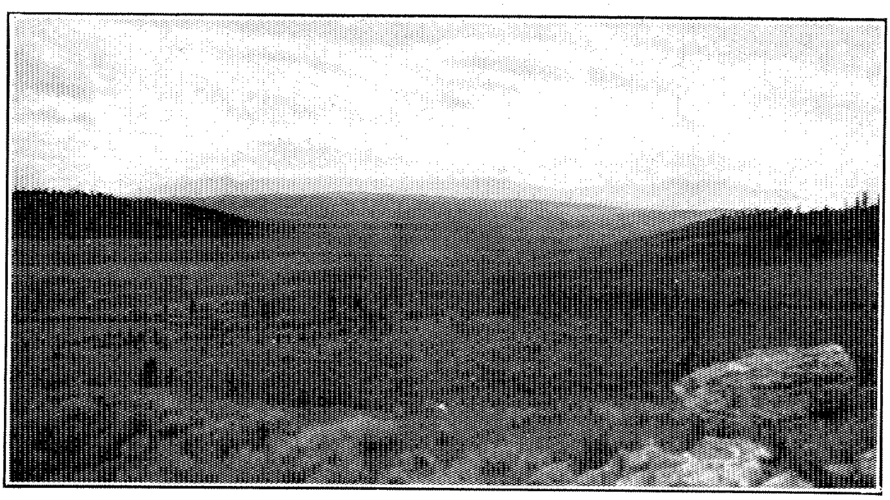
It is not the purpose of this report to discuss the possibilities of finding oil accumulations at depth within this area. The chief object has been to present some data on the lithological character and thicknesses of the formations which occur at the surface, and to give in some detail an account of the surface structure of the area.

Most of the horizons in the Cretaceous which have shown indications of petroleum in the Sheep River area occur lower stratigraphically in the Cretaceous than the beds exposed in this area. Indications of oil were present in some of the core samples taken from the Reserve well. These consisted of thin films and drops of oil along bedding or fracture planes in the Benton shales.

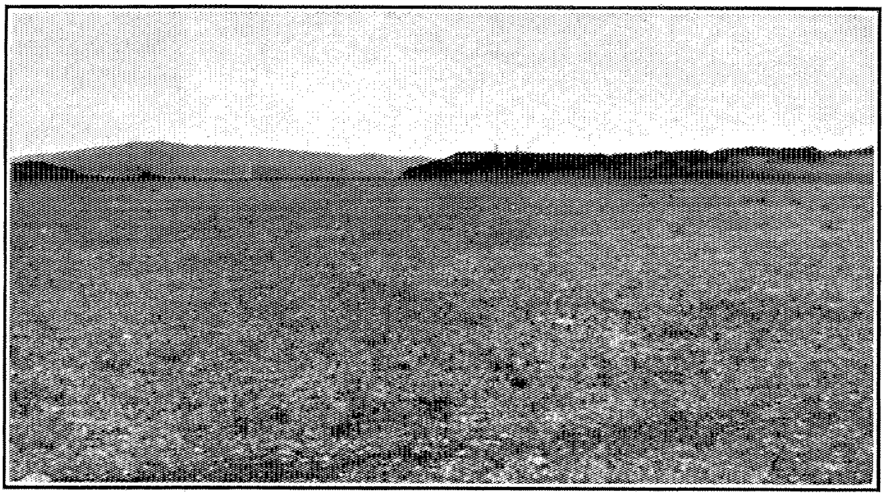
The most productive horizons in the Sheep River area are in beds of lower Mesozoic and upper Paleozoic age, which would occur at depth in this area. The rocks exposed at the surface are much faulted and folded, but it does not follow that the subsurface structures possessed by these lower horizons must necessarily coincide with those structures at the surface. In fact, it is the opinion of the writer that the substrata are much less broken and folded than the surface rocks. These upper Cretaceous and later rocks at or near the surface are as a group much softer than the lower Mesozoic and Paleozoic beds; consequently, during deformation they were easily broken and plicated into numerous folds and fault blocks which would be relatively much smaller than similar structures developed in the lower strata. From these considerations it seems that surface structure in upper Cretaceous rocks should not be followed too closely in selecting drilling sites when the object is to test the possibility of production of oil from the lower horizons. On the other hand, however, this surface structure is of considerable value in selecting drilling sites to test the higher horizons such as the Blairmore and Kootenay beds.



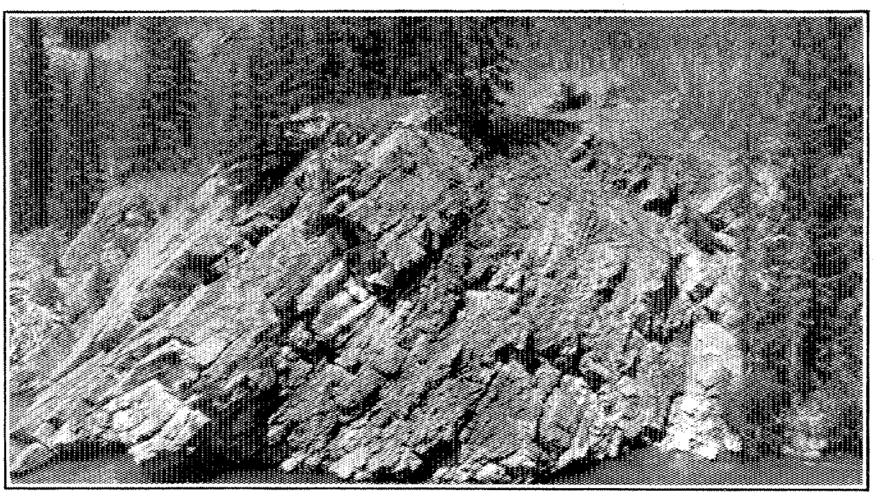
A.—Looking west up the old valley of Kananaskis river, from a point about two miles west of the west end of Chiniki lake. The front range of the Rocky Mountains, with the Kananaskis gap on the left, is shown in the background.



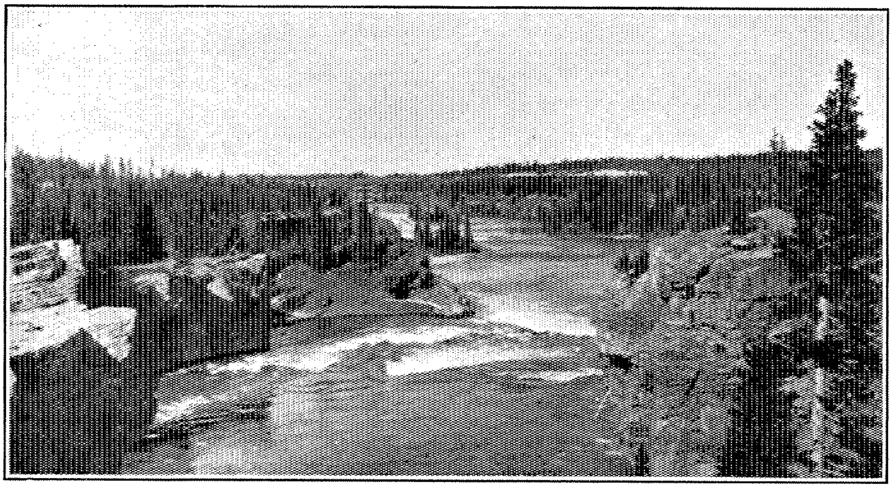
B.—Looking west up the old valley of Ghost river from the northwest quarter of section 1, township 27, range 6. The wooded hill on the left is on the east side of the present valley of the Ghost.



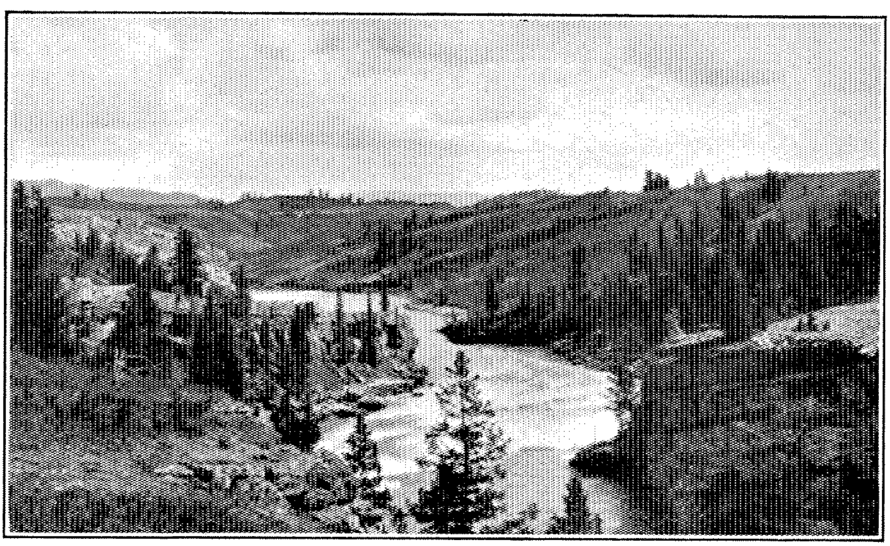
A.—Looking east across a flat terrace near Ozada. The low ridge in the right background is composed of morainal material.



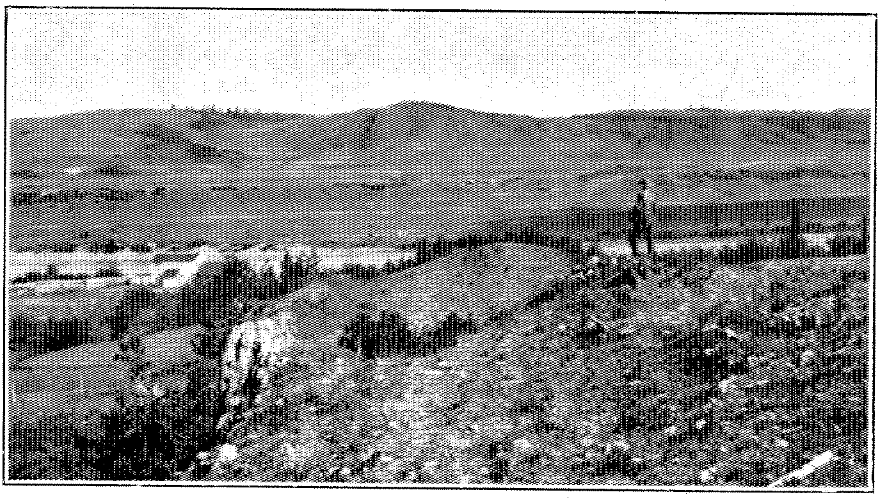
B.—Folded Blairmore beds on Kananaskis river, section 14, township 24, range 8. These beds are hardened, intercalated shales and sandstones.



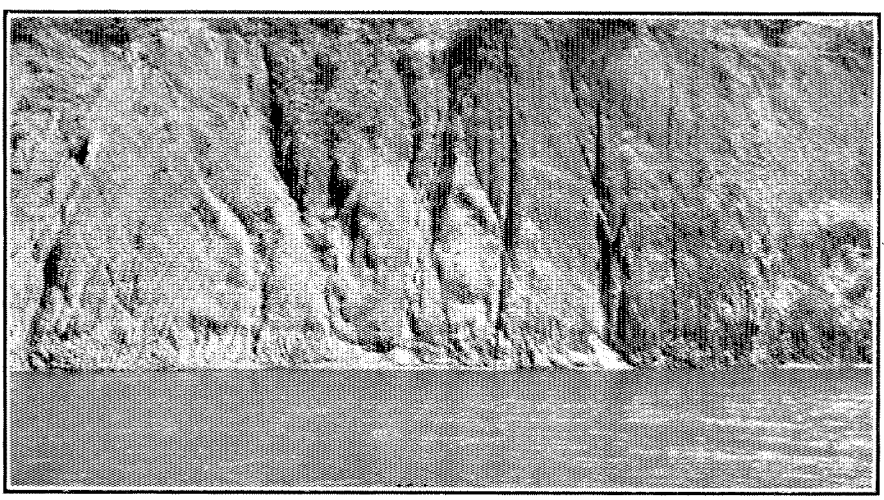
A.—Looking down Bow river from the Calgary Power Company's upper dam at the mouth of Kananaskis river, showing Cardium beds.



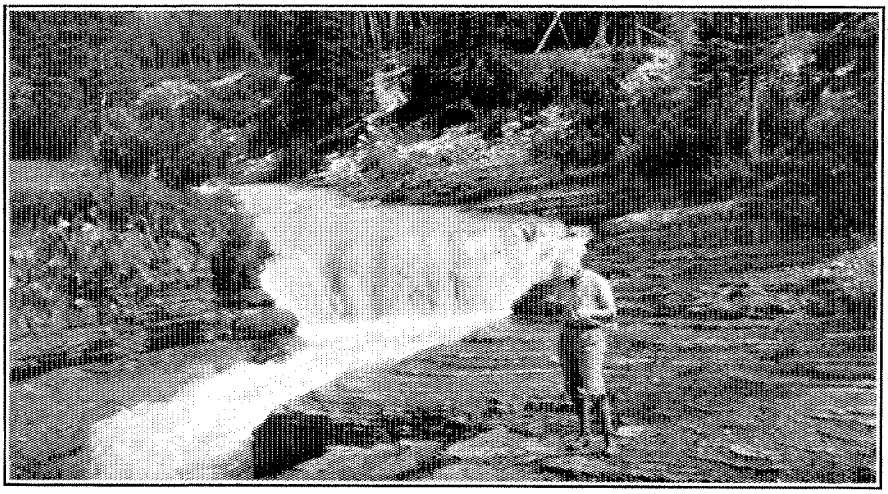
B.—Looking down Bow river from a point about one-half mile east of the lower dam, showing rapids and a restricted stream channel caused by Cardium beds.



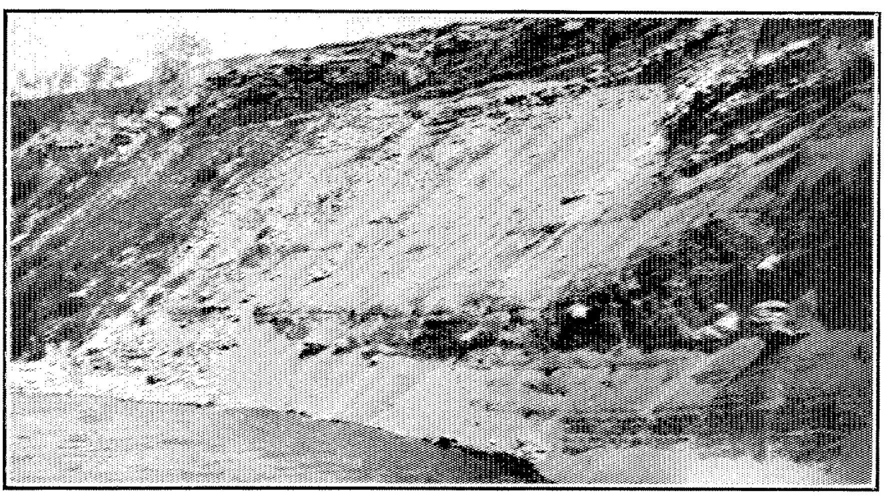
A.—Looking north across Bow valley just east of Morley bridge. Showing outcrops of Cardium conglomeratic sandstones in the foreground and hillsides of the background.



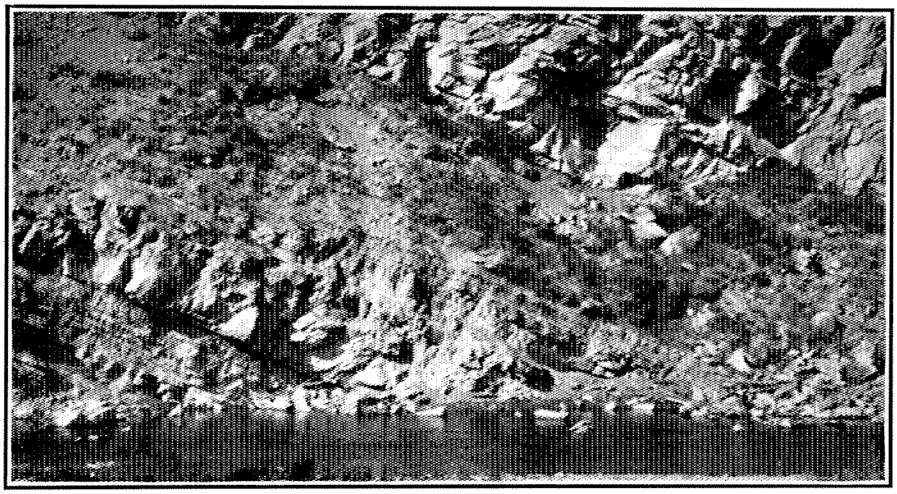
B.—Upper Benton beds on the Bow four miles west of Morley. Showing the thin-bedded character of these marine shales.



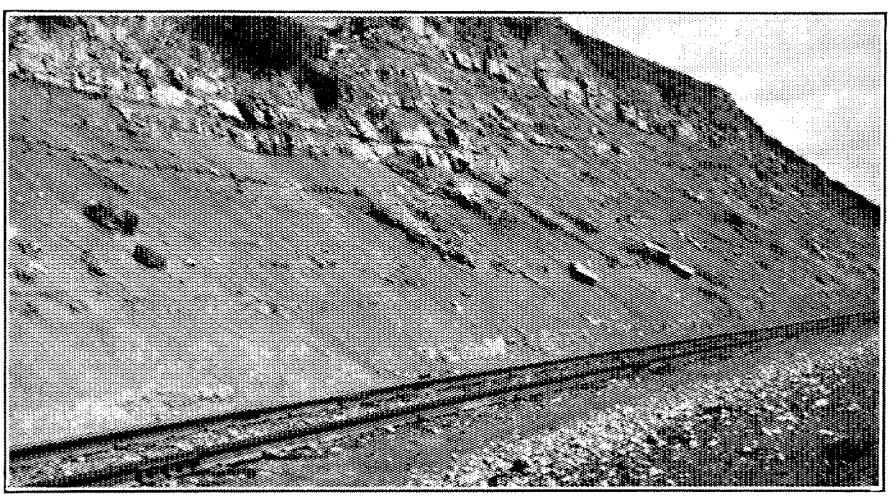
A.—Upper Benton beds on Oldfort creek at the automobile highway crossing.



B.—Transition from Upper Benton to Belly River beds exposed on Bow river just east of the mouth of Spencer creek.



A.—Basal Edmonton beds exposed on Jumpingpound creek in section 29, township 25, range 4.



B.—Paskapoo beds exposed in railway cutting in section 1, township 26, range 4. Fossils No. 11 occur near the top of this exposure.

INDEX

A

B

C

D

E

F

G

T

U

V

W

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TO ACCOMPANY MAP NO.12
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Rocky Mountains
E
F
C
D
A
B

KEY MAP
Scale in Miles
Magnetic Declination
Approximately N 25° E.
MORLEYVILLE SETTLEMENT
STONEY INDIAN RESERVE
Nos. 142, 143 AND 144
ROCKY MOUNTAINS PARK
BOW RIVER
COCHRANE
MORLEY
OZADA
KANANASKIS
Chiniki Lake
Banff-Calgary Highway
Canadian Pacific Railway
Tp.26
Tp.25
Tp.24
R.7
R.6
R.5
R.4
R.8
LEGEND
Edmonton-Paskapoo
Belly River
Upper Benton
Cardium
Lower Benton
Blairmore
Palaeozoic
SYMBOLS
Geological Boundary observed
Geological Boundary assumed
Fault observed
Fault assumed
Cardium Boundary
Dip and Strike
Main Highway
Primary Road
Secondary Road
Fossil Locality
Contour Interval
Indian Reserve boundary
Sources of Information
Geology by R. L. Rutherford, 1926
Base Map and Topography from
Sectional Maps, Numbers, 114 and 164
To Accompany Report No. 17
Scientific and Industrial Research Council of Alberta
GEOLOGICAL SURVEY DIVISION
GEOLOGICAL MAP
OF THE AREA ALONG
BOW RIVER, ALBERTA
BETWEEN
Cochrane and Kananaskis
Scale
1926
MAP No 12