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# Geology of Red Deer and Rosebud Sheets, Alberta

By

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PART ONE

# GENERAL GEOLOGY AND ECONOMIC GEOLOGY

BY J. A. ALLAN AND J. O. G. SANDERSON

## CHAPTER I.

## INTRODUCTION

*Delay in Publication.*

Most of the field investigations on which this report is based, were carried out prior to 1925. The junior author compiled and presented much of the material in this report, especially in Part Two, in a thesis written in 1928 in partial fulfillment for the degree of Doctor of Philosophy at the University of Toronto. The geological maps on the Red Deer and Rosebud sectional sheets, which accompany this report as Maps No. 8 and No. 9, were compiled and published in 1925.

The field data on which much of this report is based, were compiled after 1917 when the senior author examined the section along the Red Deer river across the entire map-area. In 1921 the senior author, assisted by R. L. Rutherford and J. O. G. Sanderson, investigated the geology in an area of about 75 square miles in the vicinity of Drumheller, along the valley of the Red Deer river and its tributaries. This report entitled "Geology of the Drumheller Coal Field", appeared as Report No. 4, in a series of reports published by the Scientific and Industrial Research Council of Alberta, which in 1930 was changed to the Research Council of Alberta. This designation will be used in this present report.

In 1924 the junior author carried out a more detailed investigation of the Red Deer sectional sheet and parts of the Rosebud sectional sheet, under the supervision of the senior author. Since 1925 much additional data have been compiled by both authors and by other geologists. Some of the more recent information, especially dealing with the coal seams, has been incorporated in this report in so far as it affects the broader geological relations.

*Plan of the Report.*

This report is compiled in two parts. Part One, under joint authorship, deals with the physiography, general geology and a consideration in some detail of the coal deposits that have a wide distribution and are of economic importance.

Part Two, compiled entirely by Sanderson, contains the results of detailed field investigations and laboratory research, carried out by the junior author. The high quality of this research warranted the publication of this report. Although most of the investigations in the field and in the laboratory were carried out prior to 1925, yet later field investigation verified or supplemented the earlier conclusions, and where changes of interpretation have been advisable, these have been incorporated in this report.

In some sections of the report dealing with the description of the Edmonton formation, there may appear to be some duplication of statement, but only of a minor character. The chapter in Part Two entitled "Detailed Palaeontology of the Edmonton Formation" contains precise descriptions of the fossil fauna that are valuable and necessary to anyone investigating the Upper Cretaceous strata in Alberta. Such theoretical considerations as are given to some of the topics in Part Two are necessary to a thesis dissertation which this part of the report represents.

There are no chemical analyses of the coal from the different seams included in this report. Details on the quality of the coal in the various horizons and in the different fields within this map-area are also omitted because since 1925 there has been much progress made in chemical research on coals, and a new classification of coal has been introduced within the past six years. The classification of Canadian coals by rank is discussed fully in Report 35, entitled "Coals of Alberta, Their Occurrence, Analysis and Utilization", prepared by Edgar Stansfield and W. Albert Lang, and published by the Research Council of Alberta in 1944. This report also contains a detailed discussion of the physical properties and the analyses of coals from all the coal areas in Alberta, including those being mined within the area of the Red Deer and Rosebud sheets. According to this new Canadian classification, the coals from Drumheller, Three Hills, Trochu, Big Valley and Ardley are classed as subbituminous B rank, and those from Carbon as subbituminous B and subbituminous C rank.

*Location.*

The area discussed in this report comprises about 8,000 square miles within the plains of Alberta. The area is about 84 miles wide, between the 112th and 114th meridians of longitude and 128 miles from south to north, between 51°05′ and 52°30′ parallels north latitude. According to the survey system on the plains, the area includes townships 25 to 40 inclusive and range 15, west of the fourth meridian, west to the fifth meridian which is on the east side of range 29. The city of Calgary is situated at the extreme southwest corner of the map-area and the town of Lacombe is situated in the northwest corner of the map-area, eleven miles east of the fifth meridian.

The area is well served with railway transportation facilities. The Calgary-Edmonton branch of the Canadian Pacific Railway follows closely the western edge of the map-area. The Lacombe-Stettler branch of the same railway extends across the northern part of the map-area. The main line of the Canadian National Railways from Calgary to Saskatoon, extends in an east-northeasterly direction, crossing the Red Deer valley at Drumheller and continuing to the east side of the area in township 31 on the north side of the Hand Hills. A branch line extends north from Drumheller to Edmonton, passing through the town of Stettler near the north boundary of the area.

*Preparation of Maps and Plates.*

The geological maps of the Red Deer and Rosebud sheets (Maps No. 8 and No. 9), accompanying this report, were published at the completion of the field work in 1925. The base maps on which the geology has been shown are the Red Deer and Rosebud sectional sheets, published by the Topographical Survey of Canada on a scale of one inch to three miles, on which the topography is shown by contour lines with 50-foot contour intervals.

Plate I contains five structure sections, and the position of each of these sections is shown on Maps 8 and 9. These sections were compiled in 1925, but have been redrawn with minor changes in 1944.

Plate II contains stratigraphic sections at twenty-two different localities, indicated by letters A to V. The position of each of these measured sections is shown on the accompanying geological maps, by the corresponding letter within a circle. The sections shown on Plate II were compiled in 1925, but were drafted for printing in 1944.

Plate III contains detailed sections of coal seams numbered 9, 11, 12 and 14, at fifty-one different localities. Each of these sections is numbered, 1 to 51, and Table 6 is the key to the location of each. These coal seams occur in the Middle and Upper members of the Edmonton formation. The sections shown on this plate were compiled in 1925. Later field information suggests that sections Nos. 11, 12 and 13, may represent No. 12 coal seam instead of No. 14 seam, so this interpretation was drawn in the revised Plate III.

Plate IV is a reduced reproduction without revision of Plate IV from "Geology of Drumheller Coal Field" by J. A. Allan, Report 4 (1921), Research Council of Alberta. This plate contains sections of coal seams numbered 1, 2, 5 and 7, in twenty-nine different coal mines operating in 1921 in the vicinity of Drumheller. Each of these sections is designated by a number which is the mine number given by the Alberta Mines Branch. A list of the mines represented in Plate IV is given in Table 3.

*Acknowledgments.*

The authors most gratefully acknowledge the assistance, helpful criticism and information contributed by Dr. R. L. Rutherford, Associate Professor of Geology at the University of Alberta. Rutherford and Sanderson assisted the senior author in 1921, in the field investigations in the Drumheller coal field, and in the preparation of Report 4, published by the Research Council of Alberta. Thanks are extended to Mr. Gordon L. Kidd, mining engineer and geologist, for useful information on the correlation of coal seams, especially in the Drumheller, East Coulee and Carbon areas, and for other important stratigraphical data on this coal-bearing formation. Full co-operation has been received from the office of the Chief Inspector of Mines in Edmonton and from District Inspectors.

It is not possible to thank individually all mine managers and other mine officials who assisted by supplying information in the field and allowing the authors to visit their respective mines and to inspect mine plans and other data compiled in these offices. The authors wish to gratefully acknowledge collectively this co-operation. This friendly willingness on their part supplied useful data and reduced the amount of time it would otherwise have been necessary to spend in the field. Railway plans and map data supplied by the Canadian National Railways were useful and thanks are extended to these officials. Highway plans obtained from the Alberta Department of Public Works, and level data supplied by the Topographical Survey of Canada, were useful in carrying out this geological survey in this map-area.

The very complete index has been compiled by Mrs. Vera Stover who also was assisted by Miss A. Melnychuk in the proofreading. The authors are most grateful for this assistance.

## CHAPTER II.

# PHYSIOGRAPHY

*General Character of the District.*

The entire area of the Red Deer and Rosebud sheets, representing about 8,000 square miles, lies within the plains of Alberta. The surface slopes with imperceptible grades, to the east. The surface elevations along the fifth meridian or longitude 114 degrees, which is the west side of the map-area, range from 3,550 feet above sea level at the southwest corner of Rosebud sheet, to about 3,000 feet at the northwest corner of Red Deer sheet. On the east side of the map-area, which is range 16, the elevations of the surface extend from 2,100 feet above sea level in the southeast and northeast corners, to about 2,700 feet in the centre at the junction of the Rosebud and Red Deer sheets. The surface plane of this slope is interrupted by low, smooth, gently rolling interstream ridges which have approximately accordant summit levels, and by several residual hills of irregular outline and no general accordance of summit level.

The lowest point on the Rosebud sheet is in the bottom of the Red Deer valley in the southeast corner of the map-area, where the elevation is between 2,100 and 2,200 feet above sea level. The plain level along the sides of the valley varies from 2,400 to 2,800 feet above sea level.

The most prominent of these residual hills are the Hand Hills (3,500 feet), Wintering Hills (3,400 feet), Three Hills (3,100 feet) and Knee Hills (3,200 feet). The most prominent topographic elevation on the plain is the Hand Hills, south of Delia. This is an erosion remnant of a pre-glacial land surface. The top of these hills is flat and the highest points in townships 29 and 30, range 17, have an elevation of 3,550 feet above sea level. The escarpment surrounding Hand Hills is steep and deeply incised. There is tree growth along the north slope and in many of the valleys.

Wintering Hills, another residual remnant, forms a long ridge south of Drumheller and Rosedale in township 26, ranges 19 to 22, with a maximum elevation of about 3,400 feet above sea level.

Knee Hills, east of Siewert lake in township 32, ranges 25 and 26, rises to an elevation of about 3,200 feet above sea level. A spur extends southeast to Swalwell. This prominence is also a remnant of erosion.

Three Hills in township 32, range 24, three miles north of the town of the same name, may also be of residual origin. The top has an elevation of 3,100 feet above sea level and is covered with moraine. The highest points in the Rosebud sheet are in the southwest corner, close to the fifth meridian in townships 27 and 28, range 29, between Airdrie and Crossfield where the tops of two local hills have an elevation of about 3,725 feet above sea level.

The lowest point in the Red Deer sheet is in the bottom of the valley of Battle river in the extreme northeast corner of the map-area. The elevation of the valley floor is about 2,150 feet above sea level. The highest elevation occurs in the ridge extending south from Red Deer valley in townships 36 and 37, ranges 25, 26 and 27. The highest points in this ridge are over 3,400 feet above sea level.

Most of the Rosebud and Red Deer sheets is open country, only the deeper valleys having tree growth. In the northwest corner and south to about Innisfail district, the upland surface is park-like with many groves of poplar, willow and some black spruce. The whole map-area supports agricultural activities, most of it being well adapted for grain or dairying, with more restricted areas, chiefly along the east side, better suited to grazing.

*Dominant Features.*

The outstanding features of the topography are related to surface relief, character of the underlying rocks and drainage development.

The maximum relief in the region is about 1,550 feet. Thus, an outstanding feature is the nearly uniform level on the uplands, broken only by a few isolated residual hills and lower ridges, irregular in extent.

The character of the underlying rocks had considerable effect in modifying the minor local relief. The Edmonton and Paskapoo formations differ sufficiently lithologically to render the character of the surface developed on them distinct. Together these formations underlie approximately 95 percent of the area. The Edmonton rocks are made up of very fine clastics with abundant clayey matter. Glacial erosion as well as normal present erosion has tended to develop very flat or low angle topography where this formation forms the outcrop. In contrast, the Paskapoo rocks in the basal portion of the formation are composed of coarse clastics predominantly. These rocks are only partially cemented with resistant matrix material, generally having softer and harder bands in any given exposure. The coarse sands are not as readily moved by wind or rain action and can form relatively steep protective taluses. This feature in conjunction with the ribbed nature of the bedding has resulted in the Paskapoo surface assuming a sharply rolling character locally. Low rounded hillocks, and irregular, minor short valley development are characteristic features.

The two formations show differences also in their relation to surface and ground water. The Edmonton rocks are clayey and impervious. Water does not seep away on the Edmonton surface; it is either retained as shallow intermittent lakes or cuts a course to drainage ways through steep-walled gullies. On the other hand the Paskapoo rocks absorb surface water readily. The surface underlain by these rocks is marked by fewer small lakes and ponds of intermittent type, and the minor drainages are of open-valley and normal type generally. Many of the larger lakes in the north part of the area lie in beds which are at the level of Edmonton strata, and are surrounded by hills of porous Paskapoo rocks, that act as collectors and reservoirs of the precipitation. At many points along the valley of the Red Deer the contact between the Edmonton and the Paskapoo is marked by the emergence of strong, steady springs. This feature is particularly notable west and northwest of the town of Big Valley.

The other dominant topographic feature is the drainage development. On the west half of the area the drainage is nearly perfect. Strong creeks in well defined valleys drain the land and there are few lakes larger than ponds. The major creeks and the Red Deer river itself have their courses partly controlled by the structure of the underlying strata. Although the drainage west of Red Deer river is nearly complete, it is in the youthful stage. This point is readily apparent upon noting the breadth of the interstream areas and the simple broad curves of the 50-foot contour lines of the upland parts. The influence of the underlying gentle folds on stream directions is an important consideration. It appears to indicate that the pressures which caused the overthrusting of the front ranges of the Rocky Mountains had effects upon the strata out to nearly 100 miles in front of the faulted ranges, and the gentle flexures resulting accord almost perfectly in alignment.

The east half of the area is imperfectly drained. There are several undrained lakes whose levels are at local base level, and there are no creeks of important length or depth of valley, except Willow and Michichi creeks, which drain the west side of the Hand Hills. This large area does not appear to have had well defined pre-glacial drainage which may have been obscured by glacial deposits, because glacial deposits, where noted, are not of important thickness. The tendency of the Edmonton rocks of this region to form flat surfaces on erosion, may account in part for this unusual characteristic.

*Surface Gradients.*

The slopes on the uplands are all gentle and the slopes from the plain level to the Red Deer river or to the major creeks near their mouths, are short and steep. The upper valleys of the western tributaries of the river have gentler slopes and broader valleys.

The regional slope is to the northeast for most of the area but more directly eastward in the southern part. The upland gradient here averages 12 feet to the mile to the east. Across the central part of the area the gradient of the surface is about 10 feet to the mile. On the north half of the area the surface slopes to the east at about 14 feet to the mile despite the fact that most of the drainage trends to the southeast to join with the Red Deer river.

The valley-side slopes are predominantly steep where the valleys carry important streams, being as high as 30° slopes, but rarely steeper. These slopes diminish greatly toward the heads of the tributary streams.

Aside from the banks of the main streams the only other steep gradients occur on the north and west sides of the Hand Hills, and on the north side of Wintering Hills. Locally the gradients at these places go up to 400 feet to the mile, but nowhere is there relief of more than 500 feet at this degree of slope.

Over most of the area the gradients are gentle and the topographic features are of broad and sweeping outline.

*Drainage.*

The whole map-area comprising about 8,000 square miles, excepting 650 square miles in the extreme northeast corner, lies within the drainage basin of the Red Deer river. As mentioned above, the drainage systems in the area are of two general classes, complete and incomplete, on opposite sides of Red Deer river. The higher country west of the river and the sides of the main residual hills are well drained, while the great flat areas east of the river are incomplete in this regard. The character of the underlying rocks and the general topographic relief are the main causes of this contrast. The same causes account for the presence and absence of lakes in the different regions, as well as for the intermittent or steady flow of the streams. On the area underlain by Paskapoo the streams flow the entire season, while none of the creeks running from areas of Edmonton rocks are persistent.

The directions of the main streams have not been markedly influenced by glaciation, although some modifications to be mentioned are possibly effects of glaciation. The directions of the main tributaries of the river from the west are partly controlled by structure in the west central part of the area. This feature has not been noted in earlier publications.

In general, the region is adequately drained because the precipitation is light and the available water is barely sufficient to supply the existent streams and lakes.

According to the Dominion meteorological records the average precipitation in inches over a period of years at a few points in or near this map-area is as follows:

| | | |
|---|---|---|
| Calgary | 1900-1939 | 17.30 inches |
| Didsbury | 1900-1919 | 21.58 inches |
| Olds | 1920-1940 | 17.78 inches |
| Carbon | 1903-1911 | 14.41 inches |
| Three Hills | 1921-1937 | 13.15 inches |
| Hanna | 1926-1935 | 15.58 inches |

The Red Deer river rises in the Rocky Mountains about 70 miles southwest from the town of Red Deer. This river enters the map-area near Innisfail in township 36 on the fifth meridian, and flows in a north-northeasterly direction to the mouth of Blindman river in township 39. Downstream from the town of Red Deer the river has developed four meanders which are incised into the plain to about 150 feet. The river then passes through a canyon 500 feet deep and 6 miles long, and runs east for 24 miles to Ardley. At the point where it is joined by Tail creek, which drains Buffalo lake, the river bends sharply to the south and keeps this direction, with a slight eastward trend, for 60 miles, to a point just west of Drumheller. Along this part of its course its direction appears to be influenced by the structure of the substrata. It probably follows the strike of gentle structural undulations which parallel the Rocky Mountain front ranges. Seven miles southeast of Big Valley the river changes its course for a short distance, then reassumes a parallel course as far as the mouth of Ghostpine creek. The river then takes a southeast course and keeps this direction for 25 miles, to the east limit of the area.

At its head the river appears to be antecedent in character, but just before leaving the outer limestone range of the Rocky Mountains its course is subsequent for a few miles. This break in its antecedent relation at this point was possibly caused by relatively rapid elevation of the outer range for a short period. The generally transverse direction held by the river across all the foothills and as far as the town of Red Deer is also indication of antecedent character.

At Red Deer the river meanders widely in a broad plain, the meanders being deeply incised in this plain. The presence of lake beds rather than tills in the cut-banks of the river indicates that this plain was the site of a lake 12 to 18 miles long, which probably originated in glacial time. The natural direction for the drainage from this lake would have been to the north through the basin of what is now Blackfalds lake and on into Wolf creek, a branch of Battle river. Instead of taking this outlet the river has cut a 500-foot canyon which is six miles long, to drain out to the east. The middle portion of the Red Deer river, from Ardley to Drumheller, was probably a much smaller stream prior to the cutting of the canyon. It received as its main affluent, Tail creek, which drains Buffalo lake, as well as the other well defined streams entering it lower down, from the west. A branch of this inter- or post-glacial system must have worked headward from Ardley west, until it had eroded back far enough to pirate the water of the lake referred to above. Such a stream, with steep gradient and abundant water-supply at the head, would easily cut a canyon like the one on the Red Deer in ranges 24, 25 and 26, in the soft Paskapoo rocks. The supply of water would be strong until the lake had been drained down to local base level of erosion.

The theory outlined above to explain this peculiarity of the course of the Red Deer is not yet completely substantiated, but sufficient observations have been made to suggest this as the most probable explanation.

After passing Ardley the Red Deer becomes a subsequent stream, following closely the direction of the axes of the low folds in the substrata. From Drumheller eastward control by structure apparently ceases and the river leaves the area as a consequent stream.

The Red Deer is of pre-glacial age essentially, but has been considerably deepened since that time (Figures 1 and 3). If the explanation proposed above is correct, the present river represents two streams which were distinct in pre-glacial time but became united by a west branch of the southward flowing stream during the period of final ice retreat.

The most important tributaries of the Red Deer drain the country west of that river. The Blindman river is also important but only runs over about 12 miles of this area. It runs from the high, wooded country northwest of Red Deer and is confluent with the main stream 6 miles below the town. It displays no unusual features.

Ghostpine, Threehills, Kneehills creeks and Rosebud river have their sources in the high ridge lying generally east of the Calgary-Edmonton highway. These streams run parallel with one another for most of their length. The three first named occupy broad valleys in which glacial deposits are found. This drainage system was developed prior to glaciation. Figure 2 shows a terrace of small area, the upper beds of which are of unsorted till. Kneehills creek exposes many such sections along its course. Glacial deposits partly fill the valley of the relatively insignificant Ghostpine creek. Figure 37 shows a bed of loose gravel, the "Saskatchewan Gravel" of G. M. Dawson, which he regarded as Late Pliocene in age. It lies only a few feet above the present level of Kneehills creek, and well down in the valley near Carbon. In the cases of these three streams, the lower 4 to 8 miles of the valleys appear young and are deep and steep-sided. This character was probably developed as a result of the rapid deepening of the main river during late glacial or early post-glacial time. The gorges were cut down allowing the waters of the tributaries to enter the Red Deer at grade.

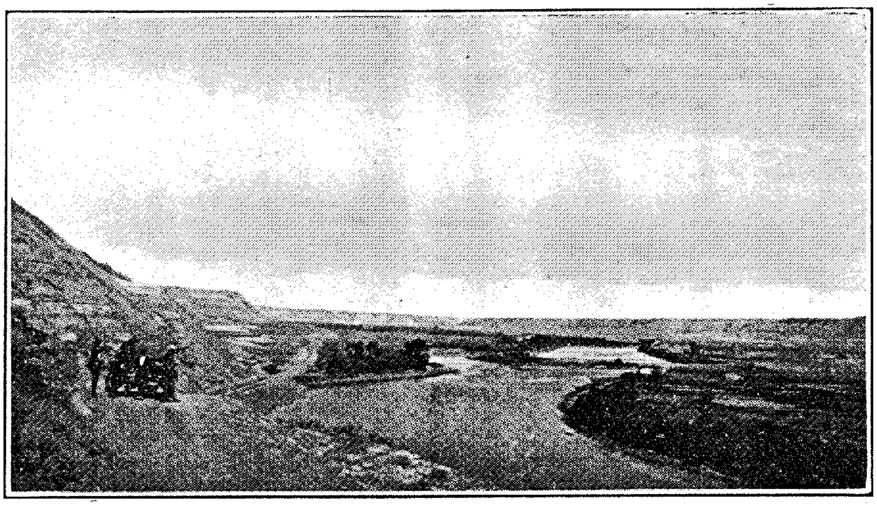

Figure 1.—Red Deer valley looking northwest towards Kneehills creek from Sec. 18, Tp. 29, R.20. The valley is pre-glacial in age.

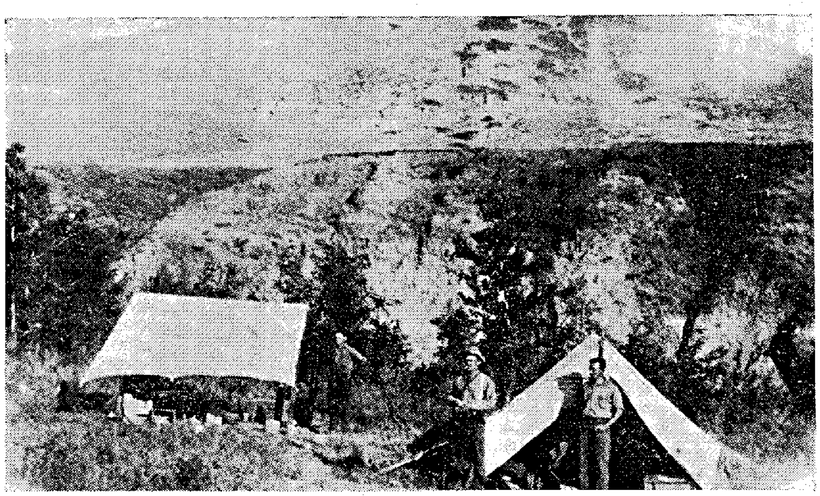

Figure 2.—Kneehills valley at Hesketh, 8 miles below Carbon. Note small terrace covered by glacial deposits, indicating the pre-glacial age of the valley.

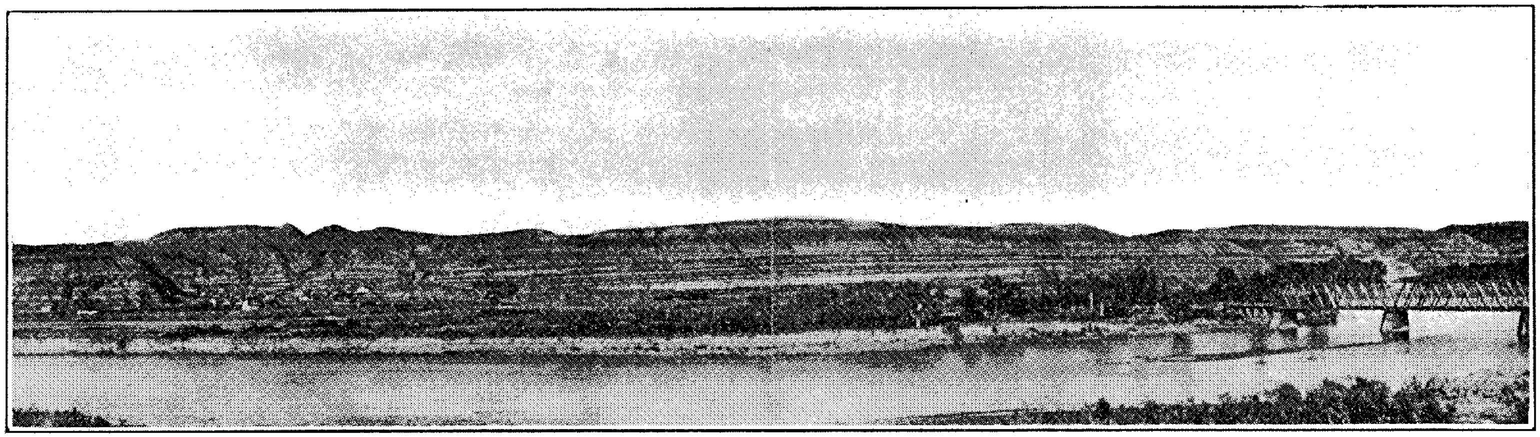

Figure 3.—Red Deer valley looking northeast from Rosedale station. Lense of white bentonitic sandstone above seam No. 1 shows in centre.

Rosebud river in its upper part closely resembles the other streams. In the region just east of Irricana, however, it flows through a large, flat area that has a cover of lacustrine beds. On leaving this section, which is about 12 miles long, the river enters a freshly cut valley which soon develops into a narrow canyon and continues as such to the mouth of the river at Rosedale (Figure 4). This portion of the valley of Rosebud river is probably post-glacial.

Tributary creeks entering the Red Deer from the east are Tail creek, Big Valley creek, Michichi creek and Willow creek. None of these show unusual features except the first named. It has a wide and relatively mature valley which suggests its pre-glacial age. It forms the outlet of Buffalo lake.

Big Valley creek runs in a wide flat valley for 20 miles of its course with a gradient of only 5.5 feet to the mile. In its last four miles it falls 300 feet. The other two streams are of intermittent character and are of the normal dendritic type.

Most of the large lakes lie on Edmonton beds and are of the interior drainage types, each lake representing the local base level of erosion. They vary considerably in size from season to season and are all shallow. The largest one, Buffalo lake, which receives considerable spring water, has a maximum depth of only 17 feet. More commonly the depths range from 2 to 5 feet.

Some of the larger lakes occupy sites which were apparently of glacial-gouging origin in part. Ewing lake is an example. Figure 5 is a view of the north end of this lake. Its greatest depth of water is 15 feet.

Lakes on the Paskapoo rocks are generally persistent, spring-fed bodies that are occupying depressions made by glacial ice, or valleys dammed by glacial debris. These lakes are also undrained, having the general characters of large ponds. Small lakes are numerous in the high country on the west of the area. Between Red Deer and Innisfail is a group designated as sloughs. These lakes are residuals of a once much larger body. The same explanation applies to each of Delburne and Mikwan lakes, south of Ardley.

*Gradients of Streams.*

Red Deer river keeps a steep gradient almost as far east as the town of Red Deer. In stretches a few miles west of Red Deer the gradient is 15 feet to the mile. From the latter town as far as Tail creek, the average is 5.5 feet per mile, and from this point to the mouth of Rosebud river the gradient averages 3 feet per mile. The rate of flow over this portion is about two and one-quarter miles per hour, and the water depth averages 3 feet. East of Drumheller the gradient is somewhat less than 3 feet per mile and the river has many sluggish reaches.

The tributaries entering the Red Deer from the east have sharper gradients at their heads and near their mouths, and each has intermediate portions of very low gradient. Near the mouths the gradient is as high as 30 feet to the mile while in the intermediate stretches the average is about 10 feet.

Big Valley creek has a gradient of 5.5 feet per mile over 80 percent of its course, then plunges to the Red Deer level in its last four miles with a gradient of over 80 feet per mile.

Michichi and Willow creeks have steep gradients which are relatively uniform from source to mouth.

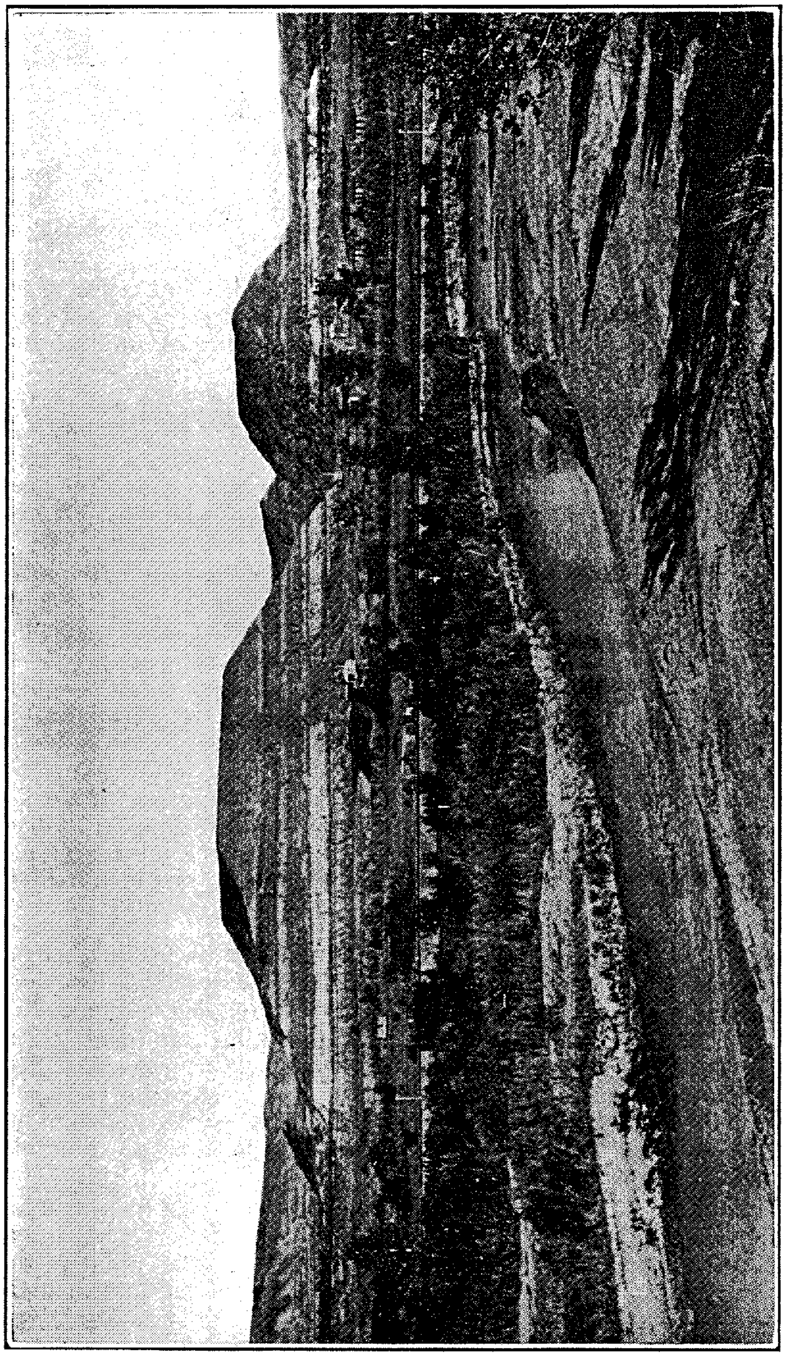

Figure 4.—Typical buttes near mouth of Rosebud river, looking east, showing characteristic bed of white bentonitic sandstone.

*Glacial Effects.*

Glaciation affected the physiographical development of this map-area in several ways. Some areas have been planed by moving ice sheets, and other areas have received deposits that filled depressions. Drainage ways were blocked and temporary lakes created. In some places long and irregular hollows were gouged out and lakes were later formed. The general surface received a veneer of till and other types of glacial sediment which has resulted in making the soil throughout the area more uniform than it otherwise would be.

The extensive flat areas east of the Red Deer river and south of Battle river were smoothed and planed by glacial action. The lower hills and ridges were also rounded or reduced. There is evidence that the pre-existing valleys had their irregular slopes smoothed by the passage of the ice. Figure 6 shows a typical example of such action on the west bank of the Red Deer west of Munson. In the middle distance may be seen a sloping, planed surface. This surface bears glacial deposits down to within 70 feet of the present river level. In other places the ice gouged and plucked the surface rocks and left irregularly rounded hills known as "rock drumloids". Figure 7 shows such a surface formed on Paskapoo strata in the south end of Hand Hills, south of Handhills lake. The valley of Ghostpine creek in township 30 shows evidence of having been rounded and otherwise modified by glacial erosion.

The pre-glacial valley of the Red Deer below Willow creek was obstructed by ice which left deposits that have been cut through by the river since the disappearance of the ice from this area. Other tributary streams, especially Kneehills creek and Rosebud river, cut through glacial deposits which partly filled their valleys at the close of glacial time.

The glacial deposits extensively distributed in this map-area occur in the form of terminal or end moraines consisting of unsorted till and boulder clay, as partly resorted material and as well sorted gravel, sand, silt or clay transported by water and deposited in glacio-lacustrine basins formed at or near the front of the ice. These deposits occur as irregular hills or undulating ridges, often quite thick, or as ground moraine, usually thin or now represented by scattered glacial boulders or pebbles. It is not always possible to distinguish the undisturbed moraine from the sorted or reworked glacial material.

The glacial deposits in this map-area have been derived from the Keewatin or Laurentide ice sheets that originated in the vicinity of Hudson Bay. The detrital material transported from the north-east by the Keewatin glaciers consists largely of igneous and metamorphic rocks such as granite, gabbro, gneiss, schist, argillite, greenstone, and locally of harder sandstone and shale from the younger rock formations under the plains over which the ice moved.

There are three major morainal areas in this map-area. The largest belt of moraine occurs in the southeastern corner of the Rosebud sheet, ranges 14 to 21, and extends north around Wintering Hills and Hand Hills. It is well developed from Morrin, northward to Rowley and across the Red Deer sheet to beyond Buffalo lake which is at the north boundary of the map-area. A second morainal ridge extends from the vicinity of Swalwell northwards to the Red Deer river in ranges 24 to 26, and includes the highland between

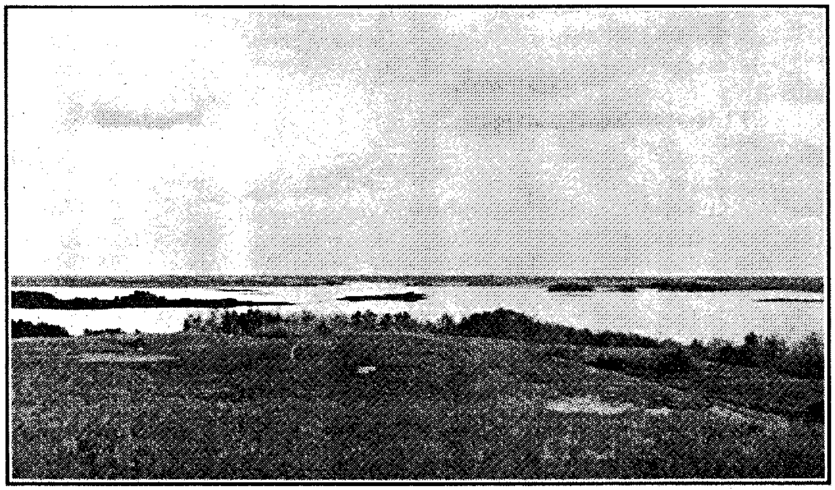

Figure 5.—North end of Ewing lake northwest of Big Valley. A typical lake occupying a depression left by the ice.

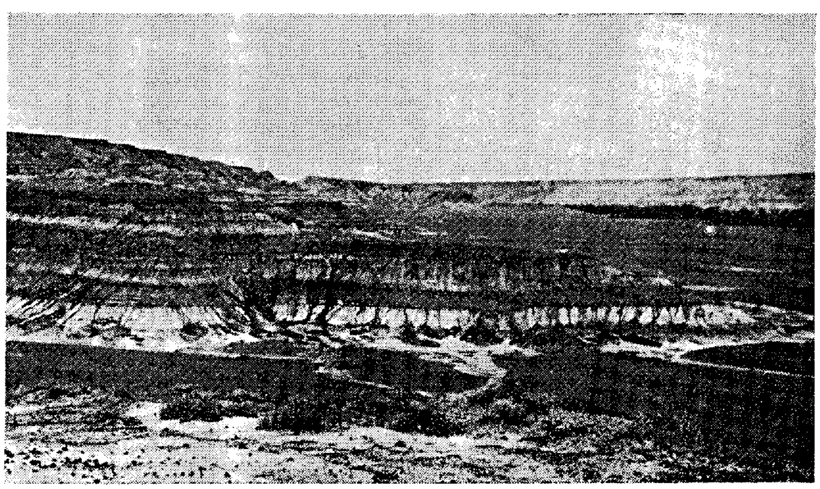

Figure 6.—The west bank of the Red Deer river west of the town of Munson, showing glacially planed slope in middle background, which indicates preglacial age of the valley at this point.

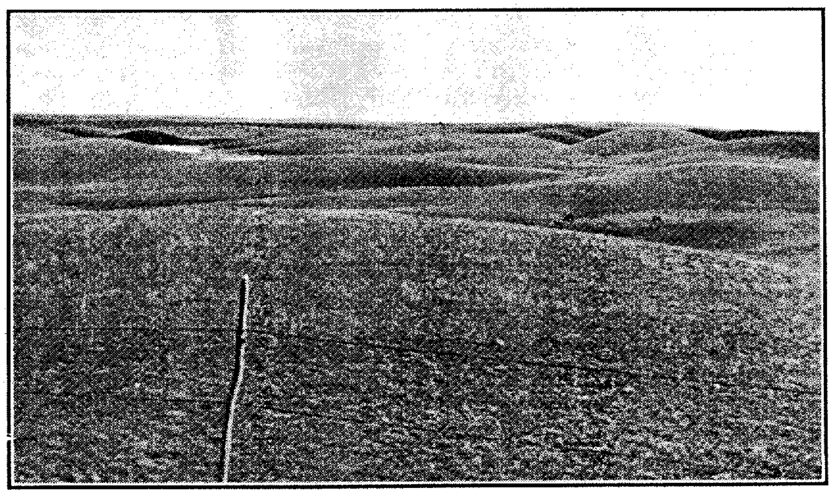

Figure 7.—Rock drumloids, upper limit of glaciation near Handhills lake.

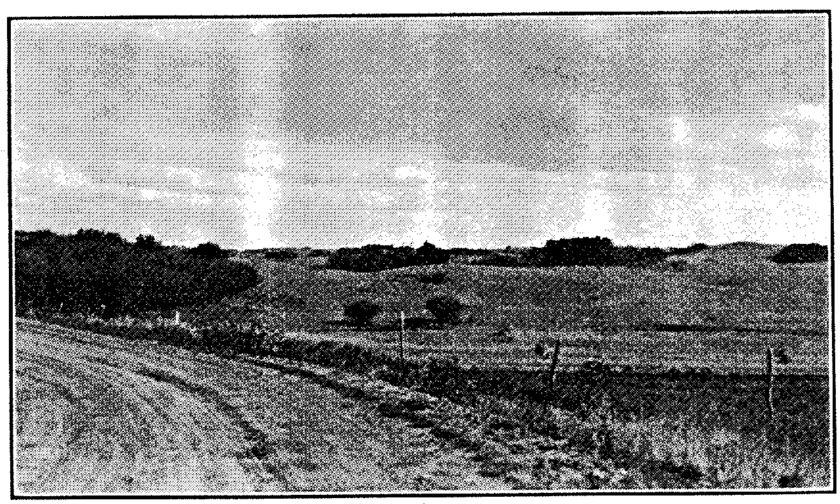

Figure 8.—Morainal hills west of Clive.

Lacombe and Clive. Figure 8 shows the typical character of this moraine west of Clive. A third morainal belt extends along the west side of the Rosebud sheet from range 26 to the fifth meridian, and north to township 34 south of Innisfail within the Red Deer sheet. These glacial deposits in the vicinity of the fifth meridian are derived in part from the Keewatin ice, but some of the material is of mountain origin and represents glacial debris transported from the foothills to the west. The morainal belt on the eastern side of the map-area contains material derived from the Keewatin ice sheets. (More recently the glacial deposits in this area have been recognized as of Early Wisconsin age.)

When the drainage down the pre-glacial Red Deer valley below Willow creek was obstructed by ice between Hand Hills and Wintring Hills, a large lake was formed to the north. The extent of this lake is defined by the distribution of the glacio-lacustrine deposits derived from the moraines bordering this basin. These lake deposits are widely distributed in the vicinity of Drumheller and extend on both sides of the Red Deer valley from Willow creek to about township 33, near the south boundary of the Red Deer sheet. This glacial lake also extended to the west up Rosebud river and Serviceberry creek to range 23.

Further field investigations on the unconsolidated deposits in this map-area will give additional data on the effect of glaciation in relation to post-glacial drainage and deposition.

## CHAPTER III.

# GENERAL GEOLOGY

### DESCRIPTION OF FORMATIONS

The geological formations that occur at the surface or immediately below the unconsolidated deposits within the Rosebud and Red Deer sheets are Upper Cretaceous and Tertiary in age. On the accompanying geological maps (Nos. 8 and 9), four geological formations are shown. The general characteristics of each formation are given below and a detailed description of each of the formations is included in Part Two. Two of the formations, Bearpaw and Edmonton, are of Upper Cretaceous age, and two, Paskapoo and Oligocene (?) conglomerate, are of Tertiary age. The Quaternary age is represented by the unconsolidated deposits of glacial and post-glacial origin. Two of the formations, the Edmonton and the Paskapoo, represent the rocks beneath unconsolidated material throughout about 95 percent of the map-area.

The rocks in this map-area, in order of age, from the youngest to the oldest, are as follows:

TABLE I.
**Table of Formations**

| Period | Formation | Character of Rock |
|---|---|---|
| Quaternary | Recent | Gravel, sand and clay of river, lake and residual origins. |
| | Pleistocene | Till, boulder clay of glacial origin. |
| Later Tertiary | Oligocene(?) | Conglomerate, loosely cemented with sand, clay and marl. |
| Early Tertiary (Eocene) | Paskapoo | Sandstone, soft, grey, clayey and calcareous, and clay shales. |
| Upper Cretaceous | Edmonton | Sandstone, shale, coal seams and bentonitic beds. Fresh and brackish water origin. |
| | Bearpaw | Shale, dark colored to grey, with sandy beds, some bentonitic. Marine origin. |

*Bearpaw.*

The Bearpaw is the oldest formation designated on the accompanying maps. Rocks of this age are exposed only in two small areas, one in the extreme southeast corner of the Rosebud sheet, along the Red Deer valley, and the other area in the extreme northeast corner of the Red Deer sheet along the Battle river.

The name Bearpaw shale was given by Stanton and Hatcher[1] to a series of beds exposed in the Bearpaw mountains in northern Montana. The Bearpaw formation has not been adequately defined in Alberta. G. M. Dawson in 1875 referred to this series as the "Pierre". J. B. Tyrrell in 1887 and R. G. McConnell in 1890 used "Pierre" and "Pierre-Foxhill" to designate this formation. In 1917 D. B. Dowling[2] made use of the name Bearpaw for the extension of this formation into southern Alberta from northern Montana. He suggests that these sandy shales in the upper part of the series probably are the equivalent of the so-called "Foxhill". The underlying shales in the lower part of the series are designated "Upper Pierre". Dowling observes that the term "Pierre" as used by Dawson included not only the dark marine shales in the Bearpaw formation, but also the dark marine shales much older than the Bearpaw and towards the base of the Belly River series. Dowling assigned the name "Pakowki" to the "lower dark shales" of Dawson's classification.

The Bearpaw consists chiefly of dark grey clay shales and sandy shales of marine deposition and contains the typical Upper Cretaceous marine invertebrate fauna. There are several thin beds of light grey bentonite interstratified with the shales, particularly in the lower part of the formation. In some areas there are numerous limestone concretions. Some of the shale bands and the concretions contain marine fossils of which the cephalopods, such as *Baculites* and *Placenticeras,* are common. The former are straight shelled and the latter are coiled shelled cephalopods. The largest *Placenticeras* observed by the writer in the Rosebud sheet measured forty-two inches in diameter. These fossils are usually coated with an iridescent layer of lime carbonate known as "mother-of-pearl".

This formation along the Red Deer valley is about 550 feet thick, but it thins to the west and to the north.

In this report the Bearpaw is defined as the dark, argillaceous, marine beds which overlie the dinosaur-bearing Pale Beds of the Belly River series, and underlie the massive fresh to brackish water sandstones of the Edmonton formation. Both lower and upper limits are reasonably definite and can usually be traced when the examination and mapping are done in sufficient detail.

*Edmonton.*

The Edmonton formation represents the uppermost Cretaceous and conformably overlies the Bearpaw. In 1886 J. B. Tyrrell designated this formation as the "Edmonton Series". The term "Edmonton" was first used by Selwyn in referring to the strata containing coal seams in the general vicinity of the present city of Edmonton [3]. Later workers extended the use of this name into districts to the north and south. The Edmonton formation was defined and described by Tyrrell who mapped the areal distribution of these beds in parts of central Alberta.

The Edmonton formation consists largely of sediments deposited under fresh and brackish water conditions, in shallow freshwater basins, or in estuaries and deltas, or in littoral zones along the border of an advancing or retreating sea. Some of the members in this formation were deposited as mud flats and along flood plains that were exposed above the water level for short spaces of time, possibly seasonal. Some of the beds, particularly those containing carbonaceous material, originated in enclosed basins or swamps. Crossbedding, current marks, lensy structure, nodular masses, ironstone bands, erosion during deposition, younger beds enclosing fragments of older beds and especially those immediately under, are a few of the characteristics that prove the continental mode of deposition of the sediments of the Edmonton formation (Figures 9 and 10).

The composition of the strata in this formation varies greatly, both laterally and vertically. The Edmonton formation in this map-area consists of fine-grained sandstones, highly calcareous sandstones, sandy shales, bentonitic sandstones and shales, bentonite, ironstone bands, carbonaceaus shales and coal. Bentonite is the pre-

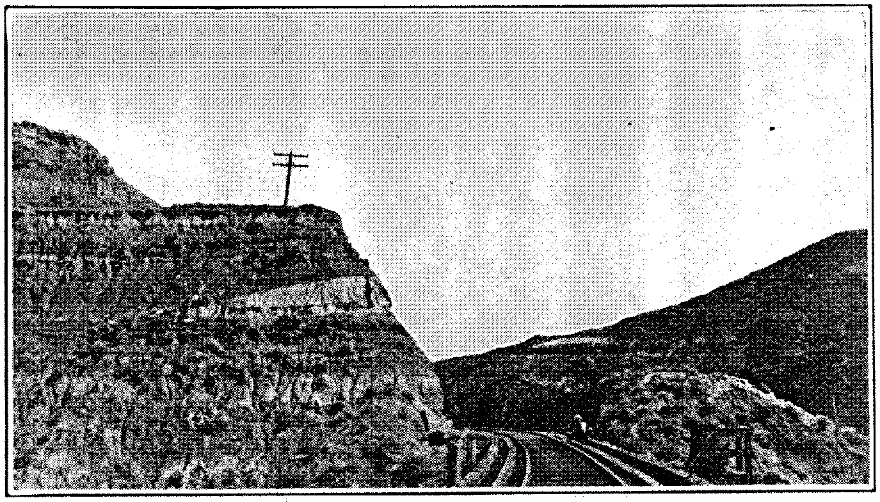

Figure 9.—Lense of white bentonitic sandstone on top of seam No. 6 along Rosebud river south of Wayne. Typical structure in the Edmonton formation.

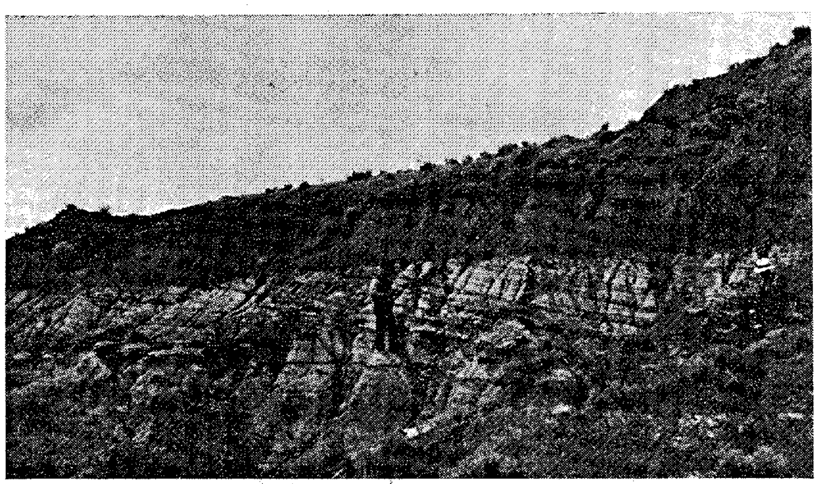

Figure 10.—Truncated foreset bedding in the Lower Edmonton member near Drumheller.

Figure 11.—Bentonitic clay interstratified with sand and silt, between coal seams Nos. 6 and 7, near Drumheller.

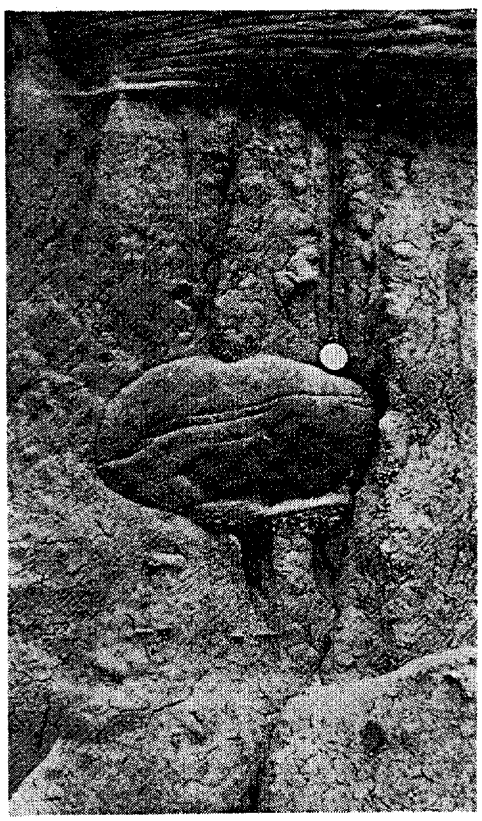

Figure 12.—Contact between indurated sand-sandstones above and soft sandstone with ball-like nodules and mud cracks on a vertical surface, in Lower Edmonton near Drumheller.

vailing constituent throughout the whole series of beds. There are thin beds of pure bentonite from a fraction of an inch up to a few feet in thickness, and many beds are classed as bentonitic clays, shales and sandstones. (Figure 11).

All the sandstone members contain more or less bentonite. The bentonitic sandstones are white on the eroded surface and give a pronounced banded appearance to the escarpments (Figures 4 and 6). Other hard bands in the bentonitic sandstone weather into flattened or spherical nodules that are more resistant to erosion (Figures 12 and 13). Many specimens of fossilized plant fragments including *Cunninghamites* sp., and silicified fruit have been collected from various horizons in the Edmonton formation in the vicinity of Drumheller.

This formation also includes some hard flaggy sandstones that occur in well-defined horizons. On account of their resistance to erosion these hard thin sandstone layers form ledges and cap the mesas, buttes and the numerous irregular outliers in the badlands along the valley of the Red Deer river (Figure 4).

Bands of ironstone and clay ironstone nodules are common throughout the Edmonton formation. These bands are seldom more than four inches in thickness and consist of hard irregularly rounded or flattened nodules that are red, brown or black on the weathered surface depending upon the iron content in the nodules. The surface of the nodule is frequently marked into small irregular polygons and they are known as septarian nodules. The markings are due to contraction cracks formed in the ferruginous muds during consolidation.

The Edmonton formation is the surface formation throughout much of the eastern half of the Rosebud and Red Deer sheets, east of range 23. Almost continuous outcrops extend along the slopes of the valley of the Red Deer river and along the slopes of the tributary valleys. The strata are nearly flat-lying and erosion has developed badland topography. The badlands are best developed along the gorge-like valley of Red Deer river from Ardley, downstream to Dorothy in township 25. This area is often referred to as the upper Red Deer or Drumheller badlands. Dinosaur bones occur abundantly in the area.

*Paskapoo and Younger Tertiary.*

In this map-area the Tertiary is represented by the Paskapoo of early Eocene age and the Oligocene (?) of later Tertiary age. The name "Paskapoo" is the Indian word for Blindman. The formation was so named by J. B. Tyrrell because the strata in this series are well exposed along the Blindman river which enters the Red Deer river about six miles north of the town of Red Deer.

The Paskapoo consists chiefly of soft, grey, clayey sandstones, soft shales and clays slightly indurated. In the lower part of the formation there is a coarse, more or less uncemented sandstone weathering to buff colour and of uniform character over a large area. The formation is of freshwater deposition and contains freshwater fossil shells, chiefly mollusks.

The Paskapoo formation has a wide distribution and occurs as the surface formation in the western half of Rosebud and Red Deer sheets (Maps 8 and 9). This formation occupies the eastern side of a trough-like depression known as the Alberta syncline in which the

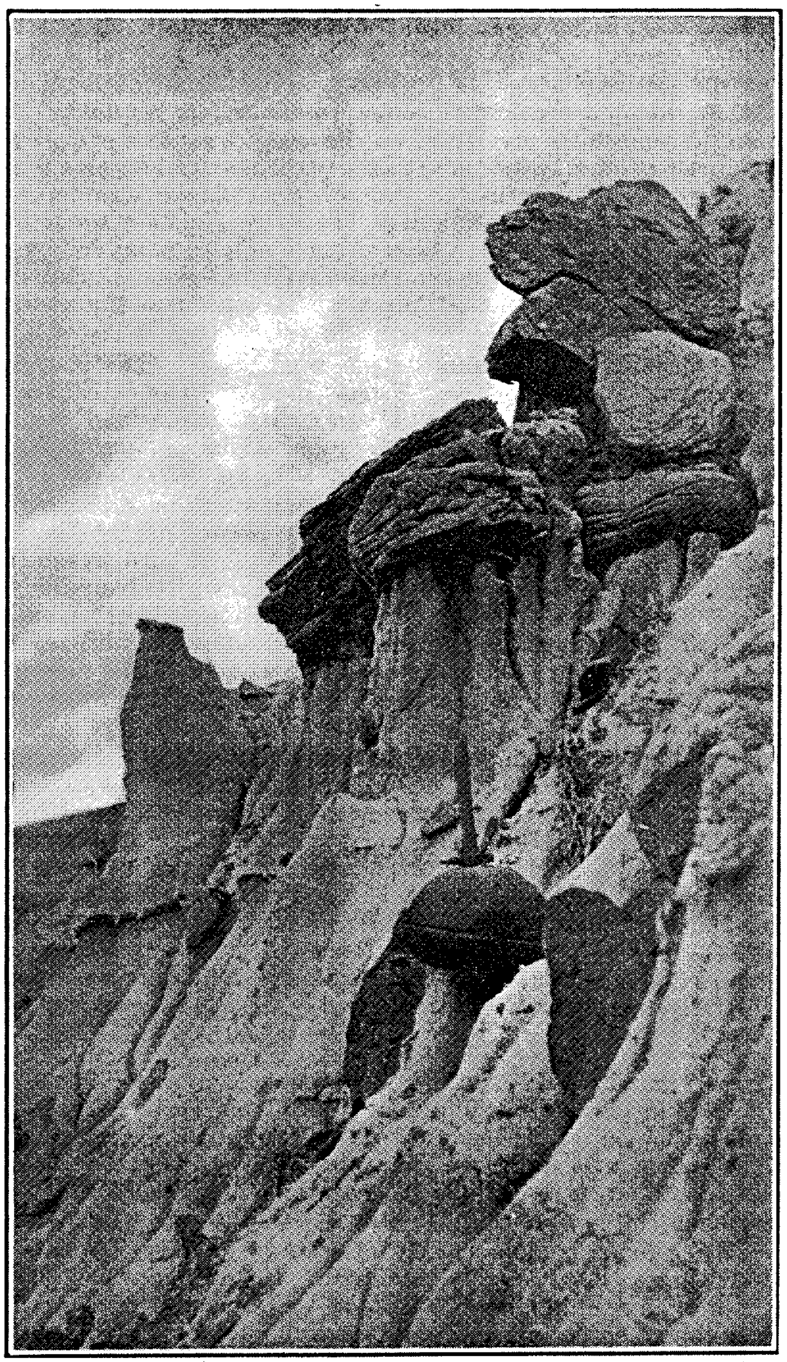

Figure 13.—Spherical and irregular nodules in bentonitic sandstone between No. 7 and No. 8 coal seams, south of Newcastle Junior mine, Drumheller.

older rock formations come to the surface both to the east and to the west of this band of Paskapoo which is about sixty miles wide. This rock formation also caps Wintering Hills and Hand Hills at the eastern side of the Rosebud sheet. A narrow band of Paskapoo occurs on the east side of the Red Deer valley from Munson north to township 38.

The Paskapoo was deposited on a low and sinking surface and apparently represents a combination of sub-areal floodplain and shallow lake conditions. The earlier interpretation is that this formation was deposited in a vast lake that was in effect a land-locked and freshened Cretaceous sea. The formation is known to become much thicker just west of the area discussed here. Within this area at least 800 feet of Paskapoo is present in the canyon between Red Deer and Ardley.

The Paskapoo lies disconformably on the Edmonton and is overlain disconformably by the Oligocene (?). The exact age is not definitely proven by the presence of Oligocene mammals, but its stratigraphic position and close lithological similarity to the Cypress Hills Oligocene is a safe basis for presuming the correlation. The presence of thick white marls and chatter-marked, cobble conglomerate at both points indicates a similar and likely synchronous origin. The formation is nearly 300 feet thick on the top of the Hand Hills. This remnant is all that remains of the Oligocene (?) in this area.

The youngest deposits in the map-area are of glacial and recent ages. The rocks of these formations are of several kinds, including boulder tills, gravel beds, lacustrine strata and local loess accumulations. Glacial beds occur over most of the area. A small portion of the top of Hand Hills probably received no glacial deposits. There has not been an extended study made of the glacial deposits since the surveys of Dawson and McConnell in 1882-85. Their work has served well for a broad understanding of this formation.

*Kneehills Tuff.*

In 1924 Sanderson discovered a tuff bed in the Edmonton formation on the Red Deer river east of the town of Ardley. He traced the outcrop of this bed down the valley of the Red Deer river to a point west of Morrin in township 31. A volcanic ash bed in this same horizon was examined at many other points where the beds of this horizon form outcrops as far south as the Wintering Hills in township 25. This ash bed was located near Big Valley, on a branch of Threehills creek six miles north of Carbon (Figure 31), in the vicinity of Carbon on Kneehills creek, at the head of Horseshoe canyon (Figure 14), close to the Calgary-Drumheller highway, at Hand Hills and in Wintering Hills. To this volcanic ash bed, Sanderson designated the name *Kneehills tuff*. This tuff where observed is seldom over 8 inches in thickness but it is a most useful marker horizon in correlating the coal seams in the Edmonton formation. In the outcrops east of Ardley, the tuff bed occurs about 220 to 240 feet below the Ardley coal seam (No. 14), and about 40 to 70 feet above No. 12 coal seam (Plate I). These intervals are not uniform throughout the area.

Fuller details on the distribution, character, lithology and composition of this volcanic ash bed are given by Sanderson in Part Two of this report. (Since this bed was discovered by Sanderson in the Red Deer valley, he has examined several occurrences of volcanic ash in the Upper Cretaceous strata in Alberta[4].)

There is a wide distribution, both vertically and laterally, of bentonite in the Upper Cretaceous strata in Alberta, and particularly in the Edmonton formation. It is the opinion of several investigators that bentonite is derived from the alteration of volcanic ash. If this is the origin of bentonite in Alberta, it is apparent that there was much volcanic ash intermixed with other sediments during much of Upper Cretaceous time in Alberta. This possible origin of bentonite has been discussed more fully in Part Two of this report.

## Structure

*General.*

The entire map-area lies on the eastern flank of the Alberta syncline. The angle of dip is very slight as far west as the Red Deer river where it appears to incline more steeply. The detailed cross-sections on Plate I show this feature, especially the four shorter sections. Along the east side of the area the dips appear to be nearly flat. In the central third of the area the westerly dip is broken by very gentle flexures of the strata. The undulation west of Big Valley has a width of about 12 miles and the closure appears to be less than 200 feet. A second undulation, shown in section on Plate I (D-D′) between Rowley and Carbon is only slightly more noticeable. The largest dips in the whole area are to be found between Brookesley Bridge and Red Deer. The Alberta syncline apparently deepens rapidly in this region. The data for plotting these gentle dips are obtained from elevations taken on coal seams and other known horizons.

There is considerable difficulty in tracing the local structure at any point because of the lack of outcrops and the cover of glacial deposits.

Mention has been made of the parallelism of the streams west of the Red Deer river. There have been no detailed traverses made to prove conclusively that the streams here are all influenced by the direction of folding. This relation was observed between the river and Ghostpine creek, where local variations in level measured on the coal seams showed depression toward the stream valley. For most of the area west of the Ghostpine, it is assumed that the same structural relations cause the remarkable parallelism in the stream courses.

In some of the coal mines troublesome irregularities in the strata are encountered. These are known as "local rolls", and to some miners as "faults". In following the seams across one of these rolls the roof and pavement generally rise above the normal level to as much as 10 feet and then gradually fall back to normal again. Some of these "humps" are only a few feet in width and others 100 feet or more. It is noticeable that these rolls are never downward, but all convex upward. This suggests that the local rolls have resulted from uneven settling of the beds during final compaction and lithification.

There is no true faulting in the entire area. Faults have been reported but in all cases that have come to our attention these have proven to be surficial slumping. None of the rocks of the formations have great strength, and they tend to slide wherever the angle is great or under-cutting by streams has rendered the slope unstable for strata of this type (Figure 15).

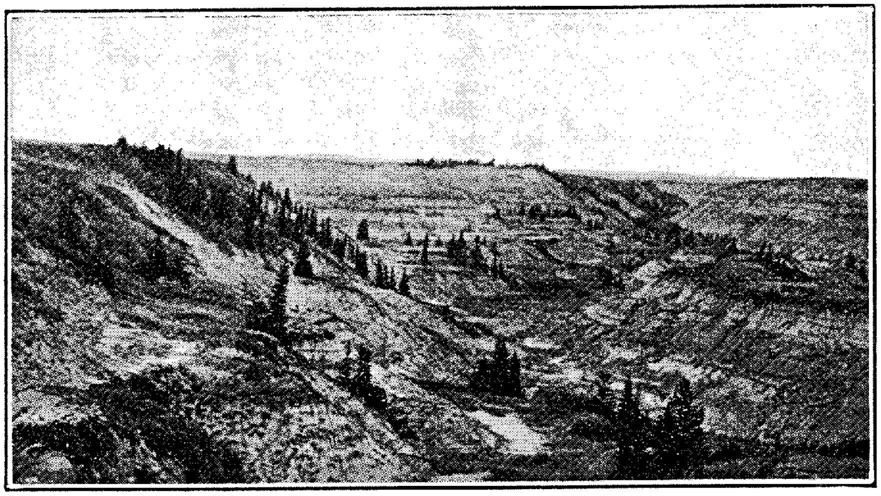

Figure 14.—Typical coulee from upland south of Kneehills creek. Shows type of vegetation in badlands and shows volcanic ash bed (Kneehills tuff) in left bank.

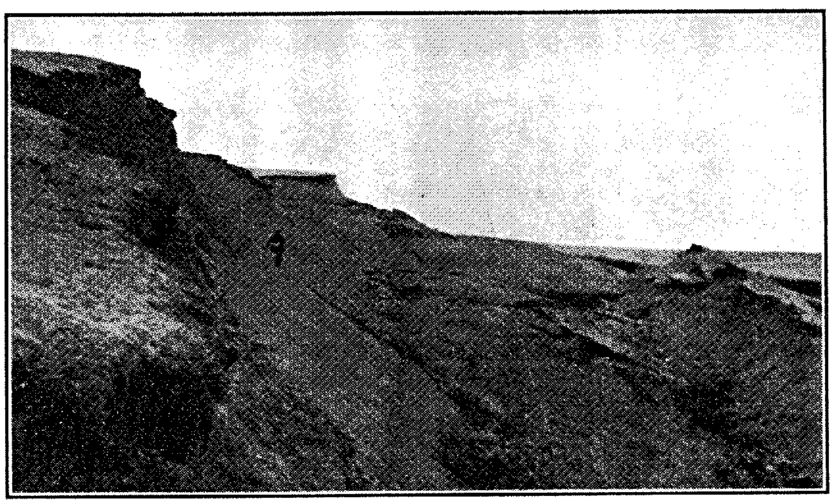

Figure 15.—A large recent slump in Paskapoo rocks on west flank of Hand Hills.

*Discussion of Disconformity.*

The main disconformity in this area separates the uppermost Cretaceous or Edmonton formation from the basal Tertiary or Paskapoo formation. The earlier workers separated the two formations at an arbitrarily chosen line which is the top of a coal seam in the Ardley region. In Alberta the formations were named and subdivided at a time when it was believed that there was continuous deposition from Cretaceous into Tertiary time, hence it seemed essential to allot certain strata to the Laramie or transition group of that time. This situation was the more aggravated because of the difficulty of securing natural lines of division between the formations which are somewhat similar in lithology and without diagnostic fossils in the critical zones. In dealing with stratigraphic problems of this kind greater importance must be accorded to small and seemingly unimportant criteria which are of physical rather than organic kind. This kind of evidence, while somewhat less dependable than comparison of workable faunas, can be relied upon when two or more lines of physical criteria fall in agreement.

For the reason that they had to cover vast areas and were obliged to generalize considerably, the earlier workers overlooked certain good, though obscure, physical evidence and gave interpretations of the stratigraphic sequence which can be revised in the light of more detailed observation and more critical analysis of the physical data.

The disconformity alluded to above is based more on interpretation of the physical evidence than on faunal grounds. While the vertebrate and invertebrate faunas in the two formations are different, they cannot be used to delimit either formation for fossils are exceedingly rare in the upper Edmonton and in the lower Paskapoo. The plants of both formations are similar and are not yet sufficiently well known to be of use.

The physical criteria that proved to be of use in separating the formations are the following:

(a) Wide distribution and uniformity of characteristic sedimentary zones in the Edmonton, e.g., coal horizons, white sediments, volcanic tuffs, etc. The absence and replacement of these zones where they should normally occur was critically noted.

(b) The presence of bentonite in abundance in the Edmonton rocks and its almost total absence as matrix material in the Paskapoo rocks. No important exceptions to this feature are known.

(c) The minutely and locally conglomeratic nature of the basal Paskapoo, or its highly oxidized condition at the contact with the Edmonton.

(d) The lower 300 feet of the Paskapoo is predominantly composed of coarse sand of quartzose character. Small, local exceptions occur. The Edmonton is uniformly fine grained and the sands all of feldspathic nature.

(e) The Edmonton rocks weather in rounded slopes, the Paskapoo (coarse basal sandstone) in sheer cliffs.

(f) The colour and the degree of induration or lithification of the rocks of the formations differ to a recognizable degree. This criterion, however, is the least dependable.

The general difference in the appearance of the formations is very clear in the neighbourhood of Ardley and on the north bank of the Red Deer, eight miles west of Ardley in section 1, township 38, range 25. Whitish Edmonton beds are seen outcropping near water level and the Paskapoo forms the sheer bank in the background. The latter strata have a rich buff color in contrast to the light coloured Edmonton. About one mile west of this point thin lenses of conglomerate, composed of single layers of pebbles and cobbles of quartzite, dioritic gneiss and ironstone, were found in the Paskapoo a few feet above the Edmonton. On the south bank of the river due west of Ardley, the contact lies 120 feet above the Ardley (No. 14) coal seam.

In the following list are given the localities where the disconformity is most apparent, as well as the evidence observed at each place.

TABLE 2.

**Field Data on Disconformity.**

| Location on Map Sec. | Tp. | R. | General Location | Observed Stratigraphic Features |
|---|---|---|---|---|
| 2 | 38 | 25 | Red Deer river 10 mi. west of Ardley | Coarse cross-bedded Paskapoo with much red iron oxide and conglomerate detritus, up to 4 inches diam. resting on white Edmonton beds, above the Ardley seam. |
| 10 | 38 | 24 | Red Reer river 6 mi. west of Ardley | Coarse, buff, Paskapoo lying directly above the Ardley seam. |
| 4 | 38 | 24 | Red Deer river 6 mi. west of Ardley | 40 feet of Edmonton beds with freshwater shells, above coal seam. On opposite side of stream Paskapoo coarse ss. lies as low as base of this section. |
| 17 | 38 | 23 | River bank ¾ mi. west of Ardley | Massive Paskapoo ss. lies 120 feet above Ardley seam. Freshwater beds of Edmonton aspect intervene. Paskapoo lies much lower at localities above. |
| 36 | 36 | 22 | River bank 3 mi. east of Trenville P.O. | Channel deposit of coarse buff sandstone (Pask.?) resting on bentonitic Edmonton 100 feet below Ardley seam. |
| 13 | 36 | 22 | River bank 7 mi. east of Mikwan lake | Buff Pask. ss. 20 feet above Ardley seam rests on 18-inch bed of ochrous sh. with pulmonate gastropods poorly preserved. |
| 22 | 35 | 21 | East bank of river due west of Big Valley | Ardley seam overlain by 15 feet of coarse buff ss., then 18 feet of varied lake clays, then more Pask. ss.<br>Strong springs emerge at contact here. Evidence here of removal of Ardley seam, in Pre-Paskapoo time. |
| 21 | 34 | 21 | Mouth of Big Valley creek | Erosion to base of seam No. 12 (Thompson seam). Overlain by coarse non-bentontic consolidated ss. |
| 24 | 34 | 22 | Opp. mouth of Big Valley creek | Contact of Paskapoo on Edmonton visible for over a mile; big seam apparently removed in one or more places. |
| 17 | 29 | 23 | 2 mi. west of Carbon | 100 foot section of massive, buff ss. with springs at base. Base of section is at level of seam No. 12. |
| 9 | 30 | 21 | 1 mi. SW. of Beleriot Ferry on Red Deer | Massive Paskapoo ss. lies on marine fossil horizon. One of lowest points noted for Paskapoo. |
| 9 | 33 | 23 | 1 mi. east of Trochu | Contact of Paskapoo, just above Ardley seam. Paskapoo here has pebble conglomerate, is very coarse and of deep buff colour. |
| 18 | 30 | 22 | On Threehills creek, 6 mi. NE. of Carbon. | Paskapoo in 15 foot section of typical ss. overlies Carbon seam (No. 11). It is coarse and oxidized. Here replaces volcanic ash and seam No. 12, the Thompson seam. |

TABLE 2—Continued

| Location on Map Sec. | Tp. | R. | General Location | Observed Stratigraphic Features |
|---|---|---|---|---|
| 18 | 30 | 22 | Same locality, ½ mile south in LSD 10 | Massive Paskapoo here rests above the volcanic ash. Contact here is 70 feet above last locality. |
| 4 | 29 | 22 | On ridge 4 mi. SE. of Hesketh | Paskapoo ss. outcrops 30 feet above volcanic ash beds. Erosion here isolated a small mound with volcanic tuff on it. A conglomeratic layer made up of tuff fragments, shell fragments and ironstone seen below Paskapoo. |
| 14 | 29 | 22 | 1½ mi. west of Hesketh | Thin remnant of soft Paskapoo? seen at top of section near highway, does not extend laterally. Erosion here is below the marine horizon (see Fig. 22). |
| 8 | 28 | 22 | Near school on highway | Paskapoo shown in road cuts and in adjacent coulee where springs emerge from below it. General surface near here is in Edmonton. |
| 16 | 28 | 22 | North of road divergence on Calgary highway | Low bluffs of Paskapoo exposed with Edmonton forming general valley floor. Pre-Paskapoo erosion down to volcanic horizon. Figures 22 and 32. |
| 24 | 29 | 18 | 1½ mi. north of Rainbow P.O. | Massive Paskapoo seen lying just above volcanic ash bed. |
| 20 | 26 | 21 | 5 mi. south of RosebudCreek P.O., Medloski mine | Massive Paskapoo beds appear 40-60 feet above the volcanic ash horizon on flank of Wintering Hills. |

The localities mentioned above are points where the relations between the two formations are to be clearly seen. Many more doubtful instances were observed but these are not referred to here. At all of the above places the general differences in the two formations, as listed in the foregoing paragraphs, are manifested.

Indications of this unconformity are very apparent south of this area, along the Bow river in townships 19 and 20, range 19, where the Paskapoo contact is drawn within 2 miles of the Edmonton-Bearpaw contact. This narrowing of the Edmonton outcrop indicates that the Edmonton has been greatly thinned prior to Paskapoo deposition.

The geological cross-sections (Plate I) indicate the extent of erosion on the Edmonton previous to Paskapoo deposition. From this data it is apparent that as much as 450 feet of Edmonton, below the Ardley seam, is removed in some places. One of the lowest places is along the Red Deer just north of the mouth of Threehills creek. The general horizon of the contact from Carbon south and southeast is about the volcanic tuff horizon. The Pre-Paskapoo surface must have been uneven with low valley and hill topography.

## Chapter IV.

# ECONOMIC GEOLOGY

## Coal

*Introduction.*

Coal is the most widely distributed and the most important mineral deposit in the Rosebud and Red Deer map-area. The coal seams in this map-area occur in the Edmonton formation which is uppermost Cretaceous in age and is the youngest of the three important coal-bearing horizons in Alberta, all of Cretaceous age. Of the other two coal-bearing horizons, the Belly River is middle Upper Cretaceous in age and the Kootenay horizon is of Lower Cretaceous age.

The Edmonton formation underlies almost the entire area covered by the Rosebud and Red Deer sheets, except in those areas where the underlying and older Bearpaw strata outcrop as shown on Maps 8 and 9 accompanying this report. The strata in the Edmonton formation outcrop along and adjacent to the Red Deer river, and its tributary valleys, especially from range 15 to range 23 inclusive. In the western half of the map-area and in the Hand Hills and the Wintering Hills, the Edmonton formation is overlain by the Paskapoo formation or by the more recent unconsolidated deposits of glacial and alluvial origins.

The detailed stratigraphy, characteristics and origin are described in this report by Sanderson in Part Two, and will not be repeated.

The geology and the relation, character, composition and thickness of the coal seams in the lower part of the Edmonton formation have been fully discussed by Allan in 1921 in a report entitled. "Geology of the Drumheller Coal Field"[5]. Sections of the coal seams mined in the vicinity of Drumheller are shown on Plate IV.

Field investigations were carried out by Sanderson in 1924 throughout much of the area included in the Rosebud and Red Deer sheets. The results of these investigations, supplemented by later field observations by both authors, form the major part of this report. Sanderson mapped geology and correlated the coal seams in the upper part of the Edmonton formation. Detailed sections of the coal seams in the Middle and Upper Edmonton are included in Plate III. The positions of the various coal seams in the Edmonton formation are shown on Plate I. Stratigraphic sections were measured by Sanderson at various points indicated by letters on the accompanying geological maps (Nos. 8 and 9), and also on Plate I. The coal seams at these various points are shown in columnar sections on Plate II.

The Edmonton formation containing the various coal seams has been measured along the Red Deer valley from a point west of Ardley, downstream to the mouth of Willow creek, by the authors and R. L. Rutherford. The uppermost beds in the Edmonton formation, overlain by Paskapoo strata outcrop in the bottom of the narrow valley of the Red Deer in township 38, range 25, about ten miles west of Ardley, and the base of the formation, underlain by Bearpaw shales, outcrops at river level in the southeast corner of township 28, range 19, near the mouth of Willow creek. This measured section, approximately 100 miles in length, contains 1,224 feet of strata assigned to the Edmonton formation, in which there are at least fourteen coal seams, having an aggregate thickness of 62 feet of coal. Figure 22 is a generalized columnar section of the strata in the Edmonton formation. As the stratigraphic interval varies locally, the entire thickness of the section will also vary from place to place. The lower contact of the Edmonton on the underlying Bearpaw marine shales is sharp, with fingers of the Bearpaw shales occurring between the basal Edmonton strata. This relationship is shown in Figures 16, 17 and 18.

The surface of the Edmonton formation has been determined by Sanderson as an erosional plain with the younger Paskapoo strata lying disconformably upon the Edmonton erosion surface. In the development of this erosional surface as much as 450 feet of the uppermost beds in the Edmonton formation, including the coal seams, were removed before the younger Paskapoo sediments were deposited in this area. On account of this disconformity the coal seams that occur in the upper part of the Edmonton formation, are not present in all parts of the Rosebud and Red Deer sheets where the top of the Edmonton occurs. This observation on the relation of the Edmonton and Paskapoo formations, of Upper Cretaceous and Lower Tertiary ages respectively, is a discovery that is of great geological significance, and is additional information on the stratigraphy of Alberta. The presence of this Upper Cretaceous disconformity was recorded by the authors in 1925[6]. This disconformity indicates that for a time the uppermost part of the sediments in the Edmonton formed a land surface which later became submerged, and on which the younger Tertiary sediments were deposited. As the land surface at that time, as now, sloped to the east, a greater thickness of Edmonton strata was removed to the east, so that interbedded coal seams removed by this erosion in the eastern part of this map-area, were not removed from the western part of this coal area. The maximum amount of disconformity between these two formations east of the Red Deer river to Hand Hills is represented by about 450 feet of strata, according to observation by Sanderson. The thickness of the Edmonton strata removed during this erosion is much less in the western part of this map-area. A fuller discussion of this disconformity or time-break is given in Chapter Three of this report and a list of the places where this disconformity was observed is given in Table 2.

The entire Edmonton formation in the Drumheller coal area is only about 850 feet thick, between the base of the Paskapoo, exposed near Hesketh, less than one mile north of Kneehills creek, and the top of the Bearpaw, exposed in the Red Deer valley at the mouth of Willow creek. This disconformity is the explanation for the thinner section of Edmonton strata in the Drumheller district. As only the lower two-thirds of the total 1,224 feet in the entire formation occur in this area, it follows that the coal seams in the upper one-third of the Edmonton strata will not be found in the Drumheller area.

*Correlation of Coal Seams.*

The coal seams in the Edmonton formation from the oldest to the youngest have been numbered 1 to 14 respectively [5 and 7]. The first important coal seam above the base of the formation at Drum-

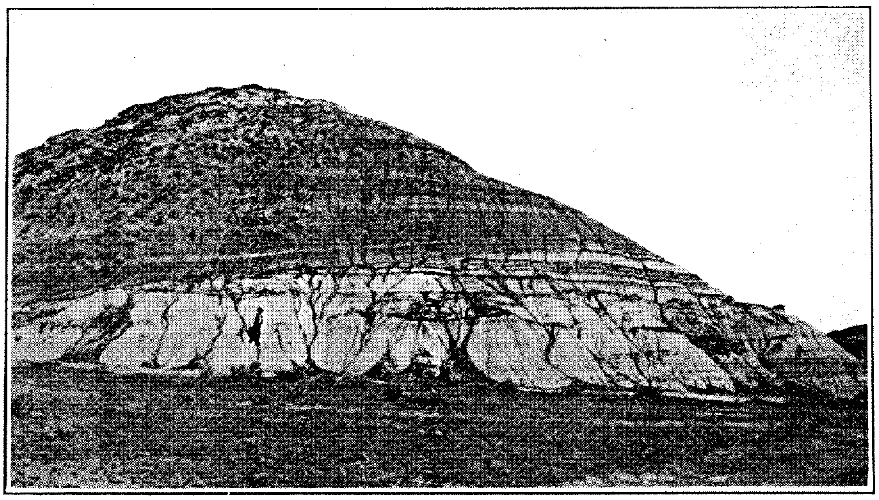

Figure 16.—Transitional beds between the Edmonton and Bearpaw formations. Marine shales locally overlapping brackish water Edmonton sandstones.

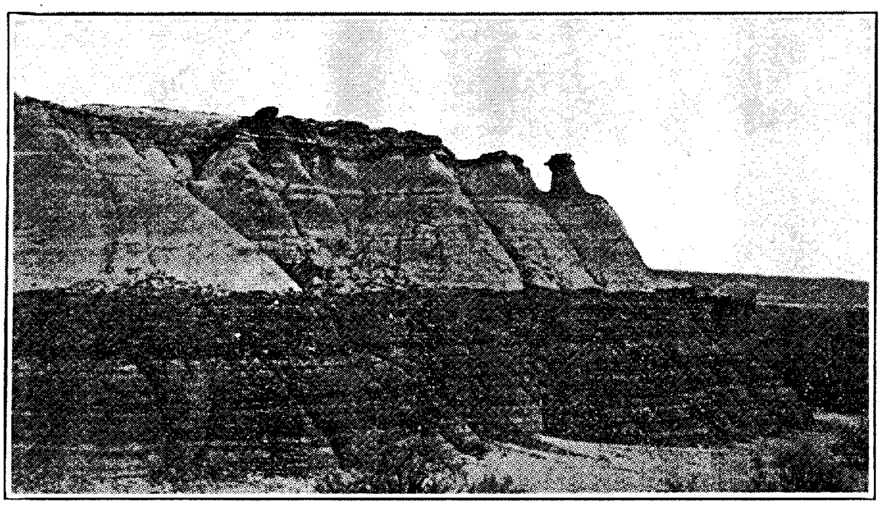

Figure 17.—Sharply defined contact between light colored basal sandstone in the Edmonton formation and chocolate brown marine shales in the Bearpaw formation.

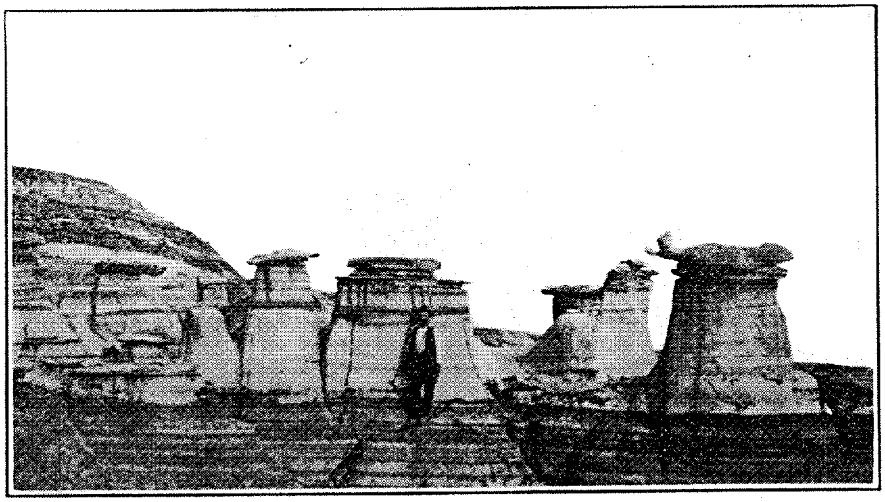

Figure 18.—Edmonton-Bearpaw contact between Rosedale and Willow creek. Shows wind-formed "hoodoo" forms in bentonitic sandstones at base of the Edmonton formation.

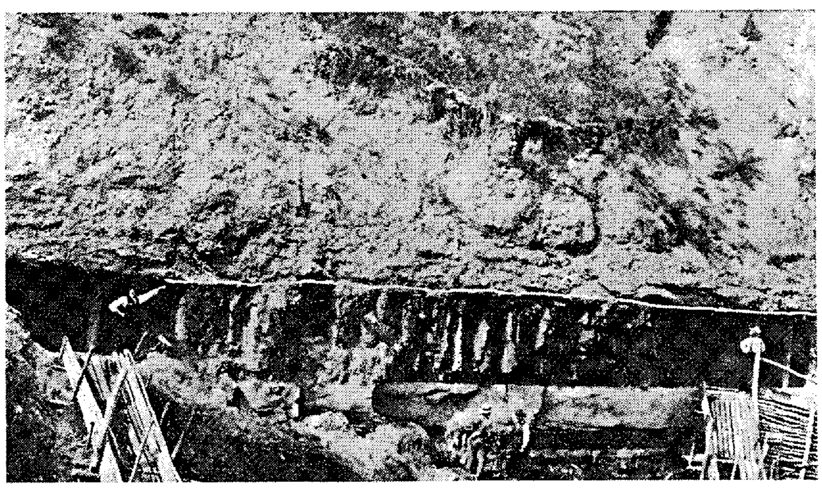

Figure 19.—Drumheller coal seam in East Coulee, 10 miles east of Drumheller. The contact of coal and sandstone is clean and sharp.

heller is designated No. 1 seam, formerly the Drumheller seam. The younger coal seams above No. 1 are numbered consecutively to the highest seam in the Edmonton formation, which is No. 14 or Ardley seam.

The thickness of the coal seams varies laterally throughout the formation, and several of the seams are too thin to be mined. The coal seams in this map-area vary in thickness from less than one foot up to a maximum of about thirteen feet. Some of the coal seams designated by a number are only a few inches in thickness, but because of their continuous lateral extent, these marker seams could be used advantageously in correlating the various seams in the coal-bearing formation. Mining operations have been undertaken in this map-area along the Red Deer valley and its tributaries in seams numbered 1, 2, 5, 7, 9, 11, 12 and 14. The seams are numbered from the lowest to the highest. In some places No. 1 seam occurs about 140 feet above the base of the Edmonton formation in the Drumheller basin, and No. 14 seam occurs about 60 feet below the top of the Edmonton formation in the Ardley area. The stratigraphic interval between the coal seams varies in different localities. Some of these stratigraphic variations are shown on Plates I and II.

Throughout most of this map-area only the more accessible coal seams near the surface or where exposed along the steeper slopes in the sides of the valleys, have yet been developed. Coal seams that are known to occur at greater depth in the formation at various places, have not yet been opened up.

In 1924 the coal production from this map-area was 1,365,592 tons. This production was from mines in the immediate vicinity of the towns of Drumheller, Rosedale and Wayne. The mines at Carbon produced 185,836 tons in 1924. (In 1943 the production from within the same area was 1,930,204 tons).

On the geological maps (Nos. 8 and 9) accompanying this report, the coal seams that have been mined at various places in the area, exclusive of the vicinity of Drumheller and Wayne on Rosebud river, are shown by circles with vertical and horizontal marks to distinguish the particular seam. (Since these geological maps were printed, it has been suggested that it is seam No. 12 (Thompson seam) that has been developed at Big Valley, and at Nevis it is No. 11 seam (Carbon seam) that has been mined.) The coal seams developed previous to 1921 at Drumheller and along the Rosebud river are discussed in Report No. 4, "Geology of the Drumheller Coal Field"[5]. These are coal seams numbered 1, 2, 5 and 7. Since the preparation of Report No. 4, several mines in the vicinity of Drumheller have been closed and others have been opened up on coal seam No. 5 (Upper seam or Newcastle seam).

It is not always possible to correlate coal seams unless the coal seam or marker can be traced on the outcrop. The various coal seams in the Edmonton formation vary greatly in lateral extent both in thickness and in the purity of the coal. Even the lithology and character of the strata in the floor and in the roof will vary within short distances. A coal seam may thicken or become thinner or even pinch out within a short lateral distance. Some coal seams are known to treble in thickness within a distance of one or two miles. Other coal seams of two to five feet in thickness are known to change to one or more bands a few inches in thickness within a few miles. A parting in a coal seam at one place may thicken rapidly to a bed of rock a few inches or even to eight or ten feet thick within one mile. Such a condition of rapid change has been noted in coal seam No. 7 (Daly seam) where it is exposed along the valley of Michichi creek. These rapid changes in the thickness of a coal seam make it difficult to describe accurately the characteristics of the coal, except at the place where the observation is made. Because of these conditions in the coal seams, important blocks of good coal may be overlooked in mining development, possibly through lack of adequate prospecting. On the other hand, mining operations may become unprofitable because of the thinning of the seam or the presence of impurities or bone beds in the coal seam. For similar reasons the correlation of the coal seams in two outcrops in adjoining valleys may become uncertain. This has been found to be the case in the Red Deer valley downstream from Rosedale.

TABLE 3.

**List of Mines Shown by Mine Numbers on Plate IV.**

Each section of the coal seams shown on Plate IV is designated only by the number of the mine. The following list gives the mine number as registered in the records of the Alberta Mines Branch, the name of the mine, the location, the seam worked in 1921 and the type of entry.

| **Number** | **Mine** | **Location, W. 4th Mer.** LSD. | Sec. | Tp. | R. | **Seam** | **Entry** |
|---|---|---|---|---|---|---|---|
| 402 | Monarch | | 7 | 29 | 20 | No. 1 | Shaft |
| 367 | Midland | 10 | 9 | 29 | 20 | No. 1 | Slope |
| 695 | Scranton | 5 | 10 | 29 | 20 | No. 1 | Shaft |
| 678 | Western Gem | 13 | 10 | 29 | 20 | No. 1 | Shaft |
| 349 | Drumheller | 14 | 2 | 29 | 20 | No. 1 | Slope |
| 346 | Rosedale | 14 | 28 | 28 | 19 | No. 1 | Shaft |
| 436 | Star | 7 | 28 | 28 | 19 | No. 1 | Drift |
| 734 | Yoho | 11 | 21 | 28 | 19 | No. 1 | Drift |
| 766 | Moonlight | 16 | 16 | 28 | 19 | No. 1 | Drift |
| 770 | Shamrock | 10 | 20 | 28 | 19 | No. 1 | Slope |
| 347 | Rosedeer | 13 | 7 | 28 | 19 | No. 1 | Slope |
| 640 | Western Commercial | 1 | 7 | 28 | 19 | No. 1 | Slope |
| 643 | Jewell | 6 | 7 | 28 | 19 | No. 1 | Shaft |
| 703 | Excelsior | 3 | 7 | 28 | 19 | No. 1 | Slope |
| 675 | Murray | 12 | 28 | 27 | 18 | No. 2* | Drift |
| 697 | Celtic | 7 | 18 | 28 | 19 | No. 2 | Slope |
| 737 | Sunshine | 6 | 19 | 28 | 19 | No. 2 | Drift |
| 317 | Newcastle | SE¼ | 9 | 29 | 20 | No. 5 | Slope |
| 620 | A. B. C. Co. | NW¼ | 3 | 29 | 20 | No. 5 | Shaft |
| 439 | Premier | 3 | 10 | 29 | 20 | No. 5 | Slope |
| 684 | Atlas | 2 | 10 | 29 | 20 | No. 5 | Slope |
| 816 | Newcastle Jr. | 9 | 3 | 29 | 20 | No. 5 | Shaft |
| 776 | Hy-Grade | 4 | 11 | 29 | 20 | No. 5 | Slope |
| 819 | Elgin | 14 | 2 | 29 | 20 | No. 5 | Shaft |
| 898 | Gibson | 1 | 2 | 29 | 20 | No. 5 | Shaft |
| 848 | Midwest | 7 | 2 | 29 | 20 | No. 5 | Shaft |
| 701 | Superior | 10 | 11 | 29 | 20 | No. 5 | Slope |
| 678 | Western Gem | 13 | 10 | 29 | 20 | No. 5 | Shaft |
| 464 | Brooks | 4 | 23 | 29 | 20 | No. 7 | Drift |

* Formerly considered to be No. 1 seam.

*Description of Coal Seams.*

There are many coal seams in the Edmonton formation. In the exposures along the Red Deer valley between Ardley and the mouth of Willow creek, where a measured section contains 1,224 feet of strata assigned to the Edmonton formation, fifteen different coal seams have been observed. Fourteen of these coal seams were used in mapping and are shown on Plate I. These seams were numbered consecutively from one to fourteen, beginning with the lowest prominent coal seam in Edmonton formation. A thin coal seam lower than No. 1 seam, has been designated No. 0 seam. In numbering the coal seams it is not suggested that it is always possible to recognize the particular seams in a single exposure, because it has already been pointed out that the thickness and character of a particular coal seam and the stratigraphic interval between the seams may change within short distances. However, the various coal seams can be correlated at so many places in this map-area that the authors have found this method of correlation most useful.

A few notes are here given on some of the important characteristics of all the coal seams observed and used in the correlation of the strata in the Edmonton formation as shown in Figure 22.

*Seam No. 0.* This seam outcrops close to the level of the Red Deer river, about 30 feet below the entrance to the Rosedale mine, formerly the Star mine, in section 28, township 28, range 19. At this point, the seam is 14 inches thick, but it thins towards the east. The exposure of this seam continues to rise above the river level in a southeasterly direction and at the mouth of Willow creek occurs about 100 feet above the river.

*Seam No. 1.* This seam was formerly known as the Deep seam or Drumheller seam, because it is the lowest workable seam in the Edmonton formation (Figure 19). This seam occurs about 75 to 100 feet above the base of the formation, on the contact of the underlying Bearpaw marine shales. Coal from this seam is being extracted in 13 mines shown in Table 3, distributed along the Red Deer valley from Rosedale at the mouth of Rosebud river, upstream to the mouth of Kneehills creek. The thickness of this seam in these mines varies from 4 feet to 7 feet, with an average thickness of about 5 feet 6 inches. In a few places it is almost 11 feet between the roof and the floor (Plate IV). Downstream from Rosedale where the seam first outcrops at river level, the coal becomes thinner and at Willow creek the seam is represented by a few inches of coal. The regional dip of the strata in the lower part of the Edmonton formation has been determined from the dip of No. 1 coal seam, which is at the rate of about 20 feet to the mile in a west-southwesterly direction. This rate of dip in the lower portion of the Edmonton formation extends beyond this area and across the Sheerness area to the east.

The most characteristic feature of No. 1 seam is its division into two benches by a band of bentonite varying in thickness from a fraction of an inch up to 20 inches. As a rule the bottom of this band is quite regular, but the top undulates. This observation applies to most of the prominent bands of impurities. In a number of mines along the Red Deer valley above Rosedale, the bentonite band is underlain by a band of bone or coaly bone or hard granular coal, and overlain by a few inches of grey granular coal. In Rosedeer and Western Commercial mines in the vicinity of Wayne in Rosebud valley, the bentonite band disappears and is replaced by bone, coaly bone, and hard granular coal which is frequently eliminated when mined. There is a zone from Rosedale southeast where the band of impurities between the upper and lower benches increases in thickness and reduces the amount of marketable coal.

The band of impurities between the two benches is in some places too wide to warrant its extraction in order to work the lower bench of coal. There is also a band of hard granular coal in several of the mines near the top of the lower bench. The texture of this coal is not attractive on the market, although analyses show that its heating value is just as high as much of the looser textured coal in this seam. The lower bench varies from 18 inches to 42 inches in thickness and in places contains a band of bone a few inches thick.

The upper bench varies in thickness from 5 feet to 6 feet 4 inches, and in places contains one or more thin bands of bone, shale or bentonite. The roof is shale and bentonitic sandstone (Figures 3 and 4). At a number of places a band of bone separates the coal from the roof, and in other places a lense of coal occurs between the bone and the true roof. In a few places the roof is soft and a few inches of coal are left on the roof for support.

The coal is bright in color when it is first mined, but assumes a dull lustre on exposure for a time to the air. The moisture content averages about 16 percent and the ash varies greatly. Exposure to the air causes slacking as shown by numerous cracks on the surface, but this class of coal does not disintegrate easily, and with reasonable care in handling the percentage of slack is low. The coal from this seam can in most places be extracted in block form, the size of the block varying from two or three inches to twelve inches across the face. The main cleavage plane in this seam of coal trends north 43 to 50 degrees east. There are local areas where the coal is finer and in some cases rusty, but these areas might easily be avoided as they are usually associated with local rolls, slips or where the seam is shattered and moist. Much of this coal is glossy and amorphous. The jet-like lenses are formed from logs and massive blocks of wood. Such lenses are quite prominent in some parts of the seam, some are two inches in thickness and often the woody structure can be seen on the glossy surface. The amorphous coal is formed from smaller types of vegetation including leaves and bark. Specimens from Rosebud valley show a very intimate association of the two varieties of coal and a very finely laminated texture is present. So-called "nigger heads" are common in some areas in the seam. These masses of hard bone represent the clay, sand and plant material, washed or blown into depressions on the floor of the basin in which the coal was being formed.

Another pronounced characteristic of No. 1 seam is the presence of numerous grey translucent and transparent crystals of selenite (gypsum) along the cleavage faces in the coal. This mineral does not lower the value of the coal but frequently produces a dull grey lustre on the surfaces of the blocks of coal when mined.

There is another distinct variety of coal in this seam which is called "granular coal" or "hard grey coal." Bands of this coal occur in some parts of this seam near the bottom of the upper bench and also below the bentonite parting in the lower bench. This granular coal is fine textured, hard, and a little heavier than the normal coal. The granular texture is due to the presence of innumerable conchoidal fracture surfaces, and not to individual grains of coal. This texture seems to have been caused by pressure and slight movement on a bed of coal material made up chiefly of plant seeds and soft structured vegetation, possibly grasses and other marsh growth.

*Seam No. 2.* This coal seam occurs 35 to 50 feet above No. 1 seam. At the mouth of Rosebud river between Rosedale and Wayne this seam varies from 22 inches to 40 inches in thickness, but the coal thickens to the southeast. It was formerly worked in the Celtic mine in LSD. 7, section 18, township 28, range 19, on the east side of the Rosebud valley between Rosedale and Wayne. There are now six mines working in this seam at Willow creek and East Coulee.

The writers are indebted to Gordon L. Kidd, mining engineer and geologist at Drumheller, for assistance and helpful suggestions in correlating coal seams at East Coulee and Willow creek with those in the vicinity of Drumheller. (He first recognized that the important coal seam at East Coulee is the No. 2 seam[8]. The coal seam at East Coulee was formerly considered to be the No. 1 seam, until the correlation was made by Kidd.)

The coal when fresh has a dull lustre due to the fact that it consists largely of the amorphous variety of coal. There are irregular lenses of glossy coal. One of these lenses was observed which measured four inches in diameter and was surrounded by the completely carbonized bark of the tree represented by the glossy coal. Rusty coal and joint planes coated with flat gypsum crystals are common features in the coal in No. 2 seam.

*Seam No. 3.* This seam is seldom more than one foot in thickness, but it has been used as an horizon marker, and is exposed from the town of Drumheller eastwards. No. 3 seam is separated from No. 2 seam by 8 to 12 feet of sediments. In Willow creek this seam contains 42 inches of coal (Plate II, V.).

*Seam No. 4.* This seam occurs 10 feet above No. 3 and it has a maximum thickness of one foot. It is continuous for some distance and is useful for correlation purposes. No. 4 and No. 3 beds are exposed near the base of the outliers between Drumheller and Rosedale.

*Seam No. 5.* This coal was formerly known as the Top or Newcastle seam because it occurs at or close to the surface and above the Drumheller or Bottom seam. The Newcastle mine was the first to work this seam. In 1921 there were eleven mines working in the No. 5 seam in the vicinity of Drumheller (Plate IV). In later years mining in this seam has been discontinued in the vicinity of Drumheller, but towards the head of Willow creek two mines have been opened up in this seam where there are 3 feet 6 inches of coal.

This No. 5 seam is exposed at the base of the badlands in contact with the outwash, one-half mile south of the water tower at Drumheller (Figure 21). It has been eroded from the flat on which the town is situated, between the railway and the river. On the north side of the Red Deer river the No. 5 seam is exposed in the escarpment below the highway bridge about 25 feet above the river level. It is also exposed near the base of the escarpment in Michichi valley. West of the mouth of Michichi creek the No. 5 seam disappears below the bottom of the Red Deer valley, as there is a southwest regional dip of about 20 to 25 feet to the mile. Between Drumheller and Rosedale this coal seam rises higher in the badland slopes (Figure 20), and near the top of the badland at Rosedale (Figure 3). The Edmonton formation rises to the southeast down the Red Deer valley. No. 5 seam occurs in the upland at Willow creek, but has been eroded southeast from Willow creek.

The stratigraphic interval between No. 1 and No. 5 coal seams increases towards the southeast. At the mouth of Kneehills this interval between these two coal seams is represented by 47 to 52 feet of beds, about 65 feet at the mouth of Fox creek, 80 feet at

Figure 20.—Badlands in S.W. ¼, Sec. 1, Tp. 29, R. 20, looking northwest, No. 5 seam showing in foreground. Seam No. 6 shows below the white bentonite band in mesa on the left.

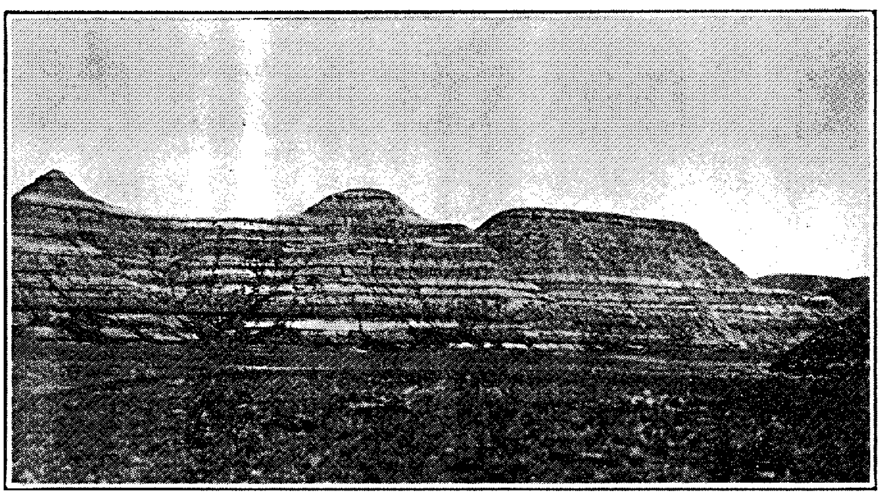

Figure 21.—Three types of buttes, north side of golf course in Sec. 1, Tp. 29, R. 20. No. 7 coal seam at top of butte on right. Seam No. 5 is prominent near the bottom of the escarpment.

Drumheller station, 85 feet at Rosedale, and 105 feet up Willow creek in township 28, range 18 (Plate II, V.).

No. 5 seam varies in thickness from 3 feet 6 inches to 5 feet 5 inches, but the average thickness where mined at Drumheller is about 3 feet 6 inches of clean coal. There is one band of bone varying from a thin parting up to a maximum of 12 inches, but in most places this band is less than 3 inches thick (Plate IV).

It appears that this seam has been mined where the coal is thickest close to the Red Deer valley, because in the mine workings the coal becomes thinner to the southwest under the upland. The coal in this seam is only 3 feet 6 inches thick in the valley of Michichi creek in section 18, township 29, range 19. It thins to the southeast down the Red Deer valley. Between Drumheller and Rosedale there are 40 inches of coal in this seam, and only about 30 inches of coal on Willow creek in section 24, township 28, range 18.

The roof of No. 5 seam consists of shale and bentonitic sandstone, both of which are lensy in character. Both the shale and the sandstone form an excellent roof to the coal seam when dry but a small amount of moisture in the sandstone will cause the bentonitic material to swell and scaling or caving will result. At several points along the west side of the valley mining operations indicate that the roof is crushed under or close to the escarpment, where there is evidence of slumping of the beds on the surface.

The physical properties of the coal vary in different parts of the seam. In some places where mined, the coal is blocky in form, but in other parts of the seam, especially under the escarpment, the coal is more broken, with smaller and irregularly angular fragments. As a rule the coal is shiny. The bright lustre is quite pronounced in coal from No. 5 seam.

*Seam No. 6.* The thickness of this seam varies from 6 inches to 37 inches, but it can scarcely be called a coal seam as it contains very little coal and at many places consists entirely of black carbonaceous shale. It is a good horizon marker 70 feet above No. 5 seam. In Michichi creek No. 6 seam is 37 inches thick and consists of brown fissile shale, fossilized wood and black carbonaceous shale. The most prominent feature in this seam is a layer, seldom more than one inch in thickness, near the centre of the band, which consists of carbonized and silicified fragments of wood, bark, leaves, and even fruit. Many of the carbonized fragments are mineral charcoal and may represent the products of forest fires of Upper Cretaceous age.

This seam is 25 inches thick in Rosebud valley about one and one-half miles east of Beynon in sections 28 and 33, township 27, range 20, but there are only about 6 inches of coal in No. 6 seam exposed in Willow creek (Plate II, S. and V.).

*Seam No. 7.* This seam was formerly called the Daly seam. In 1921 it was worked in one mine (Brooks mine, No. 464), on the north fork of Michichi creek in section 14, township 29, range 20, where the coal is 5 feet 6 inches thick. The No. 7 seam is a useful horizon marker as it occurs 20 to 28 feet above No. 6 seam and about 185 feet above No. 1 seam where sections have been measured. This seam indicates the rapid lateral change that may occur in the coal seams in this area. In section 36, township 28, range 20, and in section 32, township 28, range 19, it is less than one foot in thickness. At several places in Michichi valley, it has a thickness of 6 feet 8 inches, but this includes a shale parting 24 inches thick. The section at Brooks mine, now abandoned, shows 42 inches of coal with 13 inches of bone near the centre (Plate IV.). Along the escarpment west of Michichi creek in section 10, township 29, range 20, No. 7 seam splits into two seams, separated by 10 feet of shale and sandy lenses, but in a coulee in the southwest quarter of section 15, township 29, range 20, the parting thins to 11 inches of shale. On the opposite side of the valley, south of the A.B.C. mine, now abandoned, the seam shows 18 inches of coal, and it lies within 18 feet of No. 6 seam, but this is only local. There is a dinosaur bone bed on top of No. 7 seam at this point. Between Monarch mine and Kneehills creek, No. 7 outcrops close to the base of the escarpment. In section 14, township 29, range 21, No. 7 seam is exposed at the edge of Kneehills creek. At this point the seam is about 3 feet 6 inches thick. A section of No. 7 seam near Wayne in Rosebud valley, shows one foot of coal.

Less than two miles southwest of Wayne this coal seam is 21 inches thick, but about four miles farther up Rosebud valley in section 33, township 27, range 20, this seam is 56 inches thick. Between Drumheller and Nacmine, No. 7 seam is 60 inches thick. This indicates the irregular character of No. 7 coal seam in this district.

*Seam No. 8.* This is not an important coal seam but it is a good marker as it is persistent along the sides of the Red Deer and tributary valleys from township 31, west of Morrin where it outcrops close to river level, downstream to Willow creek where it is eight inches thick and outcrops about 360 feet above the Red Deer river. The stratigraphic interval between No. 7 and No. 8 seams between Drumheller and Willow creek is represented by about 87 feet of beds, but the interval is not regular. The seam varies in thickness from a fraction of an inch up to a maximum of 4 feet of clean coal where the seam is exposed near the top of the escarpment in section 3, township 29, range 20. In Fox coulee the seam is represented by 14 inches of coal. In Kneehills creek, No. 8 seam splits into three parts and the interbedded shale bands are in places ten feet thick. In Rosebud valley about one mile north of Beynon, there are about 26 inches of coal in this seam (Plate II.).

*Seam No. 9.* In the vicinity of Drumheller this seam is useful only as an horizon marker as at no place in this area was it observed to contain more than one foot of clean coal but the seam thickens up the Red Deer valley. Five sections of this coal band are shown on Plate III. It is also referred to as the Stauffer seam because it outcrops in the valley near the river level at Stauffer ferry in section 28, township 31, range 21, and is 30 inches thick. At Beleriot ferry west of Munson the seam is 10 inches thick, but at the mouth of Threehills creek, in section 34, township 29, range 21, the coal has thickened to 42 inches. Three miles east of Hesketh in Kneehills valley, there are only about 10 inches of coal. This seam has been worked in the Johnson mine, about 2 miles north of Beynon, in section 31, township 27, range 20, where there are 39 inches of coal. No. 9 seam is separated from No. 8 seam by 15 to 50 feet of beds.

*Seam No. 10.* This seam outcrops along the valley of Kneehills creek as far as Hesketh, where it is less than 2 feet thick, consisting chiefly of carbonaceous shale. It is a good horizon marker and has been designated the Marker seam.

*Seam No. 11.* This seam has been called the Carbon seam because it has been mined in the vicinity of Carbon in township 29. Farther north in this map-area seam No. 11 has been designated the Paton seam because in 1924 coal was mined from this seam at the Paton mine, situated east of Delburne on the west side of the Red Deer valley, in section 26, township 37, range 22. The various places where seam No. 11 was observed are indicated on the accompanying geological maps (Nos. 8 and 9). The extent and correlation of this seam throughout the map-area are shown in the structure sections on Plate I. The coal occurs about 750 feet above the base of the formation.

Seam No. 11 has a wide distribution in this map-area. It has been mined at Standard, at the extreme southern boundary of the Rosebud sheet (Map No. 9), in section 2, township 25, range 22, where the coal is 49 inches thick. This same seam, according to the correlation, has been mined about one mile northwest of Nevis in section 11, township 39, range 22, where the coal is almost three feet thick. Nevis is 85 miles north of Standard. It is to be expected that seam No. 11 will also occur under much of the western half of the map-area where the Edmonton formation is overlain by the Paskapoo formation. The depth from the surface to the coal seam increases from the outcrop toward the west.

Two fossil horizons were determined in this part of the Edmonton formation. Fossil pelecypods of marine or brackish-water origin are abundant in the beds in these two horizons which were used as markers in the correlation of the coal seams. These horizon markers are designated by the principal fossil that occurs, namely, the *Ostrea* zone and the *Corbicula* zone. At the head of Horseshoe canyon and close to the highway where these two zones occur, the *Ostrea* zone occurs 178 feet below the Carbon seam, and the *Corbicula* zone occurs 155 feet below the Carbon coal seam (seam No. 11).

The thickness and character of coal seam No. 11 (Carbon seam), measured and examined at nineteen localities in this map-area are shown on Plate III. A list of these locations is given by Sanderson in Table 6.

The Carbon coal seam, like most of the coal seams in the Edmonton formation, varies in thickness, even in short distances. This coal seam, where observed, varies in thickness from a minimum of about 15 inches to a maximum of about seven feet, but the whole seam does not contain clean coal as partings, shale bands and bone are common. As shown on Plate III this coal seam is 19 inches thick in Horseshoe canyon, 5 feet in the Peerless mine at Carbon, 6 feet 8 inches at Trentham mine, west of Morrin in section 6, township 31, range 21, and 7 feet at Mennonite mine, six miles north of Rockyford. There is a coal seam being mined in section 6, township 28, range 20, about two miles northwest of Beynon in the Rosebud valley. The coal is about 3 feet thick and may represent either seam No. 11, or a lower seam.

Coal seam No. 11 is exposed along the sides of Red Deer valley, almost all the way from township 38 east of Ardley, downstream to the mouth of Kneehills creek. At Blade mine in section 10, township 38, range 22, the coal seam is 42 inches thick with a band of shale four inches thick. Four miles down the valley in section 26 and 27, township 37, the seam has increased to 45 inches. West of

Big Valley in section 21, township 35, range 21, this coal seam is only 14 inches thick (Plate II,E.), but seven miles south, in section 19, township 34, range 21, about six miles west of Scollard, there are 27 inches of coal in this bed (Plate II,F). Thirteen miles farther south in the Red Deer valley in section 32, township 31, range 21, this seam contains twenty inches of coal, but at Trentham mine, nine miles southwest from Morrin, in section 6, township 31, range 21, there are 64 inches of quite clean coal with a few partings, overlain by 16 inches of coal and shale (Plate III,31).

(According to the recent Canadian classification, the coal in this seam No. 11 is chiefly subbituminous B rank.)

*Seam No. 12* (Thompson seam). This coal occurs about 60 to 80 feet above the Carbon seam and 30 to 70 feet below the *Kneehills tuff* bed which has been described in an earlier part of this report. This seam outcrops along the Red Deer valley in townships 31 to 36, where it varies in thickness from one foot to three feet six inches (Plate II, E,F,G, and O). The most southerly outcrop of this seam which was observed, is about 75 feet below the plain level at the head of Horseshoe canyon in section 27, township 28, range 21, where the coal is immediately overlain by a band of white bentonitic sandstone about eight feet thick which in turn is overlain by a bed of mauve coloured shale 24 feet thick. This mauve coloured shale is capped by the Kneehills tuff, a bed of volcanic ash, discovered by Sanderson in 1924. On account of wide lateral distribution of this volcanic ash bed, seldom over eight inches in thickness, it is a most useful marker in correlating the various coal seams in the Edmonton formation.

(No. 12 coal seam was mined at Big Valley. When the geological map of the Red Deer sheet (Map No. 8) was compiled, the coal seam at Big Valley was correlated with seam No. 14. Later it was found that it corresponds to seam No. 12. This correlation is noted in Plate III.)

*Seam No. 13.* When the coal seams in the Edmonton formation were correlated, a seam about one hundred and fifty feet above the tuff bed was given a separate number (Plate II,F.). It has since been determined that the coal in this horizon is a lenticular seam of local extent. It may be a split from the higher No. 14 coal seam.

*Seam No. 14.* This coal seam, known as the Ardley seam or Big seam, occurs near the top of the Edmonton formation. Sections of this coal seam at fifteen different localities are shown on Plate III. It has been mined at several places in the vicinity of Ardley, and outcrops along the slopes of the Red Deer valley from Ardley in township 38, southward to township 32. Seam No. 14 also outcrops along the base of the escarpment on the west side of the Hand Hills, about 160 feet above the volcanic tuff bed.

The Ardley seam varies in thickness and in the purity of the coal. Sections of coal and coaly shale over ten feet in thickness have been observed, but the sections of clean coal are less than six feet thick. At Ardley in township 38, seam No. 14 has been mined along the south side of the Red Deer valley, where the entire coal seam has a thickness of 10 feet 6 inches, but that part of the seam mined is 5 feet 6 inches thick. The coal seam, like most of the seams in the Edmonton formation in this map-area, lies comparatively flat and the cover is about 90 feet thick.

South of Ardley this coal seam is mined at a number of places, in the vicinity of Trochu, Three Hills, Rowley and five miles southwest of Scollard. The thickness of the coal and the impurities in the seam at fifteen different places are shown on Plate III. (The coal in the Ardley seam is classed as subbituminous B rank, according to the recent Canadian coal classification.)

Seam No. 14 (Ardley seam) corresponds to the "Big seam" which outcrops on the North Saskatchewan river west of Edmonton; the Pembina seam at Evansburg; and the Wabamun seam which outcrops in the vicinity of Lake Wabamun, west of Edmonton.

It is likely that the Ardley seam occurs under a considerable part of the map-area west of range 23 where the Edmonton formation is overlain by the Paskapoo formation and the younger unconsolidated deposits of glacial and alluvial origin.

## Petroleum and Natural Gas

No definite structural indications were observed in this map-area that would appear favorable for the accumulation of petroleum or natural gas. One weak gas seepage was observed on the side of the Red Deer river below the mouth of Rosebud river, but this gas may have been associated with some of the underlying coal seams. The structure sections shown on Plate I indicate that there are broad undulations in the surface formation. This does not mean that the structure at depth would be favorable for the accumulation of petroleum or natural gas. It would be necessary to drill the underlying formations before the possibilities of petroleum and natural gas accumulations could be definitely determined.

## Bentonite

*General Statement.*

Bentonite or soap clay is one of the chief constituents in the whole of the Edmonton formation[5 and 9], where impure bentonitic clays are ordinarily known as gumbo. The name *bentonite* has been applied to clay-like material with strong colloidal properties and high absorptive powers. It is a clay formed by alteration of volcanic ash. A consolidated volcanic ash bed is called a *tuff*. The presence of a bed of volcanic tuff, designated in this report as the *Kneehills tuff*, shown on Plate I between coal seams No. 12 and No. 14, suggests that the products from a volcano in the form of volcanic ash were falling in Alberta in late Upper Cretaceous time when the Edmonton sediments were being deposited.

The first comprehensive treatise on bentonite, compiled by H. S. Spence[10], contains a discussion of physical and chemical properties, origin, distribution in Canada and the United States, twenty-four possible uses, and a complete bibliography on bentonite. Since that date there has been much research on bentonite, and several new uses have been found for this clay. According to early reports "mineral soap" or "soap clay" as this clay was then called, had been used many years ago at various Hudson's Bay posts in Canada for washing blankets. A. R. C. Selwyn in 1873 refers to a soap clay outcropping on "the left bank of the river (North Saskatchewan) for a mile and a half below the fort . . . Immediately above the coal seam is a layer of brown greasy clay 6 to 8 inches thick. This clay works into a lather like soap and Dr. Hector says it was used by the women at the fort for washing blankets."[3] B. J.

Harrington records an analysis of this soap clay from Edmonton, in the same report, page 64 (Analysis 4). R. G. McConnell also refers to bentonite on the Mackenzie river near Bear river, in the Annual Report, Geological Survey of Canada, 1888-89, page 99D. He states, "It is used for whitewashing purposes, and in former times served the Indians as a substitute for soap." These are the earliest references to the occurrence of this soapy clay in western Canada.

This peculiar variety of clay was discovered in Wyoming in about 1885, where it was associated with "soap holes." The first shipments from Wyoming for commercial uses were made in 1888 by William Taylor at Rock Creek, Wyoming, after whom the clay was called "taylorite"(11). Ten years later it was found that this name had already been used for another quite different mineral, so the name was changed by W. C. Knight to "bentonite", from its occurrence in the Fort Benton formation of Upper Cretaceous age in Wyoming(12).

Bentonite usually contains impurities, so that the colour varies. Pure bentonite is yellowish green when fresh and white when air dried. Impure varieties are grey, light cream, brown and even black in colour, depending upon the percentage of impurities. The fresh material when moist cuts with a smooth shiny surface. Thin shavings of pure bentonite are translucent to transparent. The fracture is roughly conchoidal to shaly and when dry breaks up into small fragments with curled edges. *Bentonite absorbs three times its weight and seven times its volume of water.* On account of its high absorptive power, it is extremely soapy when wet and with further addition of water forms a jelly-like mass. When bentonite is ground finely and thoroughly mixed with water a portion of its mass will remain in suspension indefinitely.

Other varieties of bentonite with a larger percentage of impurities occur in many horizons associated with both shale and sandstone members. Some of the bentonitic sandstones contain as high as 45 percent bentonite by weight. A microscopic examination of these sandstones shows that the sand grains are coated with bentonite. When wet the exposures of bentonitic sandstone appear green but when dry become very white in colour. (Figures, 6, 9, 11, 12, 13, 14, 17, 18 and 31.) The bentonitic sandstones are hard when dry but become quite soft and easily eroded when subjected to moisture. This fact is of considerable importance in mining. The roof of No. 5 seam, in particular, in many places consists of bentonitic sandstone which is hard and stands up so long as it remains dry, but when water reaches this bed it forms a poor and even dangerous roof.

Beds of quite pure bentonite were observed at several places and in different horizons in the Edmonton formation. In fact, much of the strata in the entire formation is bentonitic in character. The purest bentonite occurs in beds which vary in thickness from a fraction of an inch up to about six feet.

There is a bed of bentonite in No. 1 coal seam, dividing the top coal from the bottom coal (Plate IV). This bed of bentonite is quite persistent throughout the whole district where the seam was observed, but varies in thickness from a fraction of an inch up to a maximum of two feet. Dark streaks and minute lenses of coal are common, especially in the lower part of the thicker portions of the bed. The quality of this bentonite is shown in Analysis 2.

A bed of pure bentonite, which varies in thickness from three feet to almost six feet, occurs between No. 6 and No. 7 coal seams in the vicinity of Gibson mine, about one-half mile south of Drumheller railway station (Analysis 1).

The best bed of pure bentonite observed outcrops on a narrow ridge on the west branch of Michichi creek, on the south side of the highway, in the northwest quarter of section 14. This bed occurs between No. 5 and No. 6 coal seams, and varies from three to five feet in thickness* (Analysis 3).

High grade bentonite occurs in the lower strata in the Edmonton formation, exposed along the Red Deer valley south of Rosedale at East Coulee and Willow creek (Figures 29). Thin beds of bentonite were observed north of Drumheller, in the vicinity of the Monarch mine and north of the mouth of Kneehills creek (Figure 1). Bentonite beds are also exposed on Horseshoe canyon, a branch of Kneehills creek (Figure 14).

*Analyses.*

Analyses of samples of bentonite from four localities are given below:

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Silica | 69.52 | 69.46 | 68.88 | 36.49 |
| Alumina | 21.64 | 16.25 | 16.34 | 13.48 |
| Iron Oxide | 3.06 | 3.35 | 2.86 | 1.80 |
| Lime | 0.00 | 2.06 | 2.18 | 2.03 |
| Magnesia | 0.21 | 2.76 | 1.32 | 0.66 |
| Sodium and Potassium Oxide | 0.00 | 1.08 | 2.15 | 0.00 |
| Ignition Loss | 5.45 | 5.04 | 6.27 | 44.32 |

1. Pure conchoidal sample from an irregular bed, 3 to 6 feet thick, between No. 6 and No. 7 coal seams, close to Gibson mine tipple.
2. Bentonite parting in No. 1 coal seam, Rosedale mine.
3. Sample from bed about 3 feet thick between No. 5 and No. 6 coal seams, Kidd pit, Michichi creek, Drumheller.
4. Sample of "soap clay" from Edmonton, analysed in 1874.

*Uses.*

Bentonite has become an important mineral product on account of the many uses that can be made of it. About one hundred different uses have been recorded for bentonite.

Bentonite has been used extensively in the manufacture of paper, textiles and other fabrics; in de-inking old news print; as plaster board, wall board and insulation blocks; in the manufacture of rubber and paints; in the sizing of yarns; in the dye industry; as a water softener; as a beauty clay; in toothpaste; as a binder for briquets; as medicinal absorbent dressings; as hoof packing and dressing for animals; and as a filler in soap. It has been extensively used as a bonding ingredient for molds and cores and as a core wash in the foundry industry; for refining of gasoline and oils, as a drilling mud; in the cement industry; in the manufacture of various ceramic products; in certain cements; as emulsions and for various other purposes. On account of the extreme hardness of bentonite when dried or burnt, it has been used as a clay ballast in the construction of certain types of roads where impure bentonite or gumbo clays can be kept dry with some kind of an impervious

*In recent years commercial use has been made of this bentonite. G. L. Kidd has opened up this bed by stripping operations. The bentonite is shipped to Calgary where it is processed into drilling mud which is used in the drilling of oil wells in Turner Valley, 35 miles southwest from Calgary, Alberta.

waterproof surface. An important use for bentonite in Alberta should be to produce muds or circulating fluid, extensively used in drilling oil wells. In recent years a small quantity of the purer grade of Alberta bentonite from Drumheller has been used in oil well drilling in Turner Valley.

Bentonite is widely distributed throughout the Edmonton formation in this map-area and in other parts of Alberta, so that any large deposit of pure bentonite should be investigated for possible utilization.

### Marl

Marl is a loose, friable clay consisting chiefly of carbonate of lime. The colour is usually white or grey, but frequently is yellow or dark grey depending upon the impurities in the marl. This material is usually deposited by springs or seepages of water along hill sides. There are several small deposits of marl in this map-area.

The occurrence of marl in the Hand Hills (Figure 34) may be of some importance. The material has not been tested but it appears in the field to be pure enough to be used as a cement ingredient, or for soil enrichment or other uses. These deposits are quite accessible and the quantity appears to be large.

### Sand and Gravel

No deposits of clean siliceous sand are known in the area. The soft Paskapoo sandstones can be easily crushed and used, but the mixed mineral constitution of the sand detracts from its quality. No pure sands occur in the Edmonton formation. In the glacial deposits local lenses of sands occur that are higher in percentage of quartz than any sands occurring lower in the section, but they are of too limited extent to be of importance, except locally.

Unsorted gravel occurs in quantity at several points, notably between Scollard and Big Valley, and along Kneehills creek, west of Carbon. In the former locality the deposit is a large one and has been used by the railway as a source of ballast. Local gravel lenses up to 5 and 10 feet thick occur at the base of the glacial section. These generally have too great a cover of useless till to be exploited.

In recent years the road building program has required gravel suitable for road construction, and several gravel pits have been opened up in this map-area. (In 1944 there were fifteen pits from which gravel was being excavated and nine of these pits were operated by the Alberta Government Department of Public Works.)

### Clay

Clays suitable for common brick occur within the glacial silts and also in alluvial clays that have been moved about in water before deposition. No commercial use is being made of the clays, but the possibilities are worthy of investigation.

# PART TWO

# HISTORICAL GEOLOGY AND SEDIMENTATION

By J. O. G. SANDERSON

## CHAPTER V.

## INTRODUCTION

*Purpose of Work.*

This part of the report, Part Two, deals with the physical features of the formations encountered in the map-area, and with the organic remains that have been found in them.

The purpose of this investigation was primarily, to correlate the coal seams of the Edmonton formation, and in doing so, to study the geology of the Red Deer and Rosebud sheets (Maps No. 8 and 9). In the course of the work on the Edmonton formation it was found convenient to collect data on the lithology and palaeontology of the formations associated with the Edmonton.

In Part Two it is proposed to outline as fully as possible the known information on the lithology and fossils of the formations in this area, with special attention devoted to the Edmonton formation, which is the most important one from both economic and stratigraphic aspects.

The field work was carried on in 1924 under the direction of Dr. J. A. Allan. The Drumheller district was studied in detail by J. A. Allan, R. L. Rutherford and the writer in 1921. During several seasons since 1924 the writer has studied the Edmonton and related formations in adjacent areas in several parts of Alberta, while employed by the Geological Survey of Canada, Imperial Oil Company Limited and other private employers.

Detailed studies of the invertebrate fauna, lithology, sedimentation and stratigraphical correlations of the Edmonton formation have been carried out at Yale and Toronto Universities, and at the latter school the subject, "The Geology of the Red Deer River Region, Alberta", formed the writer's thesis presented in partial fulfillment of the requirement for a doctorate degree in 1928.

*Acknowledgments.*

During the field season of 1924 the writer was ably assisted by Edward Jones and Eric Davis, students of the University of Alberta.

The experienced guidance and hearty encouragement of the director of the survey, Dr. J. A. Allan, were the main contributing factors to the successful conclusion of the work, and are gratefully acknowledged herewith.

In the final phase of the investigation, the helpful criticism of Professors C. O. Dunbar, Adolph Knopf, H. E. Gregory and K. C. Heald of Yale University, and of Professors W. A. Parks, E. S. Moore and A. McLean of the University of Toronto has been of great benefit and is highly appreciated. The palaeontology was studied under the excellent direction of Professor W. A. Parks, whose knowledge of western stratigraphy and palaeontology is extensive. Without his interest, this phase of the work could not have been as fully developed.

*Outline of Investigation and Summary of Results.*

The main considerations undertaken in this report are the palaeontology, lithology and correlation of the several formations that were studied. The available literature on these topics has been studied and the pertinent information obtained has been compiled and added to that obtained by the writer in the field and laboratory. This was done in order to make the present report as complete a compendium of the features and characteristics of these formations as possible.

Freshwater and marine invertebrate fossils were collected during the progress of the field work. At the same time coal and lithological samples were taken at representative localities for later analysis. A study of the faunas and rocks was conducted by the writer, and the coals were analysed in the laboratories of the Scientific and Industrial Research Council.*

The physiography and glacial geology were noted concurrently and are described in Part One of this report.

The results of the palaeontological study indicate the presence of a marine fauna of Fox Hills aspect, present as a thin tongue near the middle of the Edmonton formation. The fauna is listed and compared, and several new varieties and species occurring in it are described and figured. Some of these are not from the area described in this report, but are included because they belong in series with the forms occurring in the formations in the Red Deer and Rosebud areas. The freshwater invertebrates, vertebrates and the floras of the formations are also listed. The latter compilations have been derived mainly from previous publications and unpublished records. The above lists make up the most complete faunal record of the formations of this age for this part of Alberta that has yet been compiled.

The fossils and the stratigraphic features of the Edmonton demonstrate the close relationship of this formation to the Fox Hills of the northwestern United States in time and origin. The presence of a marked disconformity at the top of the formation seems, finally, to account for the absence of the Lance formation in Alberta. And further, the disconformity, and some related data, make possible a much closer estimation of the age of the Paskapoo formation than has hitherto existed. It is regarded by the writer as probably equivalent to formations of Upper Fort Union age, and possibly of early Eocene age.

The study of the lithology and sedimentation involved mechanical, mineralogical and some partial chemical analyses of the rocks. Thin sections of many representative samples were studied. This work has indicated the distinctions that can be made between the Cretaceous and Tertiary rocks, and has shown the singular character of the Edmonton sediments. It is concluded that the Edmonton formation is essentially of delta origin, and contains a great deal more of pyroclastic sediments than has hitherto been supposed. The mechanical analyses have indicated marked distinctions in the different formations. The Edmonton has very few well-sorted aggregates. The rocks are all fine-grained and are predominantly

*These coal analyses were useful in correlating some of the coal seams, but are not included in this report because a new Canadian classification of coals was introduced in 1938. The classification of the coals in this map-area is included in "Coals of Alberta" by Edgar Stansfield and W. Albert Lang, Report 35, Research Council of Alberta, 1944.

admixtures of extremely fine and relatively coarse detritus. There are few pure clay-grade strata, and no non-argillaceous, or well-sorted, sandstones present. The jelly-like clay, commonly referred to as bentonite, is present in all the strata, except in the marine tongue, and in some of the thin bands with calcite matrix. It forms the weak cementing matrix for most of the light coloured sandy strata.

Mineralogically the Paskapoo formation is not unusual, but the Edmonton is of singular character. The coarser constituents of the Edmonton are mainly highly angular, relatively unaltered plagioclase fragments, and milky, angular, quartz grains. Little indication of the rounding action of water, either as carrier or solvent, is noted. The most abundant heavy detritals are micas and magnetite. The iron and magnesium-rich micas are practically fresh. Other heavy detrital materials are present only in small quantity, and comprise angular zircon, hornblende (unaltered), topaz, tourmaline (generally sharply truncated rods), and rarer rutile and anatase. Garnet is less common than in ordinary clastic rocks, but is present.

In general the mechanical and mineral constitution of the Edmonton rocks is unusual and indicates a unique mode of origin and special conditions of deposition. It is concluded that the Edmonton formation was deposited under delta conditions.

The field work resulted in a systematic correlation of the coal seams of the Upper Edmonton formation, over an area of about 8,000 square miles. Other stratigraphic results were the discovery of an important disconformity at the top of the Edmonton or Cretaceous section and the finding of a true volcanic tuff as a stratum in the Edmonton. The interpretation of this disconformity has an important bearing on the long standing "Laramie Problem" in western North America. The discovery of determinable volcanic glass suggests a possible explanation for the abundant colloidal clays in the Edmonton. In general the data obtained have led to a clearer understanding of the stratigraphic relations of the different formations of the area.

# CHAPTER VI.

# SYSTEMATIC DESCRIPTIONS OF THE BEARPAW AND EDMONTON FORMATIONS

## BEARPAW FORMATION

*Distribution.*

The Bearpaw formation is of marine origin. The formation covers a vast area in Canada and the United States. Although it is exposed in only two small areas in the northeast and southeast corners of the present map-area, it is generally believed that it underlies the entire area at various depths up to 2,000 feet.

Outside of this area the Bearpaw has its greatest exposure to the east and south. It outcrops as a belt which has a maximum width, in Alberta, of 60 miles, and which extends from the North Saskatchewan river to the International Boundary, becoming gradually narrower in that direction. The extent of the formation to the west is limited and is not precisely known. The shales of Bearpaw age pinch out east of Rocky Mountain House, about 40 miles west of this map-area. The western border of the Bearpaw sea probably had deep, large bays, some of which closely approached the site of the present front ranges of the Rocky Mountains.

*Thickness and Lithological Character.*

Like all sedimentary strata, the Bearpaw shale varies in thickness from place to place. In the Red Deer river region the formation is probably thickest along the east side of the area mapped and possibly thins out completely at points along the western border of the map-area. Precise information away from the outcrops has not been obtained.

As exposed along the Red Deer river, east of Drumheller, the thickness is probably between 400 and 500 feet. J. A. Allan[13] states that the formation is about 600 feet thick in this region. Another estimate, made by Barnum Brown[14] in 1914, places the Bearpaw here at 260 feet thick. J. B. Tyrrell calculated that the Fox Hills-Pierre along the Red Deer is 600 feet thick. He probably included some of the Lower Edmonton. A careful estimate, made by P. S. Warren and the writer in 1925, of the Bearpaw exposed on Bow River near Bassano, indicated a thickness of 400 to 500 feet. The formation was originally defined by Stanton and Hatcher[1] in 1905 in the region about Bearpaw mountains in Montana. They did not determine the thickness but accepted the estimates given by G. M. Dawson and R. G. McConnell for the thickness of this formation in Canada, which is 750 feet.

Lithologically the Bearpaw is distinctive. The rocks are predominantly argillaceous, but have occasional benches of sandstones and beds of nodular limestone. The shales vary from drab grey colour to chocolate brown colours of several tints. The grey shales most frequently have calcareous and nodular layers, while the brown shales contain ironstone nodules and lenses. Fossils are found in both types and most commonly in nodules. Thin beds of bentonite and of volcanic tuff are found in the Bearpaw especially near its base. Bentonite is less common in the rocks below the Bearpaw

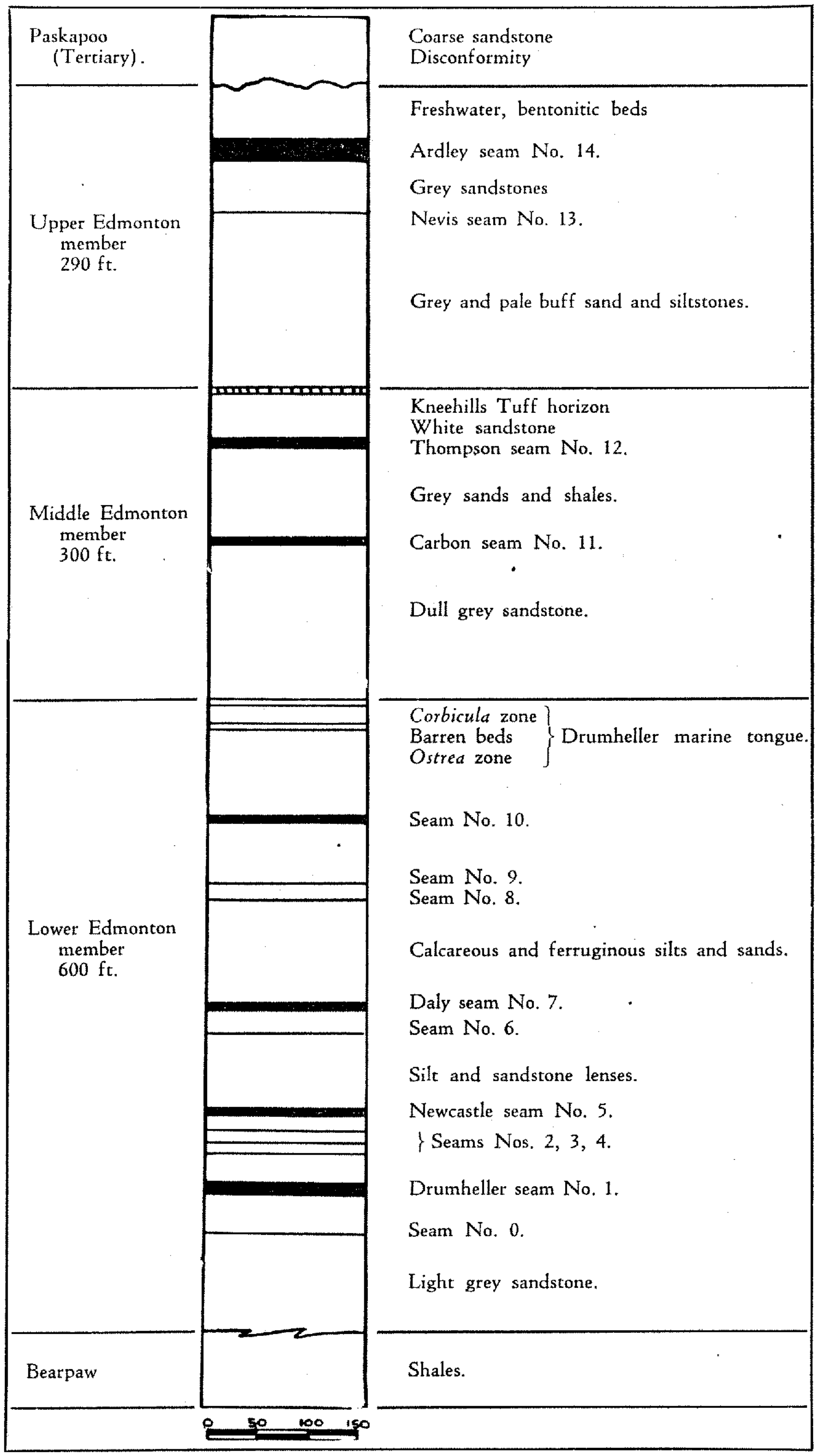


Figure 22.—Composite section showing subdivisions of the Edmonton formation.

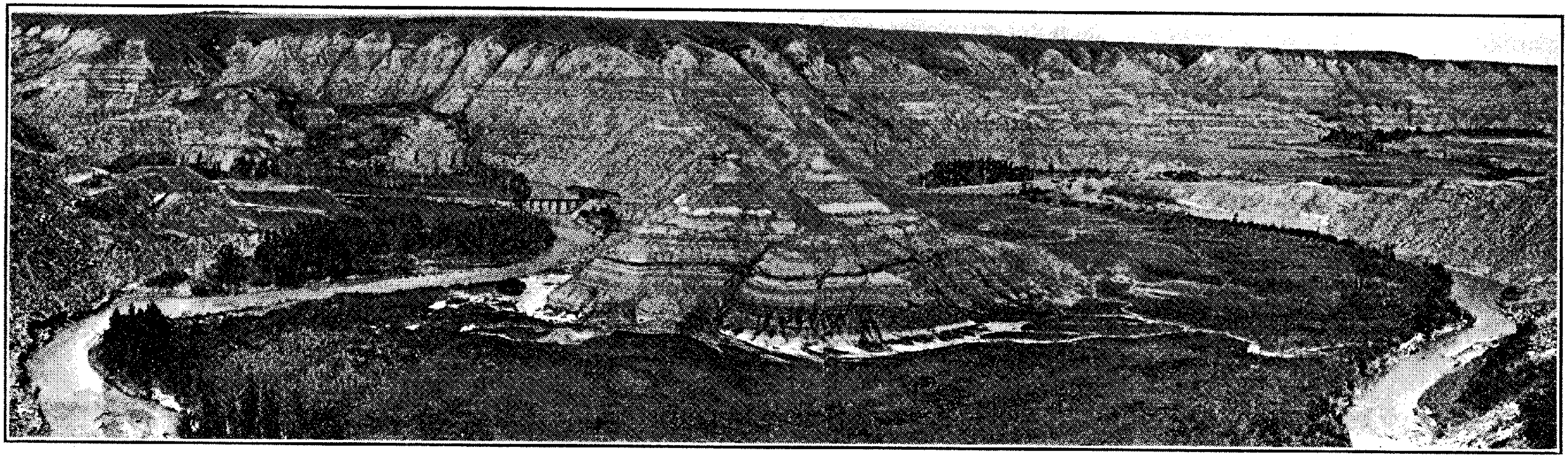

Figure 23.—Panorama of Lower Edmonton member, Rosebud river near Beynon.

in Alberta. The main features of the Bearpaw are the soft shaly character and monotonous similarity of the rocks in the formation.

*Sedimentation and Interpretation.*

The sedimentation was of normal marine character, the clastics brought down were fine grained and during diagenesis were rendered fissile. They accumulated slowly enough to allow of segregation of calcareous matter and ferruginous components to a marked degree. The bulk of these constituents in the formation is found in distinct thin layers or in bands of more or less rounded nodules. A peculiarity of the sedimentation is the apparent isolation of the fossils in the iron and calcareous nodules. Except in the nodules, fossils are rarely encountered.

The lower contact of the Bearpaw with the Belly River is everywhere sharply defined. In contrast its upper contact with the Edmonton is gradational and indistinct; interdigitation prevails. This system of contacts is apparently characteristic of the advancing and retreating phases of a marine incursion. Figure 24 is a photograph of the Bearpaw-Edmonton contact at the mouth of Willow creek along the Red Deer. It illustrates the gradational character of the contact.

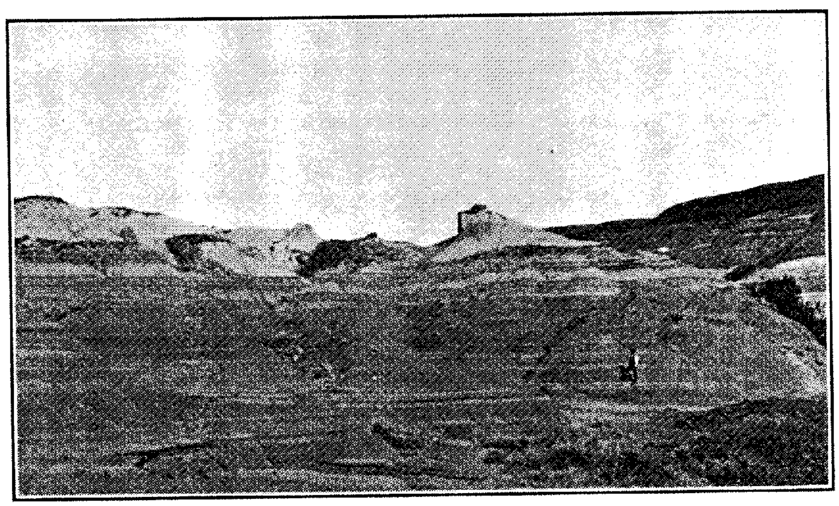

Figure 24.—Bearpaw-Edmonton contact at the mouth of Willow creek, showing the gradual change in the lithology from one formation to the other.

The Bearpaw formation does not present unusual difficulty in the interpretation of its deposition history. The deposits were laid down in a shallow sea which came in from the southeast. The cause of its incursion was probably the excessive submergence of the heavily loaded pre-montane belt occupied by the thick deposits of the Belly River series. During Bearpaw time, the forces of orogeny were quiescent in the west and only fine grained detritus reached the basin of deposition. The sediments, with such large proportions of lime, iron and aluminous matter, indicate that the dominant process was rock decay by weathering in the area supplying the detritus. The evidence of separation and segregation of those constituents during diagenesis proves that sedimentation was slow. The physical agencies causing the separation and segregation of lime, iron and silica in these deposits had ample time to take effect before packing and dehydration, resulting from superimposed strata, had become an effective check.

*Bearpaw Fauna.*

In this formation the typical Upper Pierre fauna finds its greatest development. The majority of the forms are Pelecypoda, and of these Prionodesmacea predominate slightly. Teleodesmacea almost equal the more primitive representatives in number of species.

Collections have been made from the Bearpaw in many places in the west. D. B. Dowling[2] has published a list of all the species recognized up to 1917. Since the appearance of this list the following forms have been identified by the writer from the Bearpaw of the Cypress Hills region:

Pelecypoda—*Ostrea larva,* var. nov.
*Callista pellucida,* M. & H.
*Callista owenana,* M. & H.
*Inoceramus* cf. *sublaevis,* Hall & Meek.
cf. *Cucullaea soleniscus,* Stant.
*Turnus elegantula,* M. & H.

Gastropoda—*Fasciolaria galpiniana,* Stant.
*Vanikoro ambigua,* M. & H.
*Anchura sublaevis,* M. & H.

The complete fauna to date is indicated in the following table:

TABLE 4.

**Summary of Upper Pierre (Bearpaw) Fauna of Alberta**

| Class | Order | Number of Species |
|---|---|---|
| Brachiopoda | Atremata | 1 |
| | Prionodesmacea | 21 |
| Pelecypoda | Anomalodesmacea | 2 |
| | Teleodesmacea | 20 |
| | Ctenobranchia | 6 |
| Gastropoda | Opisthobranchia | 4 |
| | Pulmonata | 3 |
| Cephalopoda | Ammonoidea | 9 |
| | Nautiloidea | 1 |
| Crustacea | Decapoda | 1 |

The Bearpaw is generally readily recognized by such species as *Liopistha undata,* M. & H., *Protocardia subquadrata,* E. & S., *P. borealis,* Whit., and the Upper Pierre ammonites. The range of the individual species has not been studied in detail, and it is not known if there are species confined to this formation.

*Age and Correlation.*

The Bearpaw of Alberta has been traced into the Upper Pierre of southern Saskatchewan and North and South Dakota, as well as into the Bearpaw shale formation as described by Stanton and Hatcher, in Montana. Its Senonian age is established by the relations of the fauna with that of the Ripley formation of the Atlantic states, and the generally accepted correlation of that formation with Senonian formations in Europe.

## EDMONTON FORMATION

*Distribution.*

As originally deposited, the Edmonton formation covered most of Alberta east of the foothills and south of latitude 56°. It grades into the thinner Fox Hills formation to the east and south, and on the west apparently becomes a part of the thick, undifferentiated deposits of the Upper Montana subdivision of the Cretaceous. Similar formations that are stratigraphically equivalent in the western States are known as the Horsethief sandstone in Montana, and the Lennep and Meeteetse in Wyoming.

Within the area described in this report the Edmonton is exposed over the eastern half, with an area of about 3,500 square miles, in a broad belt east of Alix, Big Valley and Carbon, and in the vicinity of Drumheller. Over the remainder of the area it is overlain by the Paskapoo. The accompanying areal geological maps (Nos. 8 and 9) and the general cross-sections (Plate I) show this distribution.

*Thickness.*

A nearly continuous section of the Edmonton from the flank of Hand Hills down Willow creek to its mouth reveals a thickness of 1,050 feet of beds, measured from the base of the massive buff Paskapoo sandstone to the top of the brown shales of the Bearpaw. The upper limit of this section is well defined, but the lower one is less definite. The base is placed 140 feet below the Drumheller coal seam, or at the base of the first thick whitish sandstone member of the Lower Edmonton.

A full section is not obtainable elsewhere in the region, except the one exposed along the Red Deer river from Ardley to the mouth of Willow creek, which is a distance of about 90 miles.

Careful measurements of the thickness of the upper part of the formation prove that the beds vary in thickness from place to place, and that the formation appears to be thickest near the mouth of Big Valley creek. It is believed that the Edmonton at this point is somewhat over 1,200 feet thick. Partial sections from the base to the top of the formation have been measured and correlated by means of well defined horizons, such as the marine tongue, volcanic tuff bed, and prominent coal seams. The accompanying Plate II, "Stratigraphic Sections, Red Deer and Rosebud Sheets", indicates the horizons correlated and the localities of useful sections. The average obtained from such measurements indicates an average thickness of about 1,000 feet for the formation in this area. The Edmonton thins gradually towards the east. Correlation with the Cypress Hills section shows a thinning of about 450 feet in 180 miles in this direction. The thickness of the formation or its equivalents in the foothills to the west has not been ascertained.

*Subdivisions.*

The Edmonton is divisible into three natural parts in this area. These subdivisions are as follows (See Figure 22):

Upper Edmonton member
Middle Edmonton member
Lower Edmonton member

The Upper Edmonton member includes the upper 290 feet of the formation. The top is placed somewhat above the limit set by J. B.

Tyrrell[15], which is the top of the Ardley seam. In the Ardley neighbourhood 100 feet of freshwater beds with coaly layers and considerable bentonitic clay is found lying conformably above the big coal seam. These strata lie below the disconformity and must, therefore, be considered as of Edmonton age. Locally there are two to four beds of coal lying below the Ardley seam, and within 75 feet of it stratigraphically. The remainder of the Upper Edmonton is composed of the characteristic, light coloured sandstones and siltstones, with local lenses of more argillaceous and ferruginous strata. The base of the Upper Edmonton is drawn at the horizon formed by the top of the dark, possibly marine shale, which includes the Kneehills tuff. The stratigraphic interval between the "big seam" and the volcanic tuff varies from place to place, with a range of 200 to 290 feet. The most prominent features of the Upper Edmonton member are the presence near the top of the Ardley seam, and the scarcity or lack of dinosaur fossils in it. The best exposures of this member are found from Ardley to Big Valley along the river, and in the Hand Hills.

The volcanic ash horizon forms a convenient and widespread boundary plane separating the Upper and Middle Edmonton members. The Middle Edmonton member is composed of all the beds from the top of the dark bentonitic shale containing the tuff, down to the top of the Drumheller marine tongue. This section is approximately 300 feet thick. The uppermost bed is a dark grey to mauve-black shale, which encloses selenite crystals in some places, and which includes near its base the thin persistent tuff layer. It is underlain by a prominent, white, bentonitic sandstone. This member is prominent in exposures between Big Valley and Scollard, and also in the Kneehills valley near Carbon. The sandstone is considerably lighter in colour than adjacent strata. The relative positions and thickness of these members are shown in Figure 22. The tuff bed occurring in the upper dark shale is here named the Kneehills Tuff because of its numerous outcrops on Kneehills creek and its branches.

Fifty feet below the tuff horizon there is a coal seam that is named the Thompson seam. It first reaches mineable thickness at Thompson's mine in township 36 on the Red Deer river southeast of Ardley. The intervening beds show no exceptional features; they are interlensing bentonitic sandstones and siltstones of drab colour. Below the Thompson seam, or seam number 12 of the series, occurs another locally important coal bed. This seam reaches a thickness of over 5 feet in the neighbourhood of Carbon, and is mined at several places. The interval between these two seams of the Middle Edmonton member varies considerably, anywhere from 50 to 100 feet of strata separating the two. The lower seam is called the No. 11 or the Carbon seam because of its importance in the environs of that town. It is also mined at Standard, on the Rosebud in section 23, township 27, range 23, and on the north slope of the Wintering Hills, 4 miles south of Rosebud Creek. The rocks below seam number 11 are not of unusual type; they closely resemble other parts of the Edmonton section, only differing in having slightly less admixture of calcareous and ferruginous matter. The Middle Edmonton member is best exposed in Horseshoe canyon, and along the Red Deer west of Big Valley. Near Carbon the Thompson seam does not carry mineable coal, but is represented by dark coloured, carbonaceous silts and clays. The base of the member is drawn at the top of the Drumheller marine tongue, and is marked by the occurrence of *Corbicula occidentalis ventricosa* (Figure 27).

The Lower Edmonton member is the most important in thickness and in contents of coal. Its thickness averages about 600 feet. The upper 25 feet of the member is composed of marine strata of shore-line type. It is well developed in Horseshoe canyon and in the neighbourhood north of Beynon. It is named the Drumheller marine tongue because of its occurrence in coulee exposures north, west, south and east of that town. At the type locality in Horseshoe canyon, S.E. ¼ section 33, township 28, range 21, the following section is exposed:

| | |
|---|---|
| Arenaceous limestone with abundant *Corbicula occidentalis ventricosa* | 3 feet. |
| Barren, bluish siltstone, poor in bentonite | 19 feet. |
| Arenaceous limestone with abundant *Ostrea glabra coalvillensis* | 3 feet. |

At some other localities the two zones seem to merge, and *Ostrea* and *Corbicula* occur together in a thinner marine stratum.

The remainder of the lower member is characterized by the prevalence of coal seams, higher content of bentonite in the rocks, and generally greater variation in the lithology. The development of sedimentary structures of delta origin is also most notable in this member. These structures and peculiar beds are referred to in connection with sedimentation.

Figure 23 is a panoramic view of the exposure of part of the Lower Edmonton member above and below seam number 7, along the Rosebud river between Wayne and Beynon. Figure 25 is a photograph of a freshly slumped exposure of the upper part of the lower member, showing seams numbers 8 and 9, on the north bank of the Rosebud about one mile west of Wayne.

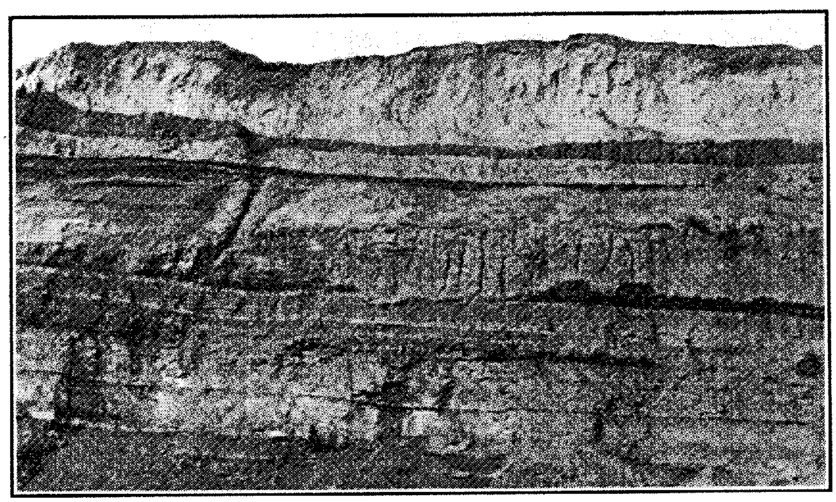

Figure 25.—Fresh exposure, the result of a recent slump in Edmonton rocks along Rosebud river near Wayne.

Under the general heading, *lithology,* the several distinct types of component rocks are described separately. The whole formation is composed of a few rock types occurring repeatedly as relatively thin strata.

*Lithology.*

Poorly sorted sandstones and siltstones, cemented for the greater part with bentonitic clay, make up the bulk of the rocks of the formation. Rocks present in small quantity are arenaceous limestone, clay ironstone, pure clays, volcanic tuff and coals. Intergradations of these, such as ferruginous sands and silts and carbonaceous shales, occur to a limited extent.

*Sandstones and Siltstones.*

Aggregates of sand, silt and clay mixed in all proportions, occur commonly. Pure, sorted sandstone or siltstone does not occur because colloidal clay contaminates all the rocks to at least 5 percent of the weight of the rock. The common association is interfingering beds of whitish, relatively coarse sandstone and grey, fine-grained silt, each with from 8 to 35 percent of colloidal clay, which acts as a binder. The clastics of the Edmonton possess remarkable uniformity in one respect; no grains over 1 mm. diameter have been observed in the many samples which the writer has analyzed. The whole formation is composed of remarkably fine-grained clastics. Unlike ordinary fine-grained sedimentary series, which have a high percentage of relatively well-sorted, fine-grained and sorted strata, the Edmonton has very little true clay or shale; the general admixture of fine and relatively coarser particles prevents this.

The most general characteristic of the lithology is the lack of sorting in the clastics. This feature is demonstrated in the table below, (Table 5) which shows the percentages of sand, silt and clay in 18 samples of Edmonton or equivalent rocks in Alberta. In each case the sample selected is representative of the common variety of sandstone for that part of the Edmonton section from which it is taken. Strikingly unusual types were not analyzed because it was desired to obtain an idea of the essential elements of the lithology rather than of the exceptional features. The coarser phases, or sandstones, were chosen in most cases because the mechanical constitution of the sands is a reliable index of the degree of sorting of all the phases. While most of the samples listed are from the area under discussion, 7 samples from other places were analyzed for purposes of comparison. In general these differ slightly in character from the sandstones in this map-area.

The analyses were made by means of an elutriator, the principle of which is the buoyant force of water moving at regular rates. The rock samples are first disintegrated, but not crushed. The type of separator used is that designed by Thomas Crooke[16] of the University of Dublin.

The following table indicates mainly the high percentages of colloidal clay present in typical Edmonton sandstone. This feature, along with the large proportions of silt grade, and variation in the sand percentage, indicates the characteristic lack of sorting. The origin and manner of deposition of such large proportions of colloidal clay, contemporaneously with sand and silt is unusual and requires special interpretation. This is considered in connection with the sedimentation of the Edmonton.

TABLE 5.

**Mechanical Analyses of Edmonton Sandstones**

| Sample Location and Horizon | Sand % 1.0-0.1 mm. | Silt % 0.1-.01 mm. | Clay % Less than 0.01 mm. |
|---|---|---|---|
| **Rosedale.** White sandstone between seams 6 and 7 | 26.15 | 53.9 | 19.94 |
| **Rosedale.** White sandstone, another locality, between seams 6 and 7 | 25.25 | 51.82 | 22.92 |
| **Rosedale.** Grey sandstone, another locality, between seams 6 and 7 | 53.2 | 29.2 | 17.5 |
| **Rosedale.** Grey sandstone, between seams 5 and 6 | 86.1 | 3.7 | 10.01 |
| **Rosedale.** Grey sandstone, between seams 3 and 4 | 50.05 | 27.05 | 22.9 |
| **Horseshoe Canyon.** White beds, 50′ below volcanic tuff | 61.10 | 16.05 | 22.85 |
| **Horseshoe Canyon.** Buff sandstone, 100′ above marine member | 76.60 | 12.40 | 11.00 |
| **Horseshoe Canyon.** Buff sandstone, 20′ above marine member | 77.85 | 9.95 | 12.15 |
| **Monarch Mine.** White sandstone, 5′ below No. 6 seam | 45.00 | 18.75 | 36.20 |
| **Monarch Mine.** Grey sandstone, 10′ above No. 7 seam | 74.45 | 9.75 | 15.80 |
| **Monarch Mine.** Buff sandstone, 30′ below seam No. 8 | 60.70 | 17.35 | 21.95 |
| **Edmonton.** 5 mi. W. of City, grey sandstone, Upper Middle Ed. | 12.97 | 75.7 | 11.32 |
| **Edmonton.** Near University, grey silty sandstone. Middle Ed. | 80.C | 11.2 | 8.7 |
| **Edmonton.** 4 mi. E. of City, grey sandstone, Lower Middle Ed. | 45.50 | 45.95 | 8.55 |
| **Barons.** W. of Town. Typical Edmonton sandstone | 90.7 | 4.3 | 4.7 |
| **Eagle Butte.** Grey sandstone, 60′ above base of Fox Hills | 91.0 | 4.65 | 4.30 |
| **Willow Creek, Cypress.** Carb. sandstone, 100′ above base of Fox Hills | 76.75 | 14.00 | 9.20 |
| **Willow Creek, Cypress.** Buff sandstone. Base of Fox Hills | 77.50 | 14.20 | 8.85 |

The mineralogy of the sandstones is of unusual character. The predominant clastic is plagioclase between An. 40 and An. 60. Next in abundance is fresh angular quartz. These two constituents make up most of the rock; small amounts of fresh biotite and muscovite, indeterminable grey fragments, possibly hard shale, and decomposed feldspar make up the remainder. The feldspar is angular and relatively fresh; twinning lamellae and sharp borders in the feldspars are common. These features are clearly seen in the photomicrographs B and C of Figure 26. The letters on the photographs indicate roughly the general proportions of feldspar and quartz seen, and the condition of the angular feldspar fragments.

The grains of feldspar and quartz are held in a bentonitic matrix. This is particularly the case in Figure 26B. In Figure 26C the matrix is essentially calcite; the individual grains lie free and uncrowded. Rosiwal measurements on several thin sections show that from 40 to 65 percent of the larger clastics are plagioclase; as high as 80 percent has been recorded.

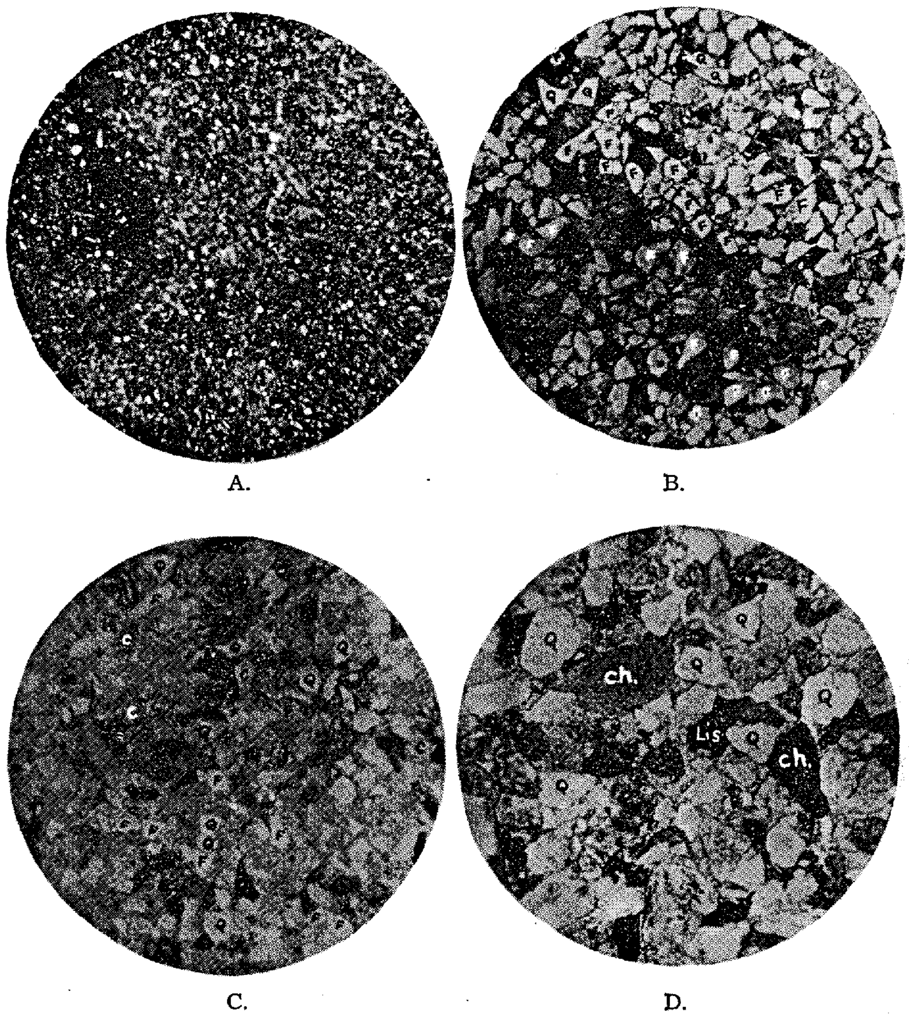


Figure 26.—Photomicrographs of Edmonton and Paskapoo sediments:

A. Volcanic tuff from near Carbon, Alberta. Shows a small group of isotropic glass chards near the centre. Magnification × 26 diameters.

B. Thin section of Edmonton sandstone from 4 miles east of Edmonton. Note the prevalence of feldspar and the loose aggregation. Magnification × 24 diameters.

C. Thin section of Edmonton sandstone from Rosedale, Alberta. Angular grains of feldspar and quartz apparent, similar to B. Magnification × 24 diameters.

D. Paskapoo coarse grained sandstone, Rocky Mountain House, Alberta. Q=quartz; Ch=chert; Lis=limestone; black fragments=shale, etc. Magnification × 24 diameters.

The sands are poor in heavy minerals. The average percentage of minerals higher than 2.69 sp. gr. is 0.215 percent and generally this quantity is largely made of magnetite, hematite and chloritic micas.

The following heavy minerals have been determined in the Edmonton sands of the Red Deer region: anatase, apatite, augite, biotite, brookite, calcite, chlorite, garnet, hematite, hornblende, ilmenite, limonite, marcasite, magnetite, muscovite, pyrite, rutile, topaz, tourmaline and zircon.

None of these minerals occurs in special abundance, and nearly all are of common occurrence in most sedimentary rocks because of their resistance to solution and attrition. Anatase, apatite, augite, brookite, marcasite, pyrite and rutile are rare or very scarce in the samples analyzed.

It is not likely that the heavy minerals of the thick western formations will prove to be of use in correlation. The clastics are all derived from the mountains to the west or from earlier Mesozoic sediments which have been elevated and eroded, and thus tend to show mineralogical similarities rather than differences.

*Clays.*

This rock occurs sparingly in well sorted beds. Considered in total the formation probably contains 30 percent of material of this grain size. In nearly all of the beds the clay is mixed with silt or sand. Pure clay beds are found as partings in the coal seams, or occasionally interstratified with other clastics. Practically all of the Edmonton clays are loosely called bentonite because of their absorbent qualities and extremely small size of particles. Between seams 6 and 7 in the neighbourhood of Monarch mine, there is a 3-foot stratum of very well sorted "bentonite". It lies between a layer of siltstone and a bed of sandstone. The clay is of greenish colour and translucent when damp, and has a tendency to break into coarse flakes. On drying it becomes opaque and cream in colour. Within this layer occur oblong, rounded masses of pure earthy, yellowish lime. These accretions vary from small size up to 6 inches in diameter. They apparently represent differentiation of the original sediment during diagenesis.

There are other limited occurrences of more or less pure clay, but they are not of sufficient importance to merit special discussion here.

*Arenaceous Limestone.*

This is a hard, tough rock, occurring particularly in the Drumheller marine tongue (see Figure 22), where it is highly fossiliferous. Photographs of this stratum are shown in Figures 27 and 28. Thinner beds of similar calcareous rock occur at other horizons, but are of more local extent and without fossils in these instances. There is a gradual gradation from arenaceous limestone to calcareous sandstone in the hard layers that occur at irregular intervals from top to bottom of the Edmonton. Thin sections of the rock from the limy layers show two interesting features. The calcium carbonate in some is the cement for very loosely aggregated plagioclase particles. Where contained in the calcite the plagioclase is remarkably fresh and unaltered. Other sections show recrystallization of calcite in such manner that the calcite has optical continuity over one or more centimeters, and the boundaries between separate crystal

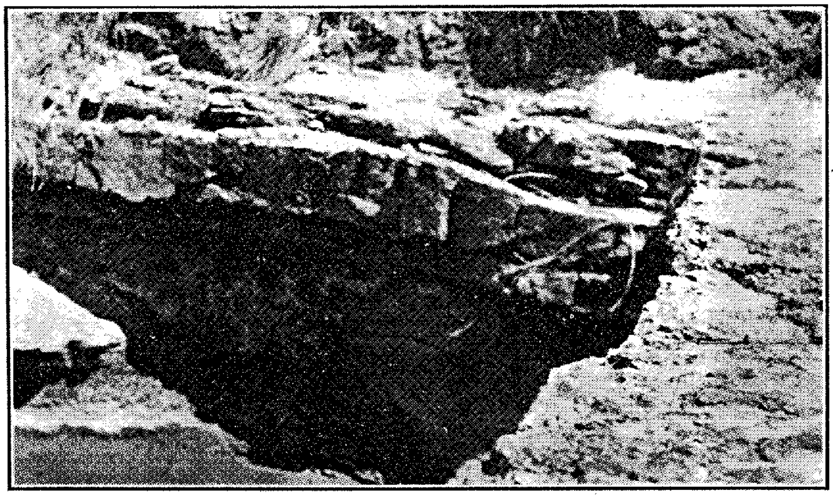

Figure 27.—Arenaceous limestone, Drumheller marine tongue, Edmonton formation, Horseshoe canyon, Kneehills valley.

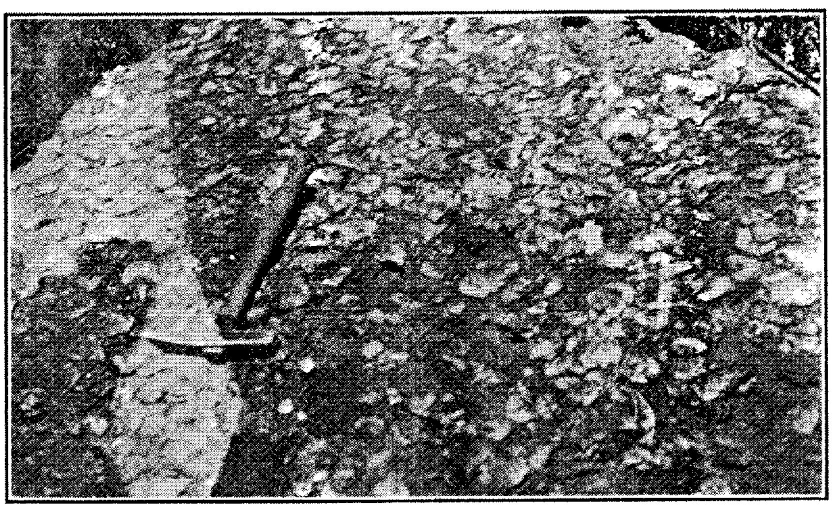

Figure 28.—*Ostrea glabra coalvillensis* on weathered surface, Drumheller marine tongue, Edmonton formation, Horseshoe canyon, Kneehills valley.

individuals are straight lines, irrespective of the boundaries of the included clastic grains. In places the upper limy band of the marine band is essentially a coquina of *Corbicula* shells.

The limy layers of the Edmonton resist erosion to a markedly greater degree than the rocks with argillaceous cement, and by virtue of this they protrude as ledges or from flat-topped buttes.

*Volcanic Tuff.*

This rock was discovered by the author in this area in 1924. It had not been noted in rocks of this age in Alberta previously.

The tuff is a very thin bed, seldom over 8 inches in thickness. Its presence was noted along the Red Deer river for many miles, and up Kneehills creek as far as Carbon. To the south and east it was detected on the north flank of Wintering Hills and on the south slope of Hand Hills. The ash bed is not entirely continuous, but is nearly so. Its stratigraphic position is indicated on Figure 22 and its adjacent beds are mentioned in the discussion of the Middle Edmonton member.

The tuff is a pale grey, massive rock of very fine grain. It resembles a rough-surfaced felsite, or massive limestone. The rock is hard and can be trimmed like an igneous rock. It rings under the hammer. Upon weathering the exposed surface bleaches to a much lighter shade than the unweathered rock. The ash layer does not weather readily but breaks into sharp edged, angular fragments and forms a surface talus. The ash was deposited under water and in some cases shows a roughly horizontal fracture, but more usually is without sign of structure or bedding. The appearance and properties of the ash are uniform wherever it has been observed. A similar thin stratum of ash was discovered by the writer in the Cypress Hills, in rocks which are apparently of the same age as those enclosing the Kneehills Tuff (Figures 30 and 31).

The Edmonton volcanic ash of the Red Deer region and that from Cypress Hills have been analyzed for the essential oxides and have proved to be very similar and of singular composition.

| | ASH Horseshoe Canyon, near Drumheller | ASH Cypress Hills, above Fly lake |
|---|---|---|
| $SiO_2$ | 87.0 | 89.6 |
| $Al_2O_3$, etc | 4.8 | 3.6 |
| CaO | 1.5 | 1.2 |
| MgO | 2.0 | 2.0 |
| $K_2O$ | 0.7 | 0.4 |
| $Na_2O$ | 0.9 | 0.4 |
| Ignition loss | 2.8 | 3.4 |
| | 99.7 | 100.6 |

(Analyzed by Wm. Gerrie, Toronto University, 1927)

The remarkably high percentage of silica in this rock is difficult to explain. No unaltered extrusive rock contains so much silica and so little alumina. The maximum percentage of silica observed in 5 analyses of pumicites by H. S. Washington[17] is 79.48, while the minimum percentage of alumina in pumicite was found to be 11.60. The suggestion is made here that the ash was high in silica as deposited and very porous, and that since deposition the pore space has been taken up by secondary silica in the form of chalcedony or opal, leached from the adjacent beds.

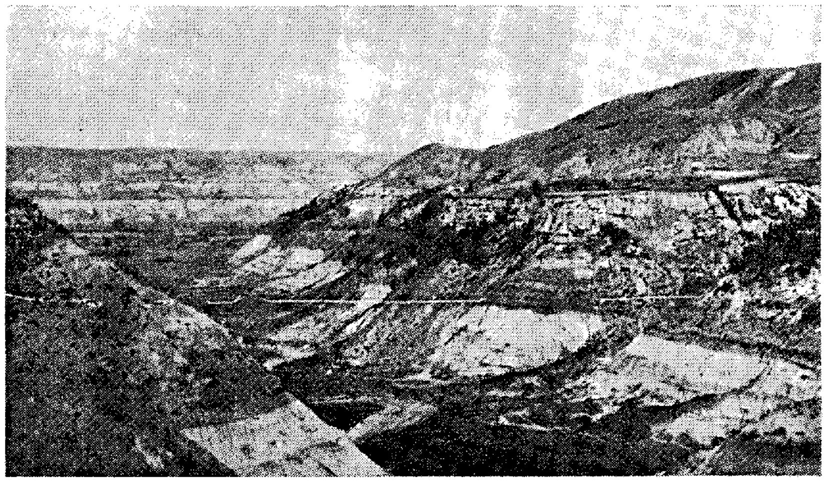

Figure 29.—River channel deposit of early Edmonton age, cutting the bentonitic delta beds for a short distance on the right-hand side of of the valley, East Coulee, near Red Deer river.

Microscopically, this rock is seen to be made up of minute, fresh mineral fragments, quartz and feldspar mainly, with varying proportions of altered glass, all set in a felty groundmass which is isotropic to dimly anisotropic. It is thought that the groundmass is made up essentially of devitrified glass along with minute masses of fibres of redeposited chalcedonic or opaline silica. In the thin section conclusive tests of the matrix matter cannot be made. The presence of vescicular, partly altered glass becomes apparent on close observations at high magnification in thin sections. The characteristic shapes of glass "chards"; long, stringy fragments, crescentic bits or angular particles showing reentrant angles, may be noted among the grains that remain isotropic under crossed nicols. Figure 26A is a photomicrograph of the Kneehills tuff, magnified 26 times and taken through a single nicol. Slightly to the right and above centre a small group of typical chards is visible. The white particles are feldspar and quartz.

The larger fragments average from 0.03 to 0.05 mm. in diameter, and grade from this down to sub-microscopic sizes. The rock is commonly vuggy, the vugs being either filled or lined with chalcedony, or lined with chalcedony and filled with bentonite. Occurrences of the latter kind suggest the derivation of the colloidal clay bentonite from decomposed volcanic glass.

The volcanism that produced this ash was not the only igneous manifestation that occurred in this part of Canada in Upper Cretaceous time. The author has noted the presence of volcanic ash[4] in the Saunders formation at Coalspur, in the Bearpaw formation at Manyberries and Lethbridge, and in the Colorado at several horizons at Skiff, southeast of Lethbridge.

The origin of the Edmonton ash is not yet known. Its fine size makes it possible that the volcano from which it was ejected may have been hundreds of miles away. J. Udden[18] has shown experimentally that dust particles from 1/64 to 1/36 mm. diameter may be carried 1,000 miles by moderately strong winds. The larger particles of the Edmonton ash are from 1/20 to 1/36 mm. diameter. Volcanoes which were active during Edmonton time are known in Montana and possibly west of the Rocky Mountains.

*Clay-Ironstone.*

Iron occurs in association with clays as iron carbonate, and also as oxide in coatings about the other clastics. Thin sections of typical, deep brown clay-ironstone show an oxidized skin of red iron oxide surrounding a core of iron carbonate and clay. In some specimens the unoxidized portion appears to be nearly pure crystalline granular siderite. All gradations from fine-grained clay, with a slight admixture of ferrous oxide, to nearly pure siderite occur. The iron of these hard bands is only red on the surface, when broken open the ironstone nodules are of greenish-grey colour.

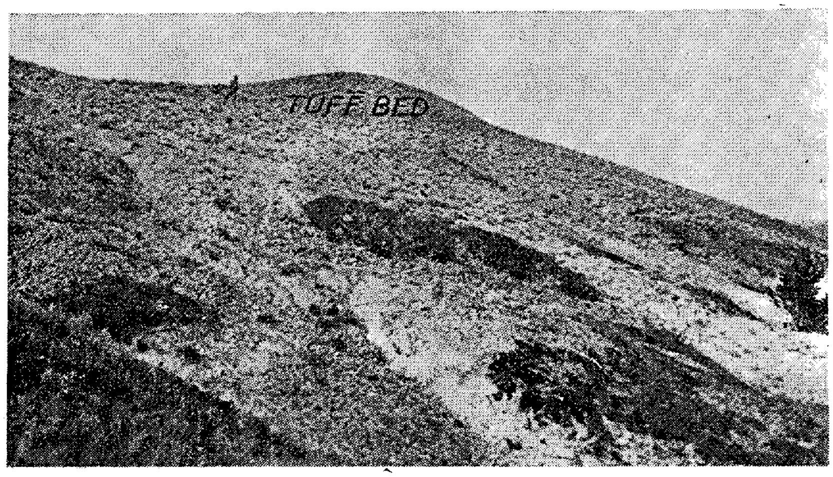


Figure 30.—Outcrop of volcanic tuff and Whitemud beds, near Fly lake, Cypress Hills.

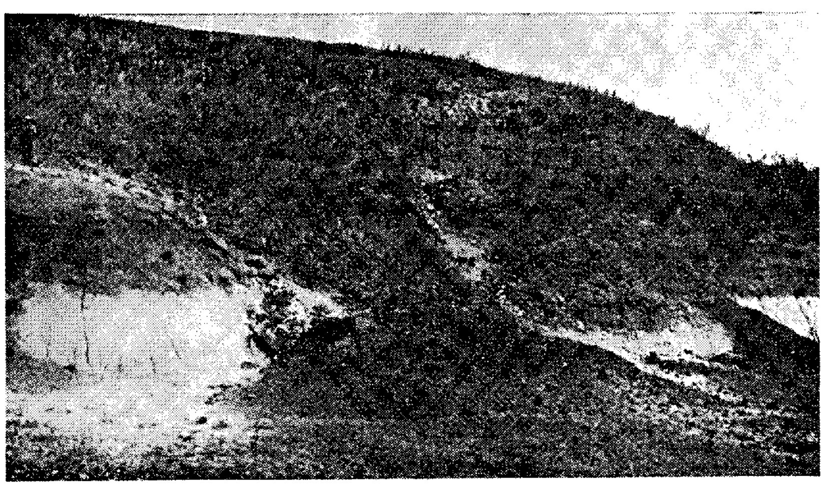

Figure 31.—Outcrop of volcanic tuff, showing relation of tuff with white bentonitic sandstone bed below. Threehills creek, 6 miles from Carbon.

Nodules composed of red oxide and coarser clastic matter occur in small amount. Dinosaur bones are occasionally found encased in iron-bearing matrix of this kind. Such an association of iron and sand probably indicates original sub-aerial surface. Thin strata of red stained to ochrous silts or sands occur in greater amount in the Lower Edmonton member.

*Coal.*

The most important rock type in the Edmonton from the economic viewpoint is coal. As may be seen in Figure 22 coal occurs in 14 seams at intervals throughout the formation. The thickest lie at the top and at the base of the section. Plate III shows the thicknesses and variation in the seams of the Middle and Upper Edmonton*. The seams of the Lower Edmonton in the region of Drumheller are fully described and figured by the senior author[5]. The coal and its composition is discussed in Part One of this report and shown in Plate IV.

The coal beds are not persistent, with mineable coal, over long distances, but the horizons can be traced over very large areas. The coal is replaced in places by carbonaceous silt or sandstone, and the location of mines must be preceded by careful examination of outcrops or by drilling to ascertain the variation in the seam where it is covered. Some of the seams such as the Ardley (No. 14) and Drumheller (No. 1) are of greater extent than the others. The seams in the Middle Edmonton member are discontinuous; the coal in these seams increases to mineable thickness only locally.

The localities at which the detailed coal sections were measured in seams 9, 11, 12 and 14 are listed in Table 6 below and shown on Plate III. The positions of the mines where the coal sections were measured in seams 1, 2, 5 and 7 are listed in Table 3 (Part One) and shown on Plate IV.

The sedimentation of the coal presents interesting aspects. Widespread carbonaceous zones, enriched locally to the rank of coal seams, indicate temporarily emergent conditions of the land, with permanent bodies of water on it, where the seams are now found. The land areas no doubt supported a rich, swampy, forest growth which gradually filled the permanently submerged and land-locked bays and bayous with carbonaceous debris. The filling-in process probably progressed as the growth of vegetation advanced towards the centres of the local depressions. There are many places where clean coal directly overlies clean sandstone without an intermediate "old soil", "root clay" or "under clay". At other points there is evidence of the accumulation of the carbonaceous debris in place.

The clean cut exposures of coal seams and accompanying beds along the Red Deer afford excellent opportunity for studying the sedimentation of coal.

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*It has been found that coal seam sections numbered 11, 12 and 13, on the above drawing were mistakenly placed under Coal Seam No. 14, and belong under Coal Seam No. 12.

TABLE 6.

**List of Detailed Sections of Coal Seams, Middle and Upper Edmonton, on Plate III.**

| Section Number | Locality | Sec. | Tp. | R. | Name of Mine, etc. |
|---|---|---|---|---|---|
| **Seam No. 14 (Ardley seam)** | | | | | |
| 1 | W. of Ardley | 2 | 38 | 24 | (River outcrop) |
| 2 | Ardley | 19 | 38 | 23 | (River outcrop) |
| 3 | Ardley | 20 | 38 | 23 | Ardley Hardite mine |
| 4 | Content bridge | 34 | 38 | 22 | (River outcrop) |
| 5 | Bullocksville | 33 | 38 | 23 | Lewis mine |
| 6 | Breda P.O. | 13 | 36 | 22 | (River outcrop) |
| 7 | Trochu | | | | Justrite mine |
| 8 | Three Hills | 36 | 31 | 24 | Palisade Coal Co. |
| 9 | Three Hills | 36 | 31 | 24 | Ellis Coal Co. |
| 10 | W. of Big Valley | 22 | 35 | 21 | (River outcrop) |
| *11 | Big Valley | 26 | 35 | 20 | Bigton Coal Co. |
| *12 | Big Valley | 26 | 35 | 20 | Vimy mine |
| *13 | Big Valley | 1 | 36 | 20 | Big Valley Coal Co. |
| 14 | W. of Scollard | 18 | 34 | 21 | Wooden's mine |
| 15 | W. of Scollard | 13 | 34 | 22 | Yard's mine |
| 16 | Rowley | 12 | 32 | 21 | Hodgson's mine |
| 17 | Hand Hills | 28 | 30 | 17 | Delia mine |
| 18 | Hand Hills | 30 | 29 | 17 | Coulter mine |
| **Seam No. 12 (Thompson seam)** | | | | | |
| 19 | E. of Lousana | 36 | 36 | 22 | (River outcrop) |
| 20 | E. of Thompson's mine | 32 | 35 | 21 | (River outcrop) |
| 21 | W. of Big Valley | 21 | 35 | 21 | (River outcrop) |
| 22 | Big Valley creek | 11 | 35 | 21 | (River outcrop) |
| 23 | S. of Big Valley | 9 | 35 | 21 | (River outcrop) |
| 24 | W. of Scollard | 18 | 34 | 21 | (River outcrop) |
| 25 | W. of Big Valley | 5 | 36 | 21 | (River outcrop) |
| **Seam No 11 (Carbon seam)** | | | | | |
| 26 | E. of Ardley | 10 | 38 | 22 | Blade's mine |
| 27 | E. of Ardley | 26 | 37 | 22 | (River outcrop) |
| 28 | E. of Ardley | 26 | 37 | 22 | Paton's mine |
| 29 | E. of Trenville | 26 | 36 | 22 | (River outcrop) |
| 30 | W. of Scollard | 18 | 34 | 21 | (River outcrop) |
| 31 | W. of Morrin | 6 | 31 | 21 | Trentham mine |
| 32 | Carbon | 14 | 29 | 23 | Shannon Coal Co. |
| 33 | Carbon | 12 | 29 | 23 | Peerless mine |
| 34 | Carbon | 16 | 29 | 23 | New Peerless mine |
| 35 | W. of Carbon | 12 | 29 | 24 | Boring test |
| 36 | Carbon | 15 | 29 | 23 | Fife Coal Co. |
| 37 | Threehills creek | 18 | 30 | 22 | (Outcrop) |
| 38 | Ghostpine creek | 28 | 30 | 22 | (Outcrop) |
| 39 | Horseshoe canyon | 27 | 28 | 21 | (Outcrop) |
| 40 | S. of Hesketh | 3 | 29 | 22 | (Outcrop) |
| 41 | N. of Rockyford | 22 | 27 | 23 | Mennonite mine |
| 42 | N.E. of Rosebud | 33 | 27 | 21 | Debrinski mine |
| 43 | Rosebud | 20 | 26 | 21 | Medloski mine |
| 44 | Standard | 2 | 25 | 22 | Costello mine |
| **Seam No. 9 (Stauffer seam)** | | | | | |
| 45 | Stauffer ferry | 28 | 31 | 21 | (River outcrop) |
| 46 | Beleriot ferry | 3 | 31 | 21 | (River outcrop) |
| 47 | Mouth of Threehills creek | 34 | 29 | 21 | (River outcrop) |
| 48 | Kneehills creek | 15 | 29 | 21 | (River outcrop) |
| 49 | Beynon | 31 | 27 | 20 | Johnson mine |
| 50 | Sheerness (No. 1) | 18 | 29 | 12 | Sheerness mine |
| 51 | Nevis (No. 12 or No. 11) | 11 | 39 | 22 | Nevis mine |

* Might be a lower seam.

*Sedimentation and Intepretation of the Deposits.*

The analyses shown in Table 5 indicate that the processes of sorting were not effective in separating the finer grades of sediment. No arenaceous sediment of greater than 1 mm. diameter reached this area in Edmonton time. Most of the clastic matter is less than 0.5 mm. in diameter. It is estimated that 30 percent of the sediment of the Edmonton is colloidal clay, 50 percent silt and 10 to 15 percent of sand grade. These constituents are intimately commingled.

The two features noted above, fine grain size and lack of sorting, are characteristic of the entire formation. Other important sedimentation phenomena which are shown in the Edmonton are the distinctive structures of delta origin, the lensed nature of the bedding, the thin layers of calcite-cemented sand and clay-ironstone bands. The fossil occurrences in the series also indicate delta conditions.

The mechanical composition of the thicker beds of the series does not vary to an important degree from top to base of the formation, except that there is a slight predominance of silts and clays in the lower part. There are also more calcareous and ferruginous bands in the basal half of the formation. In the lower part also the sedimentary structures are more pronouncedly of delta type than they are in the upper half. The commoner evidences of delta deposition are foreset bedding, lensed arrangement, local thin cross-bedded layers, and interlamination of strata of different mechanical composition on a large scale, and at an angle to horizontal (Figures 9 and 10). The occurrence of isolated lenses of crossbedded coarser sand cemented to a tough, resistent rock by calcite is strong presumptive evidence of temporary emergence, and concentration of cementing salts through evaporation in pools. River channel deposits cutting the ordinary stratification are also evidence of this type of deposition, although such deposits also generally indicate sub-aerial, flood-plain deposition.

Between Drumheller and Rosedale, and below seam No. 6, several exposures show foreset bedding truncated above by horizontal beds. Large sweeping inter-lamination of thin strata indicates changing currents and instability in the basin of deposition; sediments are swept back and forth and currents are imperfectly controlled by temporary bars and channels. Deposition of this kind is characteristic of broad flat deltas, and is not known in other normal types of basins. Examples of this type are seen in the beds at the mouth of Rosebud river below the horizon of seam No. 5 (Newcastle seam). Marked lensing of beds is also evidence of the type of deposition mentioned above. The pale grey sandstones and dark silty shales of the Lower Edmonton offer strong contrast in lensing beds and form lucid illustrations of this feature. Evidences of river channels of Edmonton age that cut the adjacent strata are found, but are not of common development. A good example occurs in East Coulee about the horizon of seam No. 1 (Figure 29) and also along the Red Deer river due west of Morrin. They are indicated by sudden changes in the lithology for limited distances. The sandstone of the channel filling is coarse and is less bentonitic than the adjacent beds.

Delta beds are deposited in a realm of unstable shore conditions. There is frequent interruption of deposition and possibly frequent exposure of the top layers of top-set beds to the air. Effects of such conditions are left in the strata so deposited. Local thin layers of wave- or stream-crossbedded sands that have calcareous or ferruginous cement result from these alternations. The prevalence of flat-topped buttes with hard sandstone caps in the Edmonton is notable, especially in the Drumheller vicinity (Figures 4, 18, 21).

No adequate explanation for such localized lenses has been found in the literature, and the author offers the following explanation of their origin. The process might be called "pool induration", a term for the induration of local beds of sands through concentration of cementing salts in shallow pools during periods of temporary emergence. The freshly deposited sands and silts of the topset beds raised slightly above the shore water-level, or left exposed due to slight lowering of water-level, did not drain readily due to the presence of bentonite, hence the water which was held on such surfaces was eventually evaporated with resulting concentration of lime and iron salts in the residue. Local drainage into the shallow pans brought surface sands, and possible winds blowing over the dry surface contributed sands that finally silted up the residual pools of the delta flats. Surface runoff into the pools with concurrent evaporation no doubt aided in concentrating abnormal amounts of cementing salts, which cemented the clastics of these local lenses or thin strata, and left them as harder members than the surrounding beds. It is possible that such a mode of concentration will account also for the ironstone bands in the otherwise iron-poor sandstones.

The repeated occurrence of coal in the series, the seams of which are of local extent generally, is likewise evidence of the delta character of the site of deposition.

In general delta deposits are poor in fossils of either land or marine life. In this regard the Edmonton formation is characteristically deltaic. Marine fossils occur only in one well-defined zone in abundance. Freshwater shells are found in small number and not at definite horizons. The remains of dinosaurs are found from near the base to well above the middle of the formation. The emergent delta flats apparently formed the habitat of dinosaurs.

*Origin of Unusual Sediments in the Edmonton Formation.*

Some of the more important aspects of the origin and environmental conditions of the unusual sediments of the Edmonton will be discussed according to the author's interpretation of them.

Most of the clastic material of the Edmonton originated in terrains to the west of the present deposits. It was laid down prior to the building of the outer ranges of the Rocky Mountains. The nature of the sediments suggests their derivation from highlands probably in the region now occupied by the Selkirk mountains and the Interior plateau of British Columbia. Re-elevation of these or quickened erosion due to climatic change caused a change from the fine grained sediments of the Bearpaw to the relatively coarser clastics of Edmonton time. Elevation and erosion of older Mesozoic rocks of the region now occupied by the front ranges possibly contributed to the filling of the Edmonton basin. The Edmonton beds appear to have been laid down along a shoreward zone of the Fox Hills sea. This zone was probably a delta plain of the composite type and was submerged concurrently with the deposition of the strata.

The presence of fresh plagioclase and fresh ferromagnesium mineral in such abundance in the formation, as well as the occurrence of the unusual colloidal clays and volcanic ash noted, suggests the probability that a considerable proportion of the sediments is of direct volcanic origin.

The unsorted nature of the unusual plagioclase sand and silts with highly siliceous colloidal clays implies that the streams were slow, but that the sediments were rapidly deposited, probably through the influence of electrolytes in the static waters encountered by the streams. The concentration of iron and calcite in thin beds at irregular intervals in the formation and the deposition of coal seams indicate unstable relations of sedimentation-level to water-level, which is a characteristic of delta deposition.

The rocks show evidence of being deposited during a time of moist, warm climate. There is no evidence of extreme dessication, the evidence of coal seams in abundance indicating a tendency toward the other extreme. The temperatures were propitious for the livelihood of such coldblooded animals as the reptiles, and in the sea for abundant *Ostrea* and similar molluscan types. A climate like that of the Gulf of Mexico at the present is probably nearly comparable with that of the Edmonton of Alberta in the Cretaceous.

Feldspar Clastics.—This occurrence is of interest by reason of the fact that this mineral is usually first to decompose in the weathering of ordinary igneous rocks. These sands must have come from areas of intermediate to slightly basic rocks having a predominance of plagioclase over quartz and orthoclase. They may have come from rapidly weathered older flows or tuff accumulations to the west. If these feldspar sands were derived from the disintegration of intrusive rock areas, the sands indicate rapid erosion and runoff and relatively short transportation.

Colloidal Clays.—It has been mentioned in the discussion of the mechanical constitution of Edmonton rocks that material of this size is present to approximately 30 percent of the total rock. Its intimate admixture with coarser clastics indicates its concurrent deposition with them. Two possibilities are that it represents the final decomposition product of feldspars, or that it is decomposed volcanic glass. In view of the presence of abundant fresh feldspar, the former assumption seems barely tenable. The occurrence of a bed of volcanic tuff in the Edmonton, and the known occurrence of formations in Montana made up entirely of andesitic tuff, makes the possibility of the volcanic origin of the Edmonton bentonite quite strong.

Volcanic Ash.—The source and origin of this rock is not definitely known. Its possible transportation from distant regions, such as Montana, or west of the Rocky Mountains has been mentioned. Another possible origin is in small volcanic vents which may have existed in the western foothills in pre-Paskapoo time, and which may have been eroded and obscured when the Paskapoo was laid down. The material is mixed with some water-carried detritus but is essentially composed of the fine ejectamenta of a volcano.

Coal.—Edmonton coal has been discussed in Part One. This coal apparently originated from the carbonaceous debris of vegetation that grew rapidly on the unstable delta plains described above. Although evidence exists of *in situ* accumulation, other evidence indicates that the vegetal material of some of the coal seams was carried a short distance from the site of growth and deposited on clean sandy or mud floors as a horizontally bedded sediment. Deposition under water is indicated by the occurrence of widespread thin, clastic partings in some of the seams, such as the Ardley seam and the Drumheller seam, (Plates III and IV).

There appears to be no major distinction in the type of coal present in the Edmonton from top to bottom of the series. Its commercial merits depend on physical conditions not directly involved in the origin of the coal.

Clay-Ironstone and Calcitic Layers.—In the discussion of the sedimentation the mode of origin of these bands has been mentioned. An affinity between iron salts and calcium was apparently in effect during the diagenesis of the sediments. This has caused the segregation of these elements in the sands and finer strata as layers or nodules or lenses at irregular intervals. During rapid deposition there was no segregation of the iron and calcium content of the material deposited. Segregation and concentration apparently took place during quieter periods in the deposition process. A probable genesis of the hard calcite-cemented layers and ironstones has been suggested in the discussion on "pool induration" in the section on sedimentation.

Calcium and iron do not occur in the Edmonton in extraordinary amounts; only special conditions favouring concentration and segregation of them has caused their prominence in the sedimentary series of the Edmonton formation.

General Conclusions.—From a consideration of all the evidence of lithology, sedimentary structures, fossil content and stratigraphic relationships, it is concluded that the Edmonton was deposited as a long and relatively broad delta deposit. Several distributaries must have contributed to its building. It may be regarded as having been a very large composite delta. The peculiarities of the sediments have been discussed; the presence of ash, bentonite and abundant easily decomposed primary minerals suggests a volcanic origin for much of the clastic matter. The sandstones as constituted may be regarded as fine-grained arkoses. The unusual mechanical aggregation is of particular interest and when fully interpreted will add to our knowledge of the former geography.

The problem of the genesis of the bentonite and of the plagioclase in this formation is as yet unsolved, and the origin of the ash remains obscure.

## CHAPTER VII.

# DETAILED PALAEONTOLOGY OF THE EDMONTON FORMATION

### ENVIRONMENT AND RELATIONS OF FAUNAS TO PHYSICAL HISTORY OF THE EDMONTON

The Edmonton rocks represent deposits which accumulated under deltaic conditions mainly, the area they now occupy having undergone continued, though irregularly interrupted subsidence during the period of accumulation. The nature of the deposits indicates successive periods of subsidence followed by times of rapid sedimentation, then "still stands", when subsidence was arrested and the shoreline advanced far seaward.

These conditions favoured the entombment of a very varied fauna and flora. Following the periods of more rapid subsidence, which led to the covering of the wide-spread vegetal accumulations, salt waters encroached and left the shells of marine animals and plants. During the times of "still stand" and advance of the shoreline seaward, freshwater organisms and finally abundant plants and land-dwelling animals occupied the area and left their remains, which were preserved as a result of subsequent subsidence of the area and renewed sedimentation.

The faunal and floral evidence bears out the above conclusions. A limited flora, together with freshwater molluscs and vertebrates characterize the periods of "still stand", and a distinctly marine fauna marks the less extensive deposits of the marine advance.

### INVERTEBRATA

*General Discussion.*

Little attention has been paid hitherto, to the invertebrates of the Edmonton formation. Several species of freshwater and brackish-water forms have been listed in geological reports on the formation, but the reference of species to horizon and locality has not been sufficiently exact, nor have all the known species been enumerated. The following lists and descriptions summarize the results previously obtained and indicate the additional data of the invertebrate fauna that have been obtained by the author.

The formation was deposited, for the most part, under varying conditions; marine, freshwater and subaerial deposits are intimately associated. Freshwater and terrestrial invertebrates occur from bottom to top of the formation, nowhere abundant, but more commonly found in scattered spots and in small numbers.

A consideration of this limited molluscan fauna gives some basis for an interpretation of the probable conditions of deposition of the Edmonton. There are ten families of *Mollusca* represented, of which eight are freshwater dwellers and two families, terrestrial *Pulmonates.* The collection embraces two families of Pelecypoda (one *Prionodesmacea;* one *Teleodesmacea*) and eight families of Gastropoda (four *Ctenobranchiata;* four *Pulmonata*), twenty-nine species in all.

This limited fauna from such an extensive formation as the Edmonton indicates two things mainly: firstly, a singular isolation of this basin of deposition from other contemporaneous areas undergoing sedimentation and bearing much more varied molluscan faunas, and secondly, very stable and uniform conditions of environment for a long period of time in this region.

The stratigraphic value of these species must still be regarded as slight although it is probable that the *Mollusca* will become of use in local correlation when the details of their varietal differences are better known. The genera range from early Montana time far into the Tertiary, and in some cases extend to the Recent.

TABLE 7.

**Edmonton Marine Fauna Compared with Related Faunas**

| | | **Formations Compared Faunally** | | | |
|---|---|---|---|---|---|
| **Genus** | **Species** | **Edmonton** | **Belly River** | **Cannon-ball** | **Fox Hills** |
| *Conopeum* | *bicystosum* | X | ...... | ...... | X |
| *Ostrea* | | X | X | X | ? |
| " | *glabra* | X | X | ...... | ...... |
| " | " var. *lata* | X | X | ...... | ...... |
| " | " var. *coalvillensis* | X | ...... | ...... | ...... |
| " | " var. *expansa* | X | ...... | ...... | ...... |
| " | " var. *ponderosa* | X | ...... | ...... | ...... |
| " | *auriculata* | X | ...... | ...... | ...... |
| *Exogyra* | | X | ...... | ...... | ...... |
| " | *incipiens* | X | ...... | ...... | ...... |
| *Nucula* | | X | ...... | X | X |
| " | *subplana* | X | ...... | X | X |
| *Cucullaea* | | X | ...... | X | X |
| " | *shumardi* | X | ...... | X | X |
| *Anomia* | | X | X | ...... | ...... |
| " | *micronema* | X | X | ...... | ...... |
| " | cf. *perstrigosa* | X | ...... | ...... | ...... |
| *Mytilus* | | X | X | ...... | X |
| " | *albertensis* | X | ...... | ...... | ...... |
| *Modiola* | | X | ...... | X | X |
| " | *dichotoma* | X | ...... | ...... | ...... |
| *Crenella?* | | X | ...... | X | X |
| " | *elegantula* | X | ...... | ...... | X |
| *Volsella* | | X | X | ...... | X |
| " | *meeki* | X | X? | ...... | X |
| *Corbicula* | | X | X | X | X |
| " | *cytheriformis* | X | X | X | X |
| " | *occidentalis* | X | X | ...... | X |
| *Callista* | | X | ...... | X | X |
| " | *deweyi* | X | ...... | X | X |
| " | *nebrascensis* | X | ...... | X | X |
| *Corbula* | | X | X | X | X |
| " | *subtrigonalis* | X | X | ...... | X |
| " | *perangulata* | X | X | ...... | ...... |
| *Panope* | | X | ...... | X | X |
| " | *curta* | X | ...... | ...... | ...... |
| " | *simulatrix* | X | ...... | X | ...... |
| *Lunatia* | | X | ...... | X | X |
| " | *obliquata* | X | ...... | X | X |
| " | *occidentalis* | X | ...... | ...... | X |

The marine invertebrates are of much greater significance in that they are confined to a known, local horizon, and, as a fauna, can be correlated with Upper Cretaceous faunas in other regions, notably eastern Montana and the Dakotas.

This fauna is small in number of genera as compared with related formations farther southward, containing only twenty species belonging to fourteen genera, while the comparable Fox Hills fauna[19] [20] embraces approximately one hundred and seven species. This disparity is accounted for by the fact that the marine deposits of the Edmonton represent a very limited incursion of the sea, the duration of which was, undoubtedly, much too short to permit the immigration of representatives of all the forms found in Montana. Table 7 gives a general view of the relations of this fauna to the faunas of the subjacent and the related formations elsewhere.

The close comparison with the Fox Hills fauna is at once obvious and suggests the equivalence of the Edmonton and Fox Hills. About 92.5 percent of the genera of the Edmonton are known in the Fox Hills, while 60 percent of the species are common. This percentage would be higher were it not for the small total of species in the Edmonton, and the fact that several of these, though closely related, are defined as new species. Only 71.3 percent of the Edmonton genera occur in the Cannonball, and 40 percent of the species. The high percentage of common genera in the three formations indicates their close relation.

It seems likely that with more collecting, and palaeontological work on other Edmonton areas many more genera will be found which will make the comparison with the Fox Hills still closer.

With the exception of *Ostrea, Modiola, Corbicula* and *Panope,* which may be regarded as belonging to marine or brackish-water environment, the remainder of the marine fauna listed below are characteristic salt water forms. The absence of *Scaphites, Placenticeras* and *Lingula* which occur in the Bearpaw, the underlying formation, and in the Fox Hills may be due to the littoral nature of this fauna.

*List of Invertebrate Fauna.*

The invertebrate fauna of the Edmonton in this district is as follows:

FRESHWATER AND TERRESTRIAL

PELECYPODA

**Prionodesmacea**

UNIONIDAE

*_Unio danae,_ M. & H.
* " _consuetus,_ Whit.
* " _minimus,_ Warren
* " _sandersoni,_ Warren
" _priscus,_ M. & H.
" _senectus,_ White
" _albertensis,_ Whit.

**Teleodesmacea**

CYRENIDAE,

*Sphaerium recticardinale,* M. & H.
" *beskethense,* Warren

GASTROPODA

**Ctenobranchiata**

VIVIPARIDAE,

*Vivipara conradi,* M. & H.
" *reynoldsanus,* M. & H.
" *prudentius,* White
" *trochiformis,* M. & H.
*Campeloma sp.
" *producta,* White

VALVATIDAE

*Valvata filosa,* White
" *bicincta,* Whit.

PLEUROCERIDAE

*Goniobasis nebraskensis,* M. & H.
" *tenuicarinata,* M. & H.
" *convexa,* M. & H.
* " sp.

HYDROBIIDAE

*Hydrobia* sp.

**Pulmonata**

BULIMULIDAE

*Thaumastus limnaeiformis* var. *tenuis,* Warren
" *limnaeiformis,* M. & H.

LIMNAEIDAE

*Acroloxus minutus,* M. & H.
" *radiatulus,* Whit.
*Limnaea tenuicostata,* M. & H.

PHYSIDAE

*Physa copei,* White
" *canadensis,* Russel

HELICIDAE

*Patula angulifera,* Whit.
" *obtusata,* Whit.

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* These species marked by an asterisk were collected by the author along the Red Deer river in the area under discussion; the others are from rocks of Edmonton age from this and other districts in Alberta and are noted in other reports.

MARINE

BRYOZOA

**Cheilostomata**

MEMBRANIPORAE

*Conopeum bicystosum* sp. nov.

PELECYPODA

**Prionodesmacea**

OSTREIDAE[a]

*Ostrea glabra,* M. & H.
* " *glabra lata,* var. nov.
* " *glabra coalvillensis,* var. nov.
* " *glabra expansa,* var. nov.

NUCULIDAE

*Nucula suplana,* M. & H.

PARALLELODONTIDAE

*Cucullaea shumardi,* M. & H.

ANOMIIDAE

* ? *Anomia micronema,* M.
*Anomia cf. *perstrigosa,* Whit.

MYTILIDAE

*Mytilus albertensis,* Warren
*Modiola dichotoma,* Whit.
* ? *Crenella elegantula.* M. & H.
*Volsella meeki,* E. & S.

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Footnote[a]—A discussion of *Ostreidae* of Alberta is given on page 82.

**Teleodesmacea**

CYRENIDAE
*Corbicula cytheriformis, M. & H.
* " occidentalis, M. & H.
* " occidentalis var. ventricosa, var. nov.

VENERIDAE
*Callista deweyi, M. & H.
* " nebraskensis, M. & H.

CORBULIDAE
*Corbula subtrigonalis, M. & H.
* " perangulata, Whit.

SAXICAVIDAE
*Panope ? simulatrix, Whit.
* " curta, Whit.

GASTROPODA

**Ctenobranchiata**

NATICIDAE
*Lunatia obliquata, (Hall & Meek)
* " occidentalis, M. & H.

*The asterisk indicates forms collected from the Red Deer river region by the author; most of these have not been reported from this region prior to 1924. All of the marine forms are from a thin zone which constitutes a reliable horizon in the region, and is named the Drumheller marine tongue.

The marine fauna in this area is much more interesting and important than is the freshwater fauna. It allows of correlation and also contains elements in the fauna which render the Edmonton quite distinct, palaeontologically, from the Belly River formation, which is easily confused with the former in the field, when outcrops are limited. Fossil *Ostreidae* are the most numerous shells found and, as the list indicates, several new forms have been distinguished. Descriptions of these and other new species with remarks on their relationship are given below.

*Discussion of the Family Ostreidae.*

A consideration of the oysters of the Edmonton necessarily involves a study of all the species in the Upper Cretaceous of Alberta. In this region but two species, *O.glabra* and *O.subtrigonalis,* have been generally recognized, although two other species, *O.patina* and *O.inornata,* have been identified from the Bearpaw(2). In the Montana field, likewise, Stanton and Hatcher record(1) only the above species. This limitation to a few species is in part due to the statement of C. A. White that several species mentioned in the United States reports, (*O.insecuris,* White; *O.coalvillensis,* Meek; *O.wyomingensis,* Meek; and *O.arcuatilis,* Meek) are founded on insecure bases and that they are all to be ascribed to *O.glabra*(21).

The present study is based on a large collection in the Royal Ontario Museum and on the material obtained by the author from the Edmonton formation in 1924 and 1926.

In examining this material it is found that certain specific differences can be recognized, and that other differences are at least of varietal significance.

In the case of *O.glabra* the departures from the type seem to follow gradational lines; in consequence, the clearly recognizable end-members are herein considered as varieties only. These varieties, as well as the several American species eradicated by White, diverge materially from *O.glabra* as originally described by Meek and Hayden. Furthermore the extremes of the series are so distinctly different that the author would be inclined to regard them as distinct species were it not for the opinion of C. A. White.

An important reason for assigning different names, whether of variety or species, to the forms occurring in the Cretaceous beds in Alberta lies in the fact that the various types seem to be characteristic of distinct horizons. The forms recognized and their stratigraphic positions are indicated in the following table.

TABLE 8.
**Stratigraphic Distribution of the Ostreidae in the Upper Cretaceous of Alberta**

| Period | Series | Formation | Name | General Locality |
|---|---|---|---|---|
| Upper Cretaceous | Montana | Edmonton | *Ostrea glabra* (rare) | Drumheller |
| | | " | " " *expansa* | " |
| | | " | " " *coalvillensis* | " |
| | | " | " " *lata* | " |
| | | St. Mary River | *Ostrea glabra* (rare) | Monarch |
| | | " " | " " *coalvillensis* | " |
| | | " " | " *auriculata* | " |
| | | " " | " *glabra ponderosa* | " |
| | | " " | *Exogyra incipiens* | " |
| | | Bearpaw shales | *Ostrea patina* | Sage creek |
| | | " " | " *inornata* | St. Mary river (near mouth) |
| | | " " | " *subtrigonalis* | Oldman river and Battle river |
| | | Pale Beds | *Ostrea inornata* | St. Mary river (near mouth) |
| | | | " *subtrigonalis* | Milk river ridge |
| | | | " *glabra* | Bullshead |
| | | Foremost | *Ostrea glabra* | Bow Island and Medicine Hat |
| | | | " " *lata* | Bow Island and Medicine Hat |
| | | | " *subtrigonalis* | Bow Island and Medicine Hat |
| | | Pakowki shales | *Ostrea glabra* | Pakowki coulee |

It is apparent that *O.glabra* and *O.subtrigonalis* are essentially Belly River-Pierre forms, rarely occurring at higher levels. On the other hand the variety *O.glabra coalvillensis,* the variety *O.glabra ponderosa* and the species *Exogyra incipiens* are characteristic of the Edmonton (St. Mary River).

## DESCRIPTON OF SPECIES

### Genus **OSTREA** Linn.

### *Ostrea subtrigonalis*, Evans and Shumard

Plate V—Figures 20-24

*Ostrea subtrigonalis,* Evans and Shumard, Trans. Acad. Sci., St. Louis, 40 (1857).

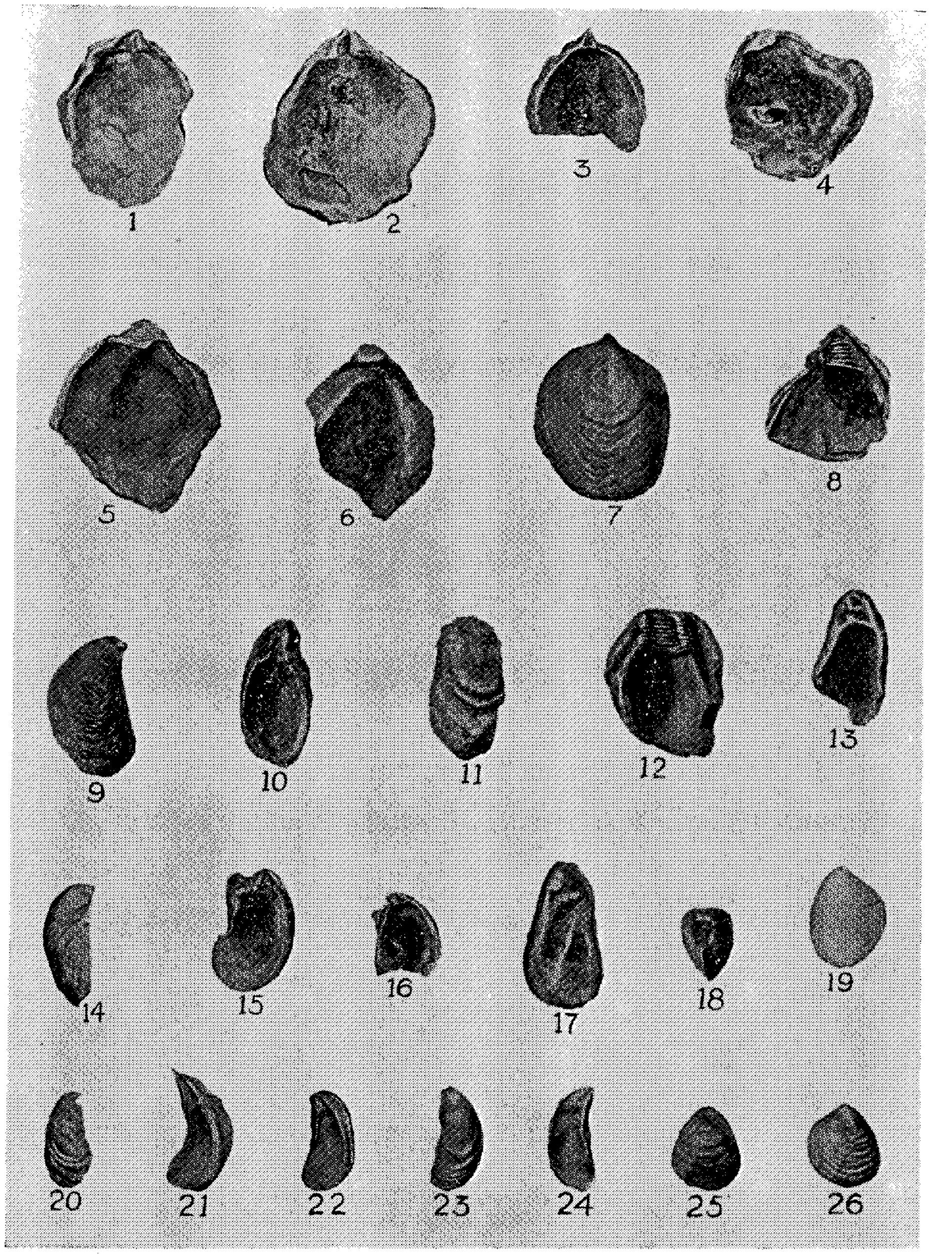
This species occurs widely over the south part of Alberta and is common also in the western States. The species is remarkably uniform in its size and shape, as well as in the direction of twist in the beaks. Of 835 specimens examined the 375 left valves all showed the beaks twisted to the left. The average length is 1.75 inches. Of the specimens 460 were right valves and of these only 1.7 percent showed torsion of the beaks in the opposite direction. This uniformity of shape and direction of torsion is not seen in *O.glabra.*

## EXPLANATION OF PLATE V.



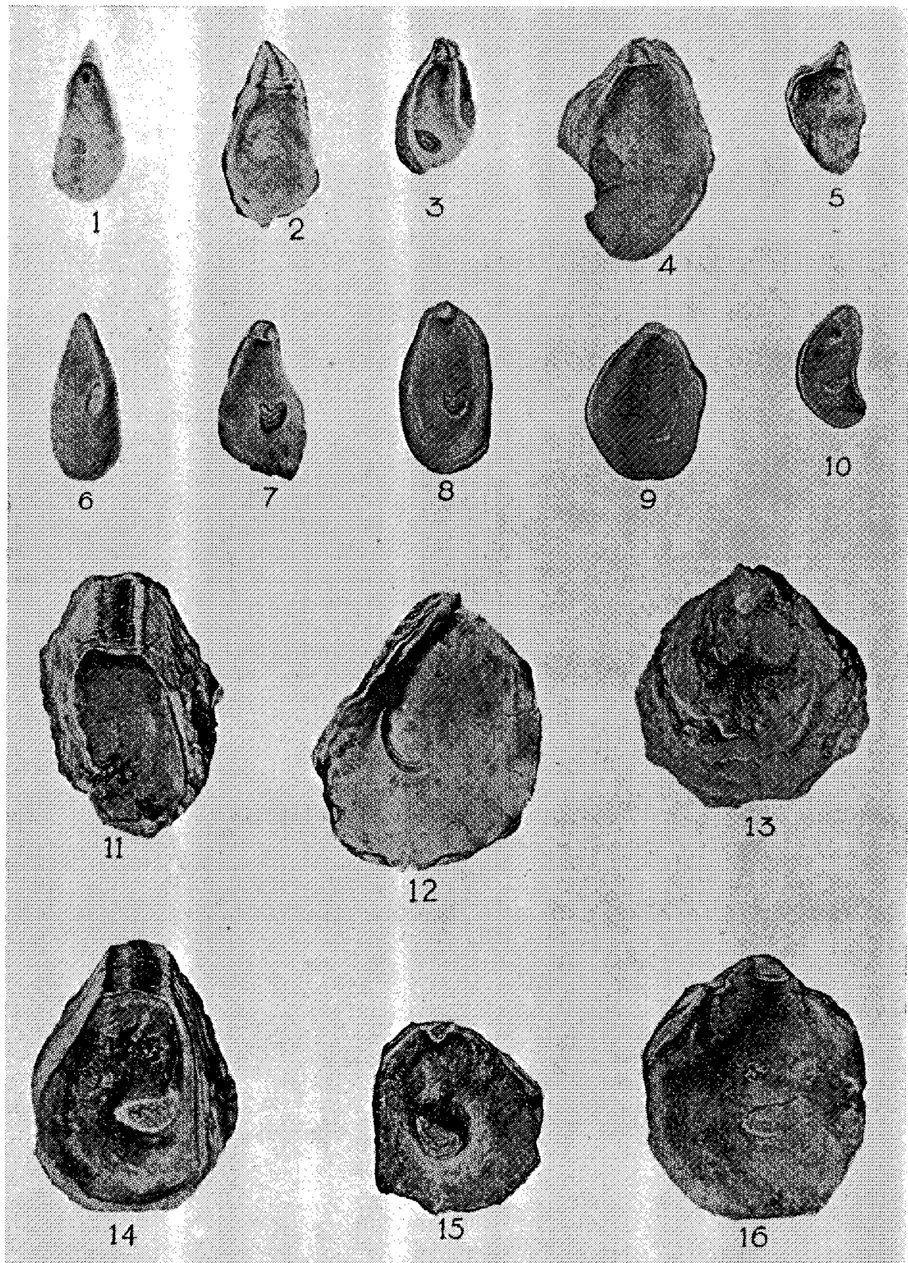
## EXPLANATION OF PLATE VI.

PLATE V.



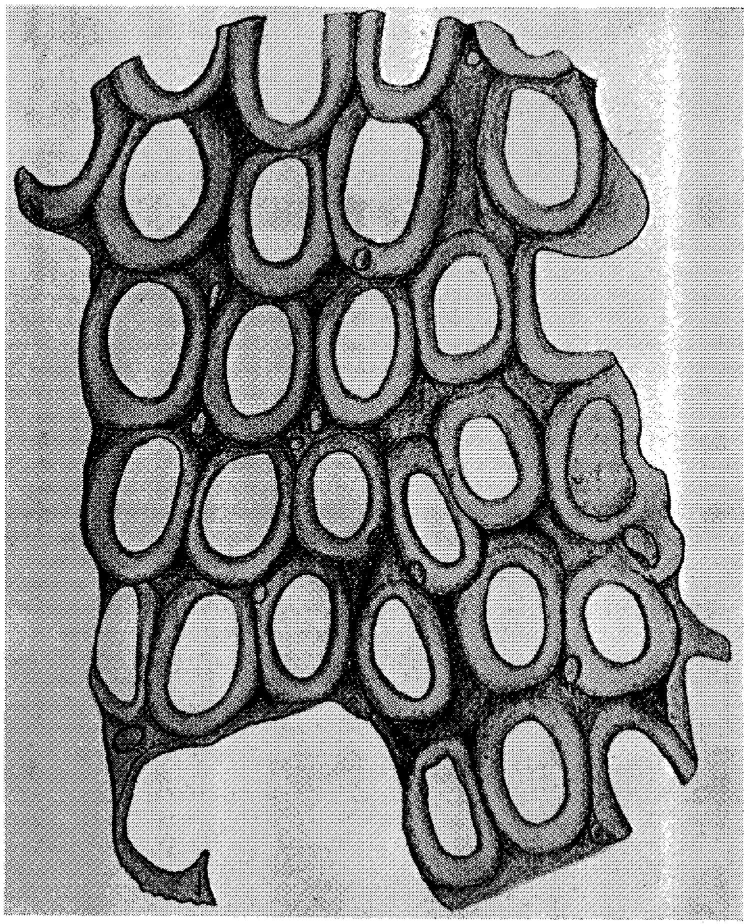

Illustrations of Edmonton and Belly River fossils×7/16.

PLATE VI.



Illustrations of Edmonton fossils×7/16.

PLATE VII.



Bryozoan, *Conopeum bicystosum* sp. nov. ×48.

The species figured are from the Pale Beds, Belly River, Upper Cretaceous; mouth of St. Mary river, Alberta.

*Ostrea glabra*, Meek & Hayden
Plate VI—Figures 1-10

*Ostrea glabra*, Meek and Hayden, Proc. Acad. Nat. Sci. Phil., Vol. 9 (1857), p. 146.

Numerous shells from the Belly River beds agree so closely with the description and figures of Meek and Hayden that the author has no hesitation in ascribing them to this species.

The several shells figured indicate the variations in size and shape that are characteristic of this species.

These oysters are from the Bow Island and Monarch localities, being of Belly River and Upper Pierre ages.

*Ostrea glabra coalvillensis* (Meek) var. nov.
Plate VI—Figures 11, 14

*Ostrea coalvillensis, Meek*, U.S.G.S., 40th Parallel, Vol. IV (1877), p. 140.

Many of the oysters of the Edmonton beds are undoubtedly very similar to the form described by Meek as *O.coalvillensis*. As stated in the Introduction, however, C. A. White regards this form as identical with *O.glabra*, not allowing it even varietal significance. Were it not for the occurrence of shells that are intermediate in character between typical *O.glabra* and Meek's *O.coalvillensis* and for the conclusion of C. A. White, already stated, the author would prefer to regard *O.coalvillensis* as a valid species. The Alberta form is nearer to *O.coalvillensis* than to any other described oyster; it has affinities, also, with *O.glabra*. In deference to White's opinion, while not entirely accepting his conclusion, the author would regard the form as a variety of *O.glabra*.

The Alberta form resembles the type of *O.coalvillensis* in general outline, thickness of shell, sub-equal character of valves, and broad ligament area. It differs from *O.coalvillensis* in its larger size, its greater thickness of shell (9 mm. to 14 mm. in a shell 87 mm. long) and its rugose exterior.

The variety is retained under *O.glabra*, in the first place, on account of White's opinion; also because intermediate forms occur, and because the differences are chiefly those of size and thickness. In a minor way the shell differs from that of typical *O.glabra* as follows: the two valves are more nearly equal; the ligament area is larger; the left valve is less concave; the shell is never arcuate; in some cases the exterior is marked by fine radiating striae; and the muscle scar is larger, of regular subcrescentic outline in all specimens, and located near the margin.

*Location and Horizon*—SE.¼ of Sec.31, Tp.27, R.20, Debrinski coulee, 1 mile north of Beynon, from the base of the Drumheller marine tongue.

*Plesiotypes* No. 5258 ct. Roy. Ont. Mus. Pal.

*Ostrea glabra expansa*, var. nov.
Plate VI—Figures 12, 13, 15, 16

This form occurs in the same beds as *Ostrea glabra coalvillensis* (Meek). It is intermediate in character between the latter and *O.glabra*. The shell is characterized as follows: larger and thicker than in *O.glabra;* no marked concavity in the lower valve; valves nearly equal; shell subcircular in outline; margin wavy and irregular; muscle scar large, moderately faint, and located near the median line of the shell.

The essential features of difference between this form and *O.glabra* are its thicker shell, its subcircular outline, the nearly equivalve character, and the general flatness of both valves.

*Location and Horizon*—NW. ¼ of Sec.4, Tp.30, R.20, 1¼ miles south of Munson; Drumheller marine tongue.

*Cotypes* No. 5259 ct. Roy. Ont. Mus. Pal.

### *Ostrea glabra lata,* var. nov.

Plate V—Figures 1-7

The description of *O.glabra* applies to this variety in a general way.

*O.glabra lata* differs from the type in its more regularly rounded outline, commonly being subcircular but presenting slight departures from this form. The shell usually is thin, but in certain specimens from the Edmonton it is thicker. In this case the lower valve commonly has low, rounded ridges running from the posterior of the shell about half way to the anterior end, and parallel to the margin. The beaks and ligament area are immoderately small and inconspicuous.

The lower valve is shallow, with occasional exceptions. The right valve is more commonly concave upward. At its posterior end on the inside of the shell is a locally thickened area, forming a raised platform which is so designed as to give the ligament area greater bearing surface, a modification no doubt occasioned by the greater area of the shell and the reduced size of the beaks.

The essential feature of difference between the variety *O.glabra lata* and *O.glabra* is the greater angle at which the lateral margins converge at the beak (75°-160°).

*Location and Horizon*—South Saskatchewan river, at Bow Island, Alberta; Foremost beds, Belly River, Upper Cretaceous.

*Cotypes* No. 5265 ct. Roy. Ont. Mus. Pal.

### *Ostrea glabra ponderosa,* var. nov.

Plate V—Figures 8, 11, 12, 13, 17

The shell in this variety is highly variable in outline and shape, especially in the degree of concavity of the lower valve. It differs from *O.glabra* in its smaller shell, which rarely exceeds 51 mm. in length. On the other hand it is unusually thick; with a length of 51 mm. the thickness may vary from 6 to 13 mm. The ligament area is relatively larger than in *O.glabra,* and is commonly truncated at its posterior end, heavy laminations of growth forming strong transverse striations across the area. The body cavity is narrow but commonly deeper than in *O.glabra.*

The ponderous left valve of large specimens reveals a special modification about the margin. The right valve, instead of being directly opposed to the left, rests in a marginal interior depression of the latter so that the outer lamellae of the left valve project beyond the margin of the right. In consequence of this arrangement the right valve is much narrower than the left, and the lateral outline more definite, being sharply and evenly defined. This characteristic articulation is seen also in typical *O.glabra* but in a less pronounced manner.

The muscle scar is small but deep. It is of subcrescentic shape with the long axis of the crescent disposed nearly parallel to the long axis of the shell.

This variety appears to be a decadent form of *O.glabra.*

*Location and Horizon*—Oldman river, Monarch, Alberta; Pierre-St. Mary River beds (Edmonton), Upper Cretaceous.

*Cotypes* No. 5252 ct. Roy. Ont. Mus. Pal.

### *Ostrea auriculata,* sp. nov.

Plate V—Figures 15, 16

This species is characterized by a heavy, thickened, ear-like growth behind the beak in the left valve.

The valves are slightly arcuate posteriorly, thickened in the cardinal region, but thinning off toward the ventral margin, and usually deformed by the scar of attachment.

The beak is defined, acuminate, relatively prominent and directed backwards.

The ligament area is of average dimension, and the ligament pit deep. The smooth, inner body-area sends a lobe towards the alar extension, which lies behind the beak. The muscle scar is small, shaped like that of *O.glabra,* and is situated near the posterior margin of the shell; the long axis of the crescent is more nearly parallel to the long axis of the shell.

The outer surface of the shell is relatively smooth, but is marked by the laminations of growth.

No right valves are available for description, but by analogy with *O.glabra,* it is unlikely that they would show unusual features.

In the largest individual the length is 38 mm., the width 26 mm., and the internal thickness 5 mm.

Somewhat similar oysters have been described from different localities and horizons, more particularly as follows:

*O.canaliculata,* (Sowerby) [22] by Henry Woods, from the Gault of England.

*Gryphaeostrea vomer,* (Morton) [23] by Stuart Weller, from the Pamunkey (Eocene) of the Atlantic Coast.

*Ostrea (Gryphaeostrea?) subalata,* Meek[19], from the Fox Hills Cretaceous of western North America.

Our species resembles more closely *Gryphaeostrea vomer,* and *Ostrea (Gryphaeostrea?) subalata.*

From the former it is distinguished by the constant absence of an auricular extension before the beak, and from the latter by the smoother exterior, the less torsion of the beaks, and absence of the crenulations on the ventral margin so characteristic of *O. (Gryphaeostrea?) subalata.* In contrast of *G.vomer* in which the auricular appendage is delicate, and frequently not preserved, the alar extension in the Alberta form is strong and essentially of the same structure as the rest of the shell.

*Location and Horizon*—Oldman river, Monarch, Alberta; Pierre-St. Mary River (Edmonton) beds, Upper Cretaceous.

*Cotypes* No. 5255 ct. Roy. Ont. Mus. Pal.

## Genus **EXOGYRA** Say

### *Exogyra incipiens,* sp. nov.

Plate V—Figures 9, 10, 14

The shell of this species is unusually thick in the umbonal region but is reduced to normal thickness at the ventral margin.

The body area is smooth, of regular and rounded outline, and situated far forward in the shell. The adductor scar was seen in only one specimen; it is relatively small and is situated near the margin. In many of the shells examined there is no trace of the scar, indicating that the attachment of the muscle was not deep-seated. The surface of the lower valve is marked only by rather smooth corrugations, the lamellae of growth. Some shells bear low nodes scattered at random over the surface. These are due apparently to the incorporation of some foreign fragments beneath the lamellae during growth.

The ligament area is subtriangular in shape and is moderately large; the ligament pits are relatively deep and broad, and are curved with the slightly exogyrate beaks.

The left valves are moderately arcuate. The curvature is shown chiefly in the cardinal region and seems to be anterior in some cases and posterior in others.

In a large specimen the length is 51 mm.; the width 26 mm. to 32 mm. In the left valve the depth to the visceral cavity is variable but is sometimes as great as 10 mm.

This form resembles *O.vesicularis,* Lamarck, a species recognized by Meek in the Cretaceous of western North America, and ascribed by him to *Gryphaea vesicularis,* Bronn, which is considered a synonym for *O.vesicularis,* Lamarck. Our form bears a somewhat closer resemblance to *O.vesiculosa* (Sowerby), as figured by Woods.

Owing to the unsatisfactory condition of the classification of the family *Ostreidae* the generic reference to this form is somewhat doubtful. Zittel includes all species of the *Ostreidae* in the genera *Ostrea, Electryonaria, Gryphaea,* and *Exogyra.* F. B. Meek considers *Gryphaea, Gryphaeostrea,* and *Electryonaria* to be sub-genera under the genus *Ostrea.* Henry Woods, in the volume on Cretaceous Lamellibranchiata of England, accepts only two genera in the family: *Ostrea* and *Exogyra;* and places forms formerly classed under *Gryphaea* in the genus *Ostrea.*

Following Zittel it would seem that the present species should be ascribed to *Exogyra,* rather than to *Ostrea* or *Gryphaea,* because in our form, as in typical *Exogyra,* the twisting of the beaks is rather more in the plane of the shell than transverse to it, which is the characteristic manner of torsion for *Gryphaea.*

In *E.incipiens* the twisting of the umbones has not developed to the marked curvature of typical *Exogyra;* hence the specific name.

*Location and Horizon*—Oldman river, Monarch, Alberta; Pierre-St. Mary River (Edmonton) beds, Upper Cretaceous.

*Cotypes* No. 5264 ct. Roy. Ont. Mus. Pal.

*Conclusion.*

The general conclusions as to the *Ostreidae* are briefly stated below:—

The Upper Cretaceous rocks of the Great Plains carry a more diverse fauna of *Ostreidae* than hitherto has been supposed.

The generic subdivision of this family does not seem to be firmly established.

Stratigraphically, the *Ostreidae* of Alberta mark the littoral zones of receding and transgressing bodies of marine water during different stages of Montana time.

It would appear that the forms *O.glabra* and *O.subtrigonalis* were most abundant during the Belly River stages. During later stages, especially in the Edmonton, typical *O.glabra* and *O.subtrigonalis* are in large part replaced by modified and more eccentric types, as for example, *O.glabra coalvillensis, O.auriculata, O.glabra ponderosa, O.glabra expansa,* and *Exogyra incipiens.*

BRYOZOA: Class Bryozoa
Order **Cheilostamata**

Hitherto no Bryozoa have been observed in the Edmonton, but our collection contains one species evidently referable to the Cheilostomatous Bryozoa of the group Membraniporae.

*Conopeum bicystosum,* sp. nov.
Plate VII.

The zoaria occurs as incrustations on oyster shells, both inside and outside, and therefore independent of the growth of the oysters. The zooecia are distinct, each opesium being delimited by a raised, rounded wall. A tiny furrow separates these walls where zooecia are closely contiguous. No lines separating the single zooecia are visible, apparently having been obscured early in the growth of the bryozoan. The interopesial areas are of various shapes, but where the zooecia assume uniform close arrangement, these areas have the shape of elongate rhombs, or spear heads, the sides all convex inwards. The zooecia, in general, are oval in shape and uniform in size, although separate areas of what appears to be the same colony have different relations of size of opesium and amount of interopesial space. This diversity may be due to difference in age or in stage of development. Gymnocysts and cryptocysts appear to be present. The zooecial wall is developed as an apparent cryptocyst in some cells and in others falls away to a low broad gymnocyst. The mural rims show traces of granulation, but this feature is not as marked as it is in the genotype. Interopesial cavities appear to be lacking, although the interopesial spaces are frequently hollow. Very small superficial cavities occur more or less at random over the mural tissue; it is questionable whether or not avicularia arose from these pits. The zooecia tend to linear arrangement, and present the appearance of several zooecia advancing abreast.

Measurement—

| | | |
|---|---|---|
| Opesia | ho | = 0.28 - 0.31 mm. |
| | lo | = 0.18 - 0.20 mm. |
| Zooecia | lz | = 0.40 - 0.44 mm. |
| | lz | = 0.30 - 0.33 mm. |

*Affinities*—This species resembles *C.wilcoxianicum*[24] of the Wilcoxian of Alabama, save in the detail of the interopesial cavity.

It also resembles *C.wadei,*[25] but not closely, owing to the lack of interpropesial cavity in our specimen.

*Location and Horizon*—SE ¼ Sec. 33, Tp. 28, R. 21, Horseshoe canyon, 8 miles west of Drumheller, Alberta. From the Drumheller marine tongue.

*Holotype* No. 5337 ct. Roy. Ont. Mus. Pal.

## PELECYPODA: Class Pelecypoda
### Order **Teleodesmacea**

#### Genus **CORBICULA**

*Corbicula occidentalis*, var. *ventricosa*, var. nov.

Plate V—Figures 18, 19, 25, 26

*Corbicula occidentalis*, Meek, (1860) Proc. Acad. Nat. Sci. Phil. XII, p. 432.

An apparent gradation exists between normal *C.occidentalis* and the present form which differs from the latter in its proportions and shape.

In *C.occidentalis ventricosa* the height is always greater than the length, this dimension being as much as 20 percent greater than the length.

The anterior and posterior dorsal margins have greater slope than these attain in *C.occidentalis*. The posterior dorsal margin slopes more steeply from the beaks than does the anterior dorsal margin. The anterior dorsal margin is straight, or slightly convex. The posterior dorsal margin is markedly convex. The beaks are elevated, moderately gibbous, and situated slightly in front of the centre of the dorsal margin.

Average height is 25 mm., length 21 mm.

Of the specimens examined only a small number were of intermediate proportions and the variety appears to be quite distinct.

*Location and Horizon*—SE. ¼ Sec. 33, Tp. 28, R.21, Horseshoe canyon, 8 miles west of Drumheller, Alberta; Drumheller marine tongue of the Edmonton formation, Upper Cretaceous.

*Cotypes* No. 5296, ct. Roy. Ont. Mus. Pal.

*Remarks.*

Bryozoans have not been reported hitherto, from the Upper Cretaceous rocks in Alberta; in fact they appear to have escaped detection anywhere in the northern Great Plains area. A more profuse development of Bryozoa was noted by the author in 1925 at Deadlodge canyon along the Red Deer, in the lowermost strata of the Bearpaw formation.

Bruce Wade mentions several species of the genus *Conopeum* in U.S.G.S. Professional Paper 137, a monograph on the basal Ripley fauna at Coon creek, Tenn. The presence of Conopeum in these two widely separated Upper Cretaceous deposits, which are here regarded as age-equivalent, suggests that these waters may have been connected.

That Bryozoan life existed in the region at an earlier date is indicated, Professor W. A. Parks having collected what appears to be another species of Cheilostome from the Belly River, Pale Beds, near Lethbridge, in 1924.

The new variety of *Corbicula occidentalis* occurs abundantly in one horizon in the Edmonton at different localities. It is very similar to the type *C.occidentalis* but has undergone marked variation in proportion and size, as have several other of the genera which pass through from Belly River to Edmonton ages. The close examination of Corbiculae collected in the future from the two formations will indicate whether or not this variety has index value in differentiating these formations.

The new Edmonton fauna contains several other new species. These were described by Dr. P. S. Warren[26], who examined the author's collections for the Alberta Geological Survey in 1925.

### Vertebrata

In order to make this discussion of Edmonton life as complete as possible all the known species of the vertebrata are listed. This information is taken from the literature and from unpublished lists available to the author, whose acquaintance with vertebrate palaeontology is limited to the general features only.

The vertebrate fauna is as follows:

Class Pisces—

*Palaeospinax ejuncidus*, Lambe (Selachian)
*Myladaphus bipartitus*, Cope (Selachian)
*Hypsodon* sp. (scales) (Teliost)
cf. *Holcolepis* sp. (scales) (Teliost)
*Pappichthys* sp. (vertebra) (Ganoid)

(The scales of a fish were collected by the author in 1927 in the Fox Hills of the Cypress. These scales most closely resembled those of the genus *Holcolepis* figured by T.D.A. Cockerell in U.S.G.S. Prof. Paper 120-i, 1919.)

Class Reptilia

(Arrangement according to classification of O. Abel and von Heune.)

Order Rhynchocephalia
*Champsosaurus albertensis*, Parks

Order Sauropterygia
*Leurospondylus ultimus*, Brown

Order Chelonia
*Aspideretes* (*Trionyx*) sp.

Order Crocodilia (sp)?

Order Saurischia
*Albertosaurus arctunguis*, Parks
*A.sarcophagus*, Osborn
*Struthiomimus brevitertius*, Parks

Order Ornithischia
*Edmontosaurus regalis*, Lambe
*Chaeneosaurus tolmanensis*, Lambe
*Thespesius edmontoni*, Gilmore
*Hypacrosaurus altispinus*, Brown
*Saurolphus osborni*, Brown
*Thescelosaurus warreni*, Parks
*Troödon* sp.
*Anchiceratops ornatus*, Brown
*Leptoceratops gracilus*, Brown
*Arrhinoceratops brachyops*, Parks
*Ankylosaurus magniventis*, Brown

This imposing list suggests that the reptilian fauna of the Edmonton is one of its most interesting scientific features.

Land dwelling reptilia apparently constituted the dominant type of life during the Edmonton, since only one species of plesiosaur has yet been found. The herbivorous types of dinosaurs outnumber the carnivores.

Students of the giant reptiles agree in general that the species of the Edmonton are intermediate members of genera or families which pass through from Belly River time to the Lance, when all the dinosaurs became extinct. Brown[14] states his opinion that the Edmonton species are nearer Judith River (Belly River) types in development, than they are to Lance types.

Class MAMMALIA—

Order MARSUPALIA

Cf. { Diaphorodon
{ Eodelphis

Only one mammal is known from the Edmonton. It is represented by a tooth, collected by C. M. Sternberg and identified provisionally by G. G. Simpson of Peabody Museum. The latter remarks that the form is an early opposum type and has close affinities with forms in the Judith River formation.

*Conclusions on Vertebrate Fauna.*

The fish fauna is not extensive and has no particular stratigraphic value. The known presence of only one long-ranging mammal of primitive persistent type, likewise has little stratigraphic value. With the reptile fauna the reverse is the case; 20 species belonging in six orders may be regarded as a large reptilian fauna. So far as known, the Edmonton dinosaurs are characteristic of that formation and distinct in anatomical features from those of other Upper Cretaceous, dinosaur-bearing formations.

## FLORA

Despite the fact that the Edmonton rocks enclose many coal seams and are more or less carbonaceous throughout, the flora described from them is not large. F. H. Knowlton's[27] catalogue of the North American plants is very incomplete in respect to the Edmonton flora; only two species are listed in the Edmonton and the list is grouped with Eocene floras. The short list given below was obtained from the works of J. W. Dawson[28], B. Brown[14], D. B. Dowling[29], and J. B. Tyrrell[15]. The lists repeat several of the better known species.

The known flora of the Edmonton is as follows:

Phylum—PTERIDOPHYTA

Family—EQUISETACEAE
*Equisetum* sp. nov.

Family—EQUISETACEAE
*Onoclea sensibilis fossilis,* Newberry

Phylum—SPERMATOPHYTA (GYMNOSPERMAE)

Family—CYCADACEAE
*Cycad* sp.

Family—GINKGOACEAE
*Ginkgo laramiensis,* Ward

Family—TAXACEAE
*Taxites olriki,* Heer
*Salisburia,* sp.

Family—PINACEAE
*Abietites tyrrelli,* Dawson
*Sequoia reichenbachii,* (Geinitz) Heer
*S.nordenskioldii,* Heer
*S.langsdorfii,* (Brongniart) Heer
*Taxodium occidentale,* Newberry
*Glyptostrobus,* sp.

Phylum—SPERMATOPHYTA (ANGIOSPERMAE)

Family—LEMNACEAE
*Lemna scutata,* Dawson

Family—?
*Carpites* (fruit)

Family—SALICACEAE
- *Populus cuneata,* Newberry
- *P. acerifolia, P. newberryi,* Cockerell
- *P. amblyrhyncha,* Ward
- *P. arctica,* Heer
- *P. richardsoni,* Heer

Family—FAGACEAE
- *Castania* sp.

Family—MORACEAE
- *Ficus russelli,* Knowlton

Family—PLATANACEAE
- *Platanus newberryana,* Heer
- *P. nobilis,* Newberry

Family—HIPPOCASTANACEAE
- *Aesculus antiquus,* Dawson

Family—SAPINDACEAE
- *Sapindus affinis,* Newberry

Family—STERCOLIACEAE
- *Pterospermites* sp.

Family—HYDROCARYACEAE
- *Trapa borealis,* Heer
- *Trapa* (?) *microphylla,* Lesquereux

The number of species is 28. Of these 2 are Pteridophytes, 10 Gymnosperms, 15 Angiosperms and 1 not definitely classified. Eight genera are Gymnospermous and 11 Angiospermous plants. This flora is not particularly characteristic of any specific environmental realm. The plants represented might all be found in the lowlands in a warm temperate climate. The flora indicates the growing importance of the Angiospermae.

### AGE AND CORRELATION OF THE EDMONTON FORMATION

Sufficient evidence of the contemporaneity in the faunas has been observed to allow of inter-continental correlation of the Upper Cretaceous formations of western Europe and the Atlantic Coast and Gulf States of this continent. The Monmouth formation of Maryland and the Ripley formation of Alabama are regarded as of the same age, and correspond in time with the Senonian of the Upper Cretaceous of Europe. In New Mexico the Ripley formation merges laterally into the Fox Hills formation of the Interior Region. T. W. Stanton[30] has firmly established this correlation. In the present paper the essential contemporaneity of the Edmonton and Fox Hills has been demonstrated. The faunal relationship indicated in Table 7 and the stratigraphical relations, discussed in the foregoing, establish the correlation. The discovery at the top of the Edmonton of a marked disconformity that appears to have been developed during the deposition of the Lance and some later beds, leads to the conclusion that the Upper Edmonton is older than the Lance of Montana and Wyoming. It is, therefore, of Fox Hills age and falls in the Senonian of the standard Cretaceous time scale.

In Alberta only very general correlations of the Edmonton have been made from one district to another. J. B. Tyrrell correctly correlated the beds in the central area from the Red Deer river to the North Saskatchewan river, and he suggested the probable equivalence of the Edmonton and the St. Mary River series of Dawson in the southwest of the province. The Wapiti Series of Dawson exposed on Wapiti and Smoky rivers, near Grande Prairie in the north of the province were considered by Tyrrell to be the equivalent of the Edmonton. J. A. Allan has revised this interpretation somewhat and draws the limiting western boundary of the

Edmonton formation far to the east of the Wapiti river[31]. In the foothills no definite correlation has yet been made with the Edmonton of the plains area, although it is thought that part of the Upper Saunders formation there is equivalent to Edmonton. McLearn and Hume[32] refer to part of the section of the rocks in Turner Valley as Edmonton, so designating a 1,300-foot section lying above the Belly River. They state "What the relation of the Edmonton and Paskapoo of this western area is to the similarly named and more typical formations of the east is not known."

During the field season of 1927 the author was enabled to make a close correlation of the lower portion of McConnell's Lower Laramie of the Cypress Hills with the Kneehills Tuff in the middle member of the Edmonton section on the Red Deer. The sections bear a close resemblance to each other lithologically and in sequence of beds. The following table indicates the relationships of the two sections.

TABLE 9.
**Comparison of Sections at Kneehills Creek and Cypress Hills**

| Willow creek, Cypress Hills | Kneehills creek, Red Deer river |
|---|---|
| **Disconformity** | **Disconformity** |
| Dark grey, bentonitic, highly gypsiferous shale—50′ (±) Including volcanic tuff. | Dark grey to mauve, bentonitic, less gypsiferous shales 10-40′. Including volcanic tuff. |
| White clay and sandstone (Whitemud formation Dyer). 25′ | White clayey sandstone of varying thickness, 10-45′ |
| Grey, slightly bentonitic sandstone and siltstone, 50-60′ | |
| Thick lignite seam | No. 12 (Thompson) coal seam |
| Grey sandstone and shale, 20′ | Grey sandstone and silty clays 50-90′ |
| Thin lignite seam | No. 11 (Carbon) coal seam. |
| Light grey sandstone and grey silty shale, 100′ | Grey sandstones and bentonitic siltstones and clays, 155′ |
| Marine fossils, Fox Hills type, 10-20′ | Drumheller marine tongue, 25′ |
| 250′ sediments | 580′ sediments (Lower Edmonton Member) |
| Bearpaw shale | |

The correspondence of the analyses of the volcanic ashes from these two places, which are separated by 185 miles, is remarkably close. The analyses are shown on page 69. Figure 30 is a view taken at the west end of the Cypress Hills at the top of the butte near Fly lake. It shows the outcrop of the volcanic tuff, at the man's feet, and the outcrop of the top of the Whitemud formation. This figure may be compared with Figure 31, a view of the outcrop of the same section on Threehills creek.

Tyrrell's correlation of the Edmonton formation in Red Deer valley with that in the North Saskatchewan river valley, and the correlation made with the Cypress Hills section by the author are the only ones of a detailed nature yet established. The broader correlations based on stratigraphic position have already been mentioned.

## CHAPTER VIII.

# TERTIARY AND LATER FORMATIONS

### PASKAPOO FORMATION

*Distribution.*

The Paskapoo formation was defined and named by J. B. Tyrrell[15] in 1886. He states that it includes all the beds lying below the Miocene and above the "Big Seam" at the top of the Edmonton, and that it corresponds with the Porcupine Hills series, Willow Creek series and all but the lower 700-900 feet of the St. Mary River series of Dawson. The formation name is used in practically the same sense in this paper except that the lower limit of the formation is now the disconformity that has been discussed.

Paskapoo rocks occupy the same large shallow basin as the Edmonton formation in Alberta. They have a smaller area than the Edmonton for the reason that erosion has planed off the rocks on both flanks of the long synclinal depression and only that fraction of the Paskapoo occupying the more depressed part of the Alberta syncline has been preserved. Residual areas of Paskapoo occur in the Swan Hills near Lesser Slave lake, in the Cypress Hills and on Milk river ridge. The outcrop of Paskapoo extends from latitude 54° (the Athabaska river) to the International boundary. It narrows at either end and has its greatest width, 96 miles, in the latitude of Ponoka in township 42.

In this map-area the Paskapoo outcrops over most of the area west of the Red Deer river. East of the river there are large, isolated, residual areas of Paskapoo of limited thickness.

*Thickness and Boundaries.*

As originally deposited the Paskapoo was of very uneven thickness. It filled a deep trough east of the present foothills and extended far to the east as a thinning apron of continental beds. Tyrrell reported a thickness of 5,700 feet, measured on the Little Red Deer river. Equivalent rocks on the Oldman river, measured by Dawson, are over 6,000 feet thick.

In the present area evidence of rapid thickening to the west has been noted. Between the mouth of Blindman river, near the Red Deer, and the base of the formation at Ardley between 750 and 800 feet of Paskapoo are exposed. East of Ardley the Paskapoo lies at the surface and does not commonly reach thicknesses over 200 feet.

In the southwest corner of the area, near Calgary, the Paskapoo is at least 2,000 feet thick.

The base of the Paskapoo lies on an erosion surface of the Edmonton in the Red Deer river area. The nature of this contact has been discussed in the foregoing pages. The upper limit of the formation is the present land surface, except in the Hand Hills where it is covered by Oligocene (?) deposits. The Paskapoo in these hills is about 360 feet thick.

*Sedimentation and Interpretation of Deposits.*

The rocks of this formation were originally considered to be the deposits of a great, inland, freshwater lake. At the time the formation was defined this interpretation was applied to all the great, Tertiary-basin deposits lying to the east of the American Cordillera. Since that time, however, interpretation of sedimentary strata has become more refined and a number of what were once considered lake deposits are now regarded as flood-plain deposits or interior basin, sub-aerial deposits of different kinds. Lake deposits have proven, on closer study, to be one type that have distinctive characteristics not to be easily mistaken. The Paskapoo is interpreted here to be the deposits of large rivers which had strong flow at their heads and which deployed upon a great, incompletely drained plain. Such streams would wander widely over such a plain and leave their burden of detritus when the currents slackened. No doubt large, temporary, shallow lakes were formed many times over, but none were of permanent basin type, or of important depth, and were probably always subject to rapid obliteration in dry seasons.

The basal 300 feet of the formation particularly, displays the characteristics of such deposits. On the west the sands are very coarse and relatively well sorted in respect to clayey components. Local, rounded-pebble, conglomerate lenses occur, and the stratification is predominantly uneven, and in places false-bedded on a grand scale. Thin bands of fine silts with clay, or limy bands containing freshwater or terrestrial gastropods interrupt the series of thicker, coarse sandstones. Such local strata represent temporary local lakes or flood pools. The coarse sands are characterized almost everywhere by the presence of "mud galls" or clayey pellets incorporated in the sands. This phenomenon is peculiar to subaerial, flood plain deposition.

Owing to the importance of some of the Paskapoo rocks of Alberta as building stone the lithology of the formation has been studied. The important features of the sandstones are stated in the report on the building stones of Canada by W. A. Parks[33]. In the general account of the Paskapoo the irregularity of the bedding, lenticularity of the strata, local variation in grain size, porosity, lime content, presence of mud galls and cross-bedding are described. Mention is also made of the uniformity in the mineralogy of the rock and its effect in giving the rock a "pepper and salt" effect upon close inspection. The peculiar behavior of the sandstones on weathering is also discussed and is of important economic consideration, but of less moment in a consideration of processes of deposition, with which this discussion is concerned. Little new information can be added on the lithology of the Paskapoo to that contained in the above report. In the table that follows, results of mechanical analyses of typical samples of Paskapoo rock from widely separate regions are included, as well as some results of chemical analyses of the cementing matter of the rock. The analyses indicate important characteristics of the lithology.

Samples 1, 2, 3, and 5 were carefully analyzed for $CaCO_3$ and the average for these samples is 13.3 percent lime. Four typical Edmonton samples showed an average lime content of 5.29 percent. The Paskapoo sands analyzed showed an average of 1.77 percent by weight of minerals over 2.7 sp.gr. Edmonton rocks yield an average of 0.215 per cent.

The material of clay grade in the Paskapoo rocks is found to be uniformly low, averaging 5.97 percent by weight as compared with over 10 percent in the Edmonton sands.

TABLE 10.

**Mechanical Analyses of Paskapoo Sandstones**

| Location and Horizon | Sand % 1.0-0.1 mm. | Silt % 0.1-.01 mm. | Clay % Less 0.01 mm. | $CaCO_3$ Cement |
|---|---|---|---|---|
| 1. Mouth of Nordegg river near base of formation | 85.6 | 9.5 | 4.8 | 7.32 |
| 2. 1 mi. north of Rocky Mountain House, 100′ above base of formation | 88.2 | 6.5 | 5.3 | 12.10 |
| 3. Bridge at Rocky Mountain House, 150′ above base of formation | 83.4 | 9.5 | 7.0 | 11.90 |
| 4. Ditto, (silty layer) | 9.71 | 85.20 | 5.08 | much |
| 5. Evansburg, Pembina river 150′ above base | 63.4 | 26.9 | 9.5 | 21.89 |
| 6. Elkwater lake, Cypress Hills, 100′ above base | 91.85 | 3.0 | 5.15 | trace |
| 7. Ditto ("Hard head" nodule) | 47.90 | 28.60 | 5.0(±) Clay + | 18.0(±) soluble |

The mechanical analyses above show the relative completeness of sorting, except in the limy layers, and the close similarity in relative proportions of grade sizes in samples from near the base of the formation, collected at widely separate localities, for example, Cypress Hills and Pembina river.

Mineralogically the Paskapoo is composed of a much more heterogeneous suite of minerals than is the Edmonton. Quartz grains constitute the bulk of the Paskapoo sands; feldspars are present in small amount and are usually highly decomposed. Shale, lime, chert, and quartzite fragments make up an important percenage of the typical Paskapoo sandstone. This feature is plainly seen in Figure 26D, which is a photomicrograph of a typical Paskapoo sandstone. This specimen was collected near the base of the formation at Rocky Mountain House. The picture is placed beside those of the Edmonton sands to facilitate their comparison.

As indicated above, the author considers the Paskapoo, especially the basal portion, with which he has greater familiarity, to be the product of streams that deposited their load on a flat or gently sloping plain at the foot of uplands which had been raised to the west. Several characteristic features in the sedimentary structure have been pointed out in support of this interpretation. The occurrence of local, thin lenses of woody coal, or of local bands of laminated lake clays, or of thin, non-persistent limestone which occasionally holds numerous freshwater or terrestrial gastropods is all supporting evidence of this manner of origin. Commonly the massive basal sandstones hold water-worn fragments of uncoalified wood. A large, silicified, fir log was observed projecting from a cliff face of Paskapoo sandstone, which lies near the base of the formation 14 miles west of Ardley, on the south bank of the Red Deer. This tree lies horizontally and was probably stranded on a bar after long transportation. It measures about 18 inches in diameter. Evidence of this kind with notable absence of finely laminated lacustrine structures in the sediments favours the flood-plain rather than the lacustrine origin for the Paskapoo. The occurrence of buff colored, oxidized strata in large proportion also indicates sub-aerial conditions during deposition. The Paskapoo is sombre in aspect as

Figure 32.—An uplands exposure of drab-coloured Paskapoo sandstone, due south of Hesketh, near highway.

compared with the Edmonton. Figure 32 is a view of a typical uplands exposure of Paskapoo. This outcrop occurs near the Drumheller-Calgary highway due south of Hesketh.

*Fauna and Flora of the Paskapoo.*

Invertebrata.—The Paskapoo is not rich in fossils. The most abundant types are freshwater and terrestrial gastropods. Freshwater pelecypods occur in more limited numbers. The known invertebrate fauna of the Paskapoo has recently been listed by L. S. Russell[34]. The writer's collection, made in 1924, was studied by Russell during the preparation of his paper.

A summary of the known fauna is given in the table below:

**Systematic List of Paskapoo Invertebrate Fauna**

| Class | Family | No. of Species |
|---|---|---|
| Pelecypoda | Unionidae | 3 |
| | Cyrenidae | 5 |
| Gastropoda | Hydrobiidae | 1 |
| | Viviparidae | 6 |
| | Physidae | 3 (several varieties) |
| | Helicidae | 1 |
| | Bulimulidae | 2 |
| | Stenogyridae | 2 |
| | Valvatidae | 2 |
| | Pleuroceridae | 2 |
| | Limneaidae | 2 |

The species *Unio, Sphaerium, Vivipara, Physa* and *Valvata* are most commonly encountered. In some places the shells occur as a coquina of freshwater origin.

Most of the genera represented are long-ranging types, known from Belly River to Tertiary time. It is believed that when the varietal differences are sufficiently well known this fauna will be of use stratigraphically. At present it can only be used as an index of the past environment.

Vertebrata.—As in the Edmonton formation the vertebrata of the Paskapoo are of great significance, although the fauna is very small in the Paskapoo.

In 1911 Barnum Brown discovered the remains of a few mammals in a slide on the Red Deer river near the present site of Brookesley bridge. In 1914 he published[14] a provisional list of this fauna. It proved to be hard to properly classify this fauna as to age. W. D. Matthew attempted to do this and was led to the conclusion that it is comparable to a Lance fauna. G. G. Simpson was given permission to restudy the fauna in 1925. He found that by an error in labelling the specimens, some which had been collected from the Lance beds of Montana had been placed with the Paskapoo material. This explained the confusion which Matthew tried to interpret. Simpson[35] recognized important elements in the material that were certainly from the Alberta Paskapoo, and he published the following list:

Multituberculata
 *Catopsalis calgaryensis*, Russell.
Insectivora
 *Propalaeosinopa albertensis*, Simpson.
 ?? *Pantolestid*, gen. and sp. undet.
Menotyphla
 *Nothodectes* cf. *gidleyi*, Matthew.
? Carnivora
 *Elpidophorus elegans*, Simpson.
Condylarthra
 ? *Phenacodus*, sp. undet.
? Taligrada, gen. and sp. undet.

Simpson considers this limited fauna to be sufficient evidence for placing the lower Paskapoo from which they are obtained in the Upper Fort Union, or above the Fort Union.

Flora.—In the catalogue of North American Plants prepared by F. H. Knowlton[28] 85 species of plants are ascribed to the Paskapoo. This is the most complete list yet published. In the paper by Barnum Brown, quoted above, the names of the species found on the Red Deer river are given. Little of special importance is noted in this flora. The types are of long range as a rule, or so similar to related forms in the older or younger beds that only the most refined study can establish differences. This flora is not depended upon for use in stratigraphic subdivision.

*Age and Correlation of the Paskapoo.*

Until Simpson's discovery of the post-Fort Union age of the mammal fauna, the Paskapoo had been regarded as equivalent to the Fort Union of the central-plains area. The earlier works in western Canada called it Upper Laramie with the inference that it represented an uninterrupted continuation of Cretaceous sedimentation. The discovery, in 1924, of a marked disconformity at the base of the Paskapoo indicated that the formation is younger than had formerly been supposed. According to Matthew's interpretation of the Paskapoo fauna being of Lance age the disconformity separating it and the Upper Edmonton could not be regarded as of great importance. This point of view has been profoundly altered, however, as a result of the more detailed study made by Simpson.

Simpson[35] now states "But it seems possible even on the basis of the few teeth of the present collection to establish the age of at least part (lower 400 feet) * of the Paskapoo as probably post-Tor-

*Brackets by present author.

rejon-Fort Union and pre-Wasatch, that is, as equivalent to the Tiffany-Clark Fork-Cernaysian." The Cernaysian of Europe is a formation in the Thanetian stage of the Eocene (*sensu stricto*) and overlies the Danian or Montian of the Paleocene, which is equivalent to the Fort Union. The combined evidence of the disconformity and mammal fauna is sufficient basis for reclassifying the Paskapoo as the latest, rather than the earliest Fort Union, as had formerly been supposed. The former classification of the Paskapoo was based more upon assumption than upon facts.

The Paskapoo has been correlated, on the basis of stratigraphic position, with the Fort Union of Saskatchewan and with the upper St. Mary River, Willow Creek, and Porcupine Hills series. It is probable that there is equivalence with part of the Tertiary section of Dawson in the south, but its correlation with the Fort Union of Saskatchewan is no longer correct. The Paskapoo might be of the same age as the Sentinel Butte Shale Member in east and southeast Montana which overlies the typical Fort Union and is classed by Thom and Dobbin[36] as Fort Union (?). Typical Paskapoo sandstone is present to a limited thickness in the Cypress Hills; the correlation is based upon close lithologic similarity and stratigraphic position. Paskapoo equivalents are believed to overlie the Fort Union of Wood Mountain plateau. R. G. McConnell[37] mentions several instances of the grey Fort Union overlain by buff, coarse sandstones. It is likely that a disconformity separating these two sandy formations would be obscure.

## OLIGOCENE (?) FORMATION

*Distribution.*

Less than a township in area is occupied by this formation in the present map-area. The outcrop is an erosion residual resting on the top of the Paskapoo in the Hand Hills between elevations of 3,500 and 3,200 feet. Only the highest plateau areas on the west rim of the Hand Hills are covered by this formation. The same relations exist in the Cypress Hills where proven Oligocene caps the monadnock.

*Thickness, Boundaries, and Section.*

A section slightly over 200 feet thick was observed by the author in 1924. The details of this section are shown in Figure 33. The lower part of this section was obtained 3 to 5 miles south along Willow creek. The section does not quite agree with the one published by J. B. Tyrrell[15] in 1886, which is restated below.

| | |
|---|---|
| "Loose quartzite pebbles imbedded in a sandy calcareous matrix | 15 ft. |
| Quartzite pebbles cemented into a hard conglomerate by calcareous cement | 2 ft. |
| Loose mass of pebbles, sand and marl | 10 ft. |
| Light-grey, and yellowish, stratified, argillaceous marls, with some intercalated beds of fine-grained brown sands. In the upper beds thin layers of limestone occur, which show on broken surfaces dendritic markings of oxide of manganese | 270 ft. |
| Light brown, false-bedded sandstones (Paskapoo) | 100 ft." |

The marl member of this section is subject to slumping and the writer observed the base of the marl to be 30 to 40 feet from the

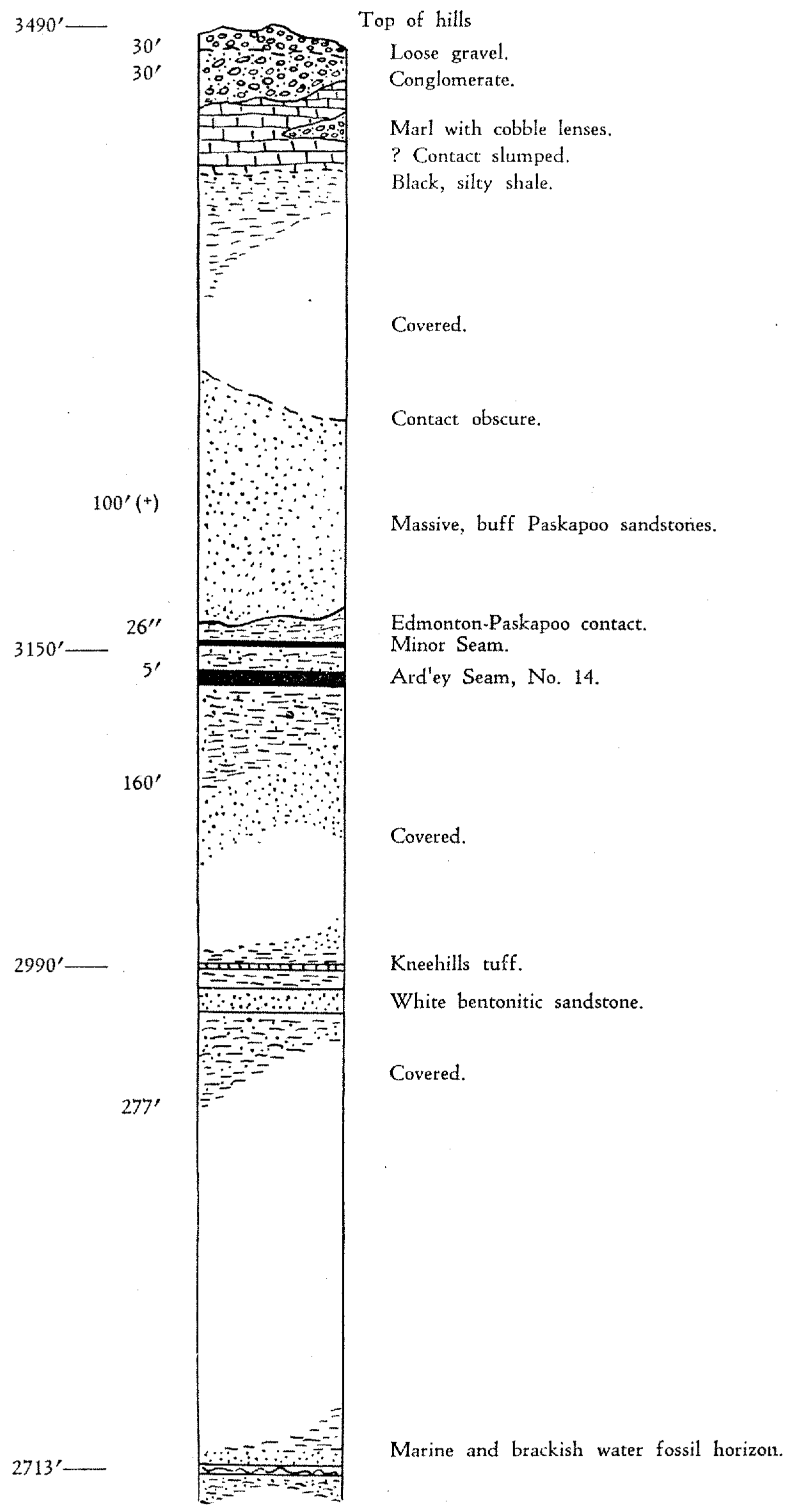



Figure 33.—Stratigraphic section at the west side of Hand Hills. The data for the lower part of this section were measured 3 to 5 miles to the south, on a branch of Willow creek which heads in these hills.

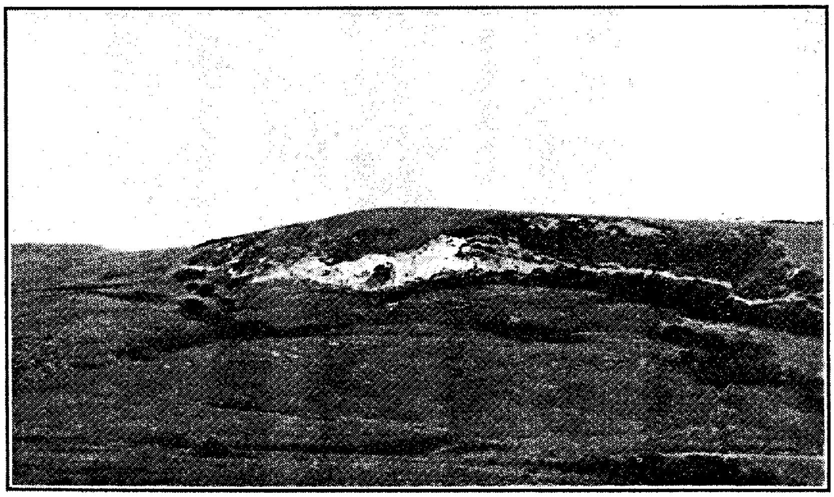


Figure 34.—Oligocene (?) marl exposure at the top of Hand Hills. Extensive slumping has produced this exposure.

top of the exposure and does not believe the marl series here is 270 feet thick. Figure 34 is a view of the Oligocene (?) exposure at the top of the Hand Hills in section 18, township 30, range 17. The rock is practically unconsolidated, and moves readily under the influence of seepage water.

The upper limit of the Oligocene (?) is the present surface which is a hard conglomerate layer of varying thickness. The formation rests on the buff, coarse sandstones of the Paskapoo. In the Hand Hills the actual contact could not be found. It is obscured by superficial cover.

The section is essentially as shown in Figure 33. Under a mantle of loose, cobble gravel there is a chatter-marked, very well rounded, cobble conglomerate which varies in thickness. The cobbles are all of vitreous quartzite; dark green and red chert pebbles make up a small percentage of the material. This bed is locally cemented with light grey calcareous matter into a tough conglomerate. The cemented layers are lenses of limited extent.

Well sorted, fine, brown, loose sands occur in the lower part of the marl section as thin bands. A section of 40 feet of silty, black, freshwater shale was observed 100 feet below the marl. The exact thickness relations are not obtainable from surface outcrops.

*Origin and Sedimentation.*

W. T. Thom*, after careful study of the evidence in the Interior Plains region, concludes that the entire area was undergoing irregular and interrupted subsidence until Oligocene time. In certain areas the rate of deposition of sediments was faster than the rate of subsidence and local erosion, and basin formation resulted. Thus it is apparent that in areas where subsidence was halted erosion occurred, the sediments being swept to the areas that continued to be lowered. In the Hand Hills region the Paskapoo was reduced in this way and eventually large shallow lakes formed on the low, peneplaned surface. The marl deposits of the Hand Hills and Cypress Hills were deposited in such lakes. Near the end of

*Unpublished thesis, Johns Hopkins University, Baltimore, Md.

Oligocene time renewed uplift of the mountains caused an invigoration of the drainage, and the streams swept down vast quantities of gravel, which was deposited above the marls in the Oligocene lakes. Soon after the advent of the strong, gravel-carrying rivers, the whole area experienced uplift and deposition of sediments was finally halted.

*Age and Correlation.*

Most of the facts available in a discussion of this topic have been mentioned. No typical Oligocene mammals or other fossils have been found in the Hand Hills. On the other hand, the Cypress Hills beds have yielded a large and interesting fauna. E. D. Cope studied this fauna and correlated the beds with the White River beds of Nebraska. L. M. Lambe[38] published a full list of the Cypress Hills fauna, which contains 50 species embracing turtles, rodents, carnivores and many ungulates.

The close similarity in physical constitution and stratigraphic sequence of the Hand Hills and Cypress Hills deposits makes it most probable that the two formations are of the same age and origin, but until fossil evidence corroborates the physical evidence, the Hand Hills deposits must be considered as Oligocene (?).

## Pleistocene Formations

*Description of Formations.*

The glacial and recent deposits of this map-area were not intensively studied by the author. Only outstanding features were noted where such were most readily observable.*

The glacial effects in relation to physiography are discussed jointly by the authors in Chapter II. Dawson and McConnell in 1895 provided a good description of the glacial deposits in Alberta[39]. In this paper are presented typical sections of glacial deposits, one of which is at Calgary in the extreme southwest corner of this map-area. This section is given below:

*Calgary, "on the north side of the Bow river about a mile below the bridge."*

| | |
|---|---|
| Gravel and silty soil | 5 feet |
| Stratified silts with layers of boulder clay | 35 feet |
| Boulder clay with stratified silty layers | 20 feet |
| Gravels | 15 feet |

The *Saskatchewan Gravels* found at the base of this section is an interesting formation. It occurs over a great area at the base of the glacial section. Dawson and McConnell found that this gravel merged with a thick deposit of boulder clay in the foothills country. They interpreted it as the peripheral deposits of a mountain glaciation which shortly preceded the encroachment of the Keewatin ice sheet, and called it the Albertan formation, a subdivision of the Pleistocene. F. H. Calhoun[40] who has studied northern Montana glaciation, interprets the same deposits differently. He believes the gravels to be residual, stream gravel accumulated on the pre-glacial surface, that has been reworked and incorporated with the earlier deposits of the Keewatin sheets. Calhoun urges the abandonment of the Albertan formation or stage.

In Alberta there appear to be two well defined boulder clays, in some places with interglacial deposits separating them. These lie

*Since 1924 considerable further work on glacial stratigraphy has been done in Alberta and some of the results have been published.

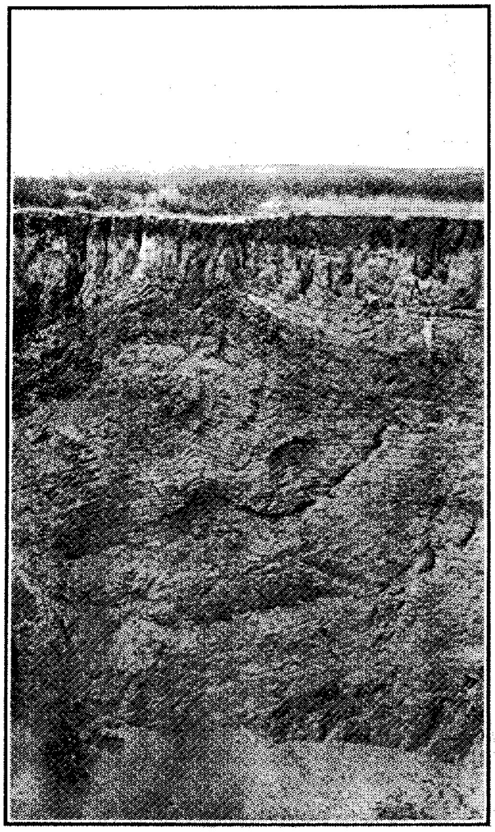


Figure 35.—Varved glacio-lacustrine beds in the valley of Rosebud river. The river cuts similar deposits for several miles along its middle course.

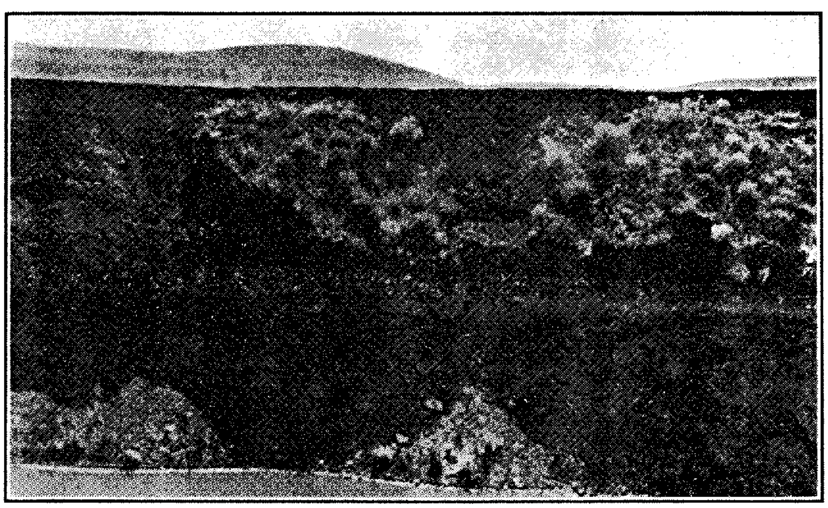


Figure 36.—Saskatchewan Gravels (?) in the valley of Kneehills creek, near Carbon.

above gravel beds, the age of which is not definitely determined. Lying above the boulder clays are local loess and local lacustrine beds. (The most recent and comprehensive discussion of the Saskatchewan Gravels in central Alberta has been given by R. L. Rutherford in 1937[41].)

In the Red Deer river country there is a wide variety of glacial deposits. Low lying areas commonly show lacustrine beds lying above gravels. Figure 37 is a typical section showing the gravels lying on Paskapoo beds and overlain by lake silts. This view is from the Red Deer river 5 miles below the town of Red Deer. In Figure 36 similar gravels are seen overlying Edmonton sandstones in the valley of Kneehills creek near the town of Carbon. This deposit demonstrates the pre-glacial age of this valley. A typical section of lacustrine beds was measured in the valley of Rosebud river near Redlands. This section is as follows:

| | |
|---|---|
| Oxidized, sandy soil | 2 feet. |
| Yellow, massive, loess-like silt, columnar joints | 4 feet. |
| Varved yellow silt, grey shale partings, contorted | 18 feet. |
| Massive, yellowish-grey till | 8 feet. |
| Cross-bedded, fine, loose sand, with much coaly detritus, gravelly at top and bottom | 28 feet. |
| Clayey sands, with coal fragments | 40 feet. |
| Covered, possibly gravel to creek level | 30 feet. |

Figure 35 shows the varved beds at the top of this section.

The uplands have a thin cover of boulder clay usually showing two distinct tills. Locally the upper till grades into typical yellowish loess clay without boulders. Figure 25 shows an uplands exposure bared by recent slumping. The lower boulder clay is brown and apparently much oxidized. It is overlain by 8 to 12 feet of pale grey, unoxidized till which, in turn, is overlain by vertically jointed loess. This view is from near Wayne along Rosebud river.

*Age of Glacial Deposits.*

Dawson and McConnell regard the Alberta boulder clays as of Kansan? and Iowan age. Calhoun disagrees with this interpretation and states that the bulk of the Alberta deposits were left after the Wisconsin advance. His opinion is corroborated by that of W. C. Alden[42], who agrees that the Alberta drift is of Wisconsin age. He doubts if the earlier Kansan and Iowan drift reached northwestern Montana or Alberta. The latter opinion seems to have the best basis. Erosion and oxidation of the most recent drift in Alberta is still in an early stage of development, and if the interglacial periods, as well as the post-glacial time, have been as long as the glaciologists maintain, these deposits should now be thoroughly weathered and oxidized if they are as old as Kansan or Iowan.

*Loess Deposits.*

At a few localities deposits of this material have been noted at the top of the glacial section. It is probably quite widespread but has escaped notice. The rock is of pale yellow colour, of impalpable fineness, and nearly perfectly sorted. It contains no pebbles or boulders. Where best developed it is massive and shows no bedding. At other places a finely laminated bedding is observable. It weathers in vertical cliffs by reason of a vertical jointing present where unlaminated. A typical exposure of this loess deposit occurs below the upland on the north side of Michichi valley at Drumheller.

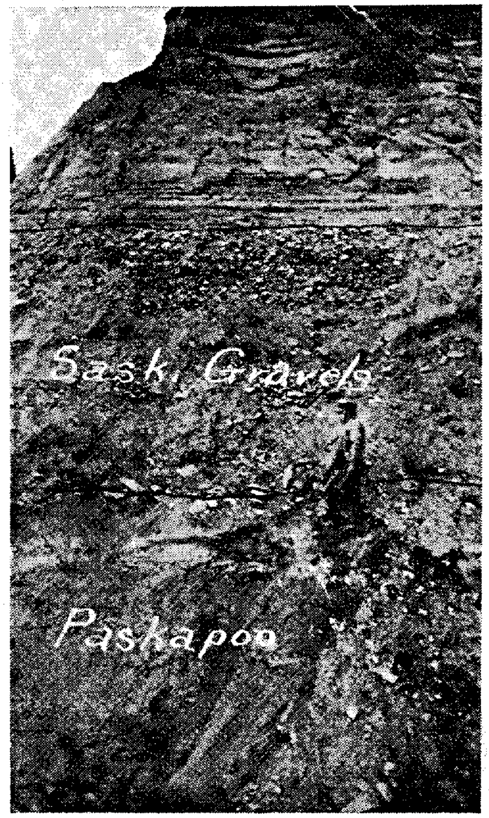



Figure 37.—Saskatchewan Gravels (?) and overlying lake beds on Red Deer river, 5 miles north of Red Deer.

The loess has a high content of calcium carbonate and is composed of relatively fresh mineral particles. It has not been analysed chemically, but when subjected to acid tests reacts violently for some time, losing about 20 percent of its volume.

The author submitted specimens to Dr. G. F. Kay of Iowa University and the latter expressed the following opinion*:

"I examined the specimen which you sent, and do not hesitate to state that I feel sure the material is loess."

The loess-like character of this material was first noted by R. G. McConnell[37] who mentioned it in the report on the Cypress Hill-Wood Mountain country. The wide-spread occurrence of this rock above the tills may be judged by the fact that the occurrence mentioned by McConnell was near the mouth of the Red Deer, about 100 miles southeast of the Rosebud sheet, while the author observed it along the Red Deer in several places in this map-area as well as on Ribstone creek near Wainwright, about 90 miles northeast of the map-area. At the latter locality the peculiar loess concretions "loess-kindschen" occur in abundance. Much more field work will have to be done in Alberta before the distribution and stratigraphic significance of the loess deposits are fully known.

*Personal communication.

## CHAPTER IX.

## SUMMARY AND CONCLUSIONS

*Summary.*

The survey of the area included in the Red Deer and Rosebud sheets, adjacent to the Red Deer river, was undertaken primarily as a study of the stratigraphy of the Edmonton formation which was to form the basis for the correlation of the several coal seams and coal horizons that make up part of that formation.

Since the western part of the area is underlain by the younger Paskapoo formation, it was necessary to note carefully the characteristics of the lower part of that formation and to map its areal extent and contact with the underlying Edmonton formation.

These two formations are of particular interest in Alberta since about two-thirds of the population of Alberta dwell on areas underlain by their strata.

The geology of this general area had last been mapped and formally described by J. B. Tyrrell and his associates in 1884-86. Their observations were carefully made, and their interpretations reflect their sound understanding of the principal geological features.

The growth of an important coal mining industry in the Red Deer river country made it urgently desirable that the physical features of the Edmonton formation, and especially the distribution and interrelationship of its coal horizons, should be studied, measured and mapped.

In the course of doing this work it became apparent that important features bearing on the historical geology of the western interior region of the continent were revealed by the strata of the Edmonton and Paskapoo formations. Significant data pertaining to the dating and regional correlation of these formations were observed.

The feature of greatest scientific importance described in this report is the disconformity that separates Mesozoic and Cenozoic formations in the central and southeastern parts of Alberta. The discovery of this stratigraphic hiatus gives new and important evidence for the final solution of the long-standing "Laramie Problem."

Part One.—The field work and surveys that form the basis for the body of this report were conducted by the authors in 1921 and in 1924. Due to the size of the report and the costs required in printing, the publication of the report was delayed.

The data compiled by the senior author have been obtained mainly for the purpose of reporting on the coal and other economic deposits of the region.

The systematic descriptions of the palaeontology and sedimentation prepared by the junior author compose part of a relatively complete study of the stratigraphy of the main Cretaceous and Tertiary formations that are found in the area, which was submitted in partial fulfillment of the requirements for a doctorate degree at Toronto University.

A relatively extended discussion of the physiography of the area is included for the reason that this aspect of the natural history of the area had not formerly been studied or described. No detailed or systematic study of the physiography was undertaken however, and the notes submitted should be regarded as incidental and incomplete. Several interesting features and problems that invite more intensive study were noted and are mentioned in the discussion.

The general features and definitions of the stratigraphic geology have long been well established. The report supplies detailed descriptions and subdivision of the stratigraphic sequence and provides a detailed correlation of the economic coal deposits of the Edmonton formation.

The structural geology was not studied by use of accurate instrument surveys. Such surveys may conveniently and easily be made because of the excellent exposures of the formations that are found along the main drainage ways in the region. The stream pattern in part of the area indicates some degree of sub-surface structural control of the drainage.

Considerable detailed location data, referring to points where evidence of the Cretaceous-Tertiary disconformity is found, are given in conjunction with the discussion of that discovery. The establishment of a definite depositional hiatus between formations of Cretaceous and Tertiary ages in Alberta provides highly significant stratigraphical information, the import of which may be applied in regions far removed where rocks belonging to these different ages occur together.

The discovery of pyroclastic deposits within the Edmonton is described. This information also has important bearing on the geological history of this and related regions, as well as on the nature of the sediments that compose the Edmonton formation.

Chapter IV contains a systematic description of the coal seams of the Edmonton formation, as well as a discussion of the various members of the formation in their relationship to the correlation of the coal seams.

Bentonite is described and its properties and uses are fully discussed.

Other non-metallic potentially economic deposits of the Red Deer river region are described.

Part Two.—This portion of the report contains a great deal of descriptive matter that would lose its usefulness and meaning if it were condensed. The palaeontology and sedimentation of the Edmonton and Paskapoo are systematically described for the first time. New species and genera of the invertebrate faunas are described formally. Hitherto unstudied and undefined types of sub-aqueous clastic deposits were collected from the Edmonton, and were analysed and described. Because of its novelty, utility and interest this descriptive material is included in the present report.

In the introduction to Part Two there is a summarized account of the main geological features that are described and discussed in this part of the report.

Reasons are given for the reference of the Edmonton to Fox Hills time rather than to Lance equivalence as had been done earlier.

The evidence obtained and the authors' interpretation of it point quite definitely now to the pre-Lance age of all of the Edmonton formation. It is considered to be a shoreward facies of the Fox Hills, or "Fox Hills-Pierre" sea. The overlying Paskapoo formation likewise, is now more definitely classified in the geological time scale. Former interpretations placed it in the Paleocene, a Fort Union equivalent, or as belonging to transition beds uniting the Cretaceous and the Tertiary. In this report it is demonstrated (with some reservation) that it belongs to post-Fort Union, pre-Wasatch time, or to the Cernasian stage of the Tertiary.

The report includes as complete a compendium of the life of the Edmonton as possible. Quite a detailed account of the type sediments is included because of their unusual character and wide distribution in Alberta. The widespread occurrence of the less than one foot thick volcanic tuff bed of the Edmonton is described.

*Conclusion.*

Stratigraphical geology is no doubt the most comprehensive of the natural sciences. A full account of the stratigraphy of any region requires consideration of other related regions. Stratigraphy is essentially correlation. The final scale to which a stratigraphic deposit is compared is the geological time scale. No stratigraphic unit or rock occurrence is so isolated that it cannot be referred to its place in this scale.

In order to establish correlation the whole constitution of a rock, or series of strata, must be considered. The organic, as well as the inorganic aspects require complete study if the criteria they afford are to be of value. Other important factors entering into a stratigraphic study are palaeoclimatology, palaeophysiography and palaeogeography.

The authors realize that a great deal more systematic work could be done to make the account of the stratigraphy of this region more complete. Many interesting and inviting subjects for study and research presented themselves as the above work was in progress. It is their hope that readers of these pages, especially beginners, will become attracted by some of the problems suggested, will delve deeply into them and eventually add much more to the store of knowledge of the historical geology of Alberta.

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# GEOLOGICAL MAP ROSEBUD AND RED DEER SHEETS

PROVINCE OF ALBERTA WEST OF FOURTH MERIDIAN

1946

SCALE IN MILES

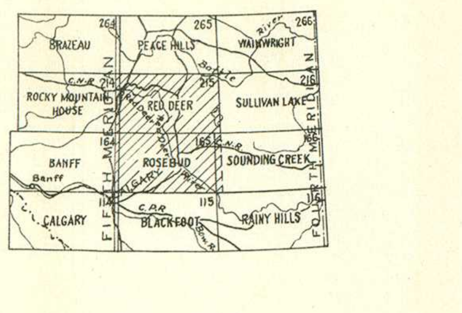
2 0 2 4 6 8

**NOTE**

*This map on a scale of one inch to four miles is essentially a reproduction in one sheet of the original maps No. 8 and No. 9 on a scale of one inch to three miles. The profile sections in Plate I, accompanying Report 13, are drawn from the original maps on a scale of 1 inch to 3 miles.*

*Subsequent to the publication of maps No. 8 and No. 9 (1925), a more detailed study was made by R. L. Rutherford of the area north of township 34. The results of this later work are shown on maps 503A and 504A as published in 1939 by the Geological Survey of Canada.*

*The authors have accepted some of the changes shown on these two later maps in the vicinity of Big Valley, where a revision in the correlation of coal seams was necessary. This explains the minor discrepency between profile section C - C' and this revised map.*



## GEOLOGY LEGEND

*Coal mine on № 14 (Ardley) seam* ........ ⦶

*Coal seam № 12 (Thompson) seam* ........ ⊖

*Coal seam № 11 (Carbon) seam* ........ ⊕

*Figure in circle denotes mine on seam lower than № 11* ........ ⑦

*Columnar section measured* ........ Ⓐ→

*Oligocene*

*Paskapoo*

*Edmonton*

*Bearpaw*

*Contact observed*

*Contact assumed*

## REFERENCE

*Railway*

*Intermittent stream*

*Contours (Interval 100 feet)* ........ 3100

*Depression contours*

*Height in feet above sea level* ........ 2772

*Marsh*

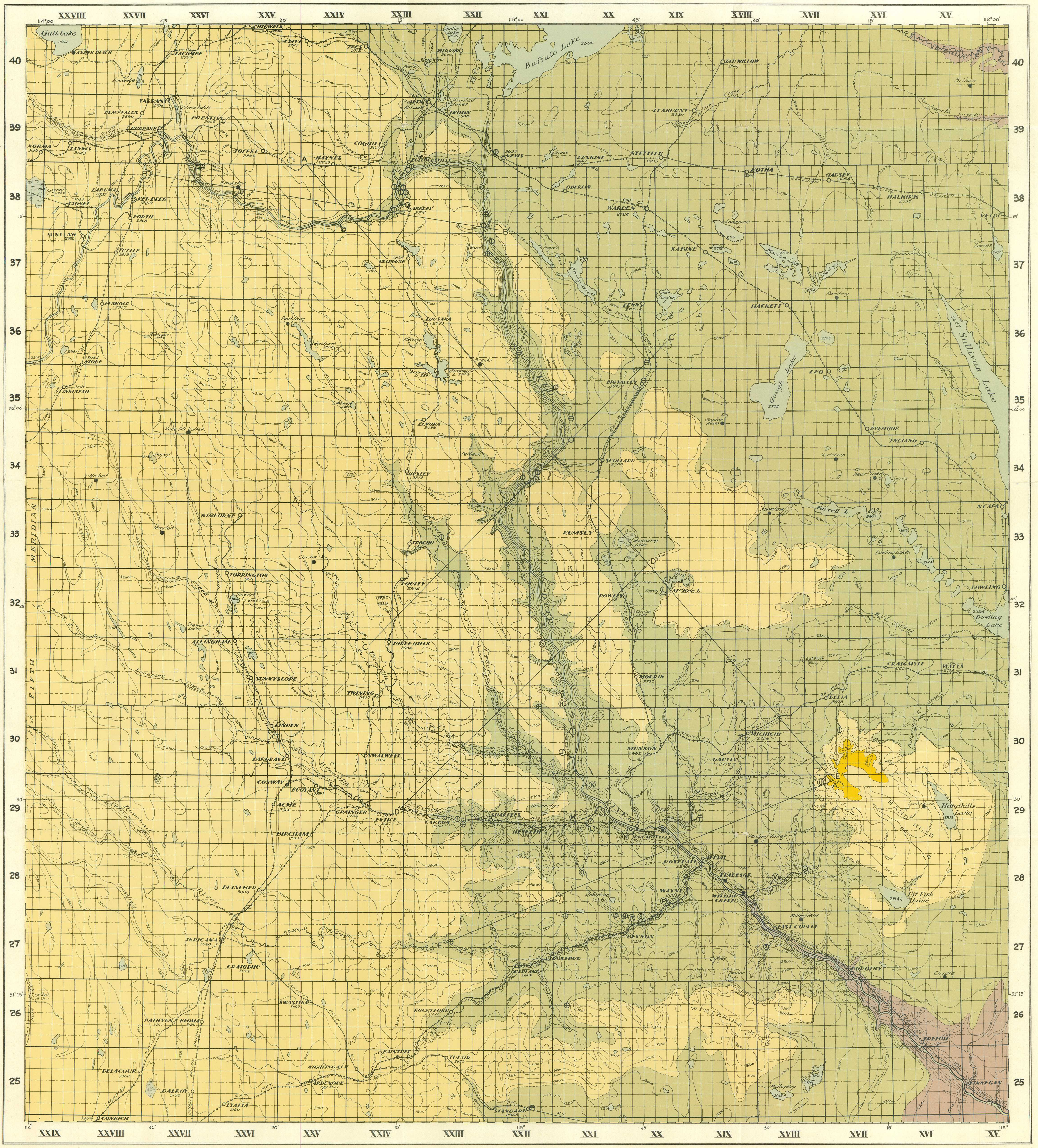
DIAGRAM OF TOWNSHIP

| | | | | | |
|---|---|---|---|---|---|
| 31 | 32 | 33 | 34 | 35 | 36 |
| 30 | 29 | 28 | 27 | 26 | 25 |
| 19 | 20 | 21 | 22 | 23 | 24 |
| 18 | 17 | 16 | 15 | 14 | 13 |
| 7 | 8 | 9 | 10 | 11 | 12 |
| 6 | 5 | 4 | 3 | 2 | 1 |

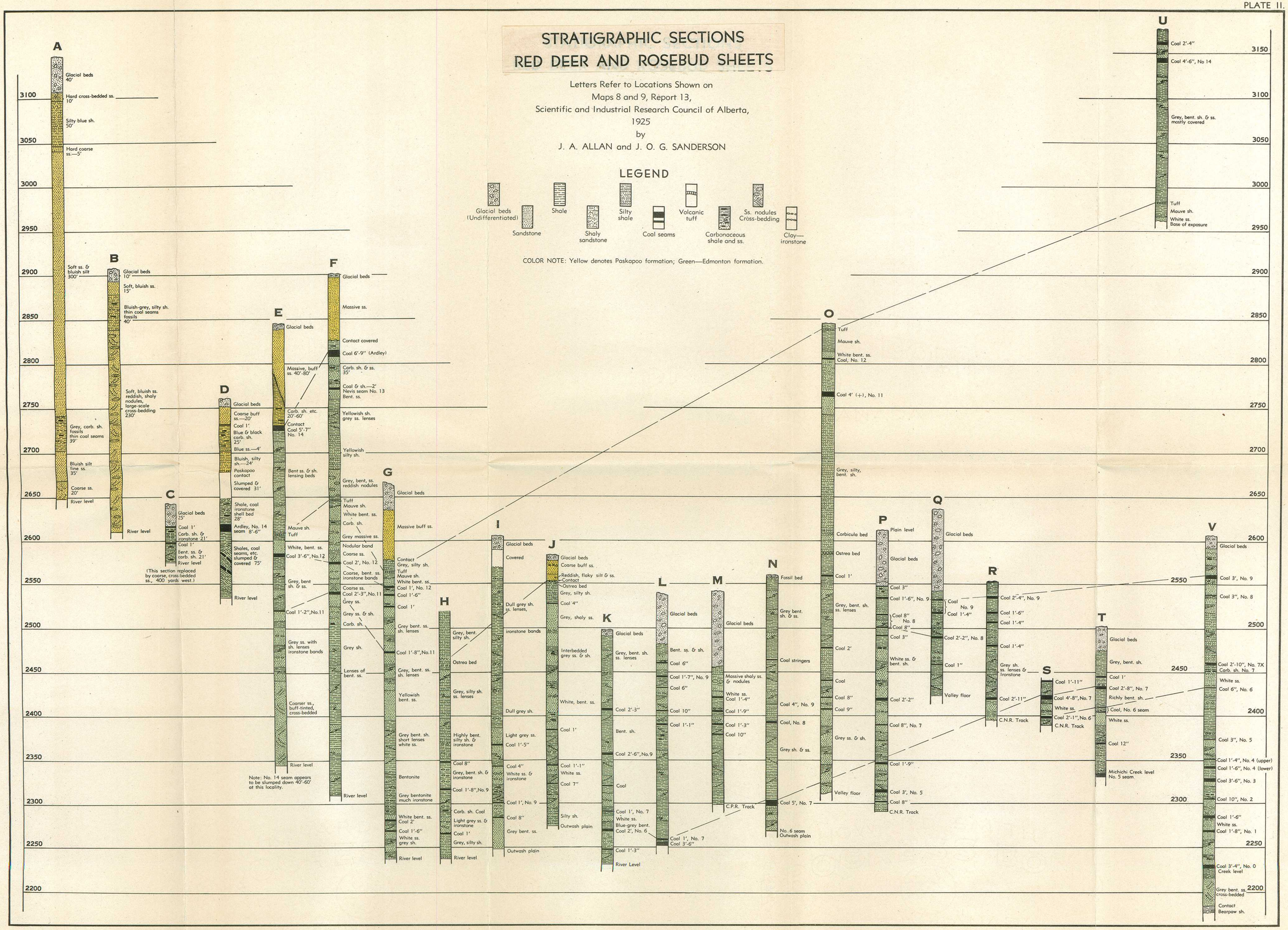
RESEARCH COUNCIL OF ALBERTA

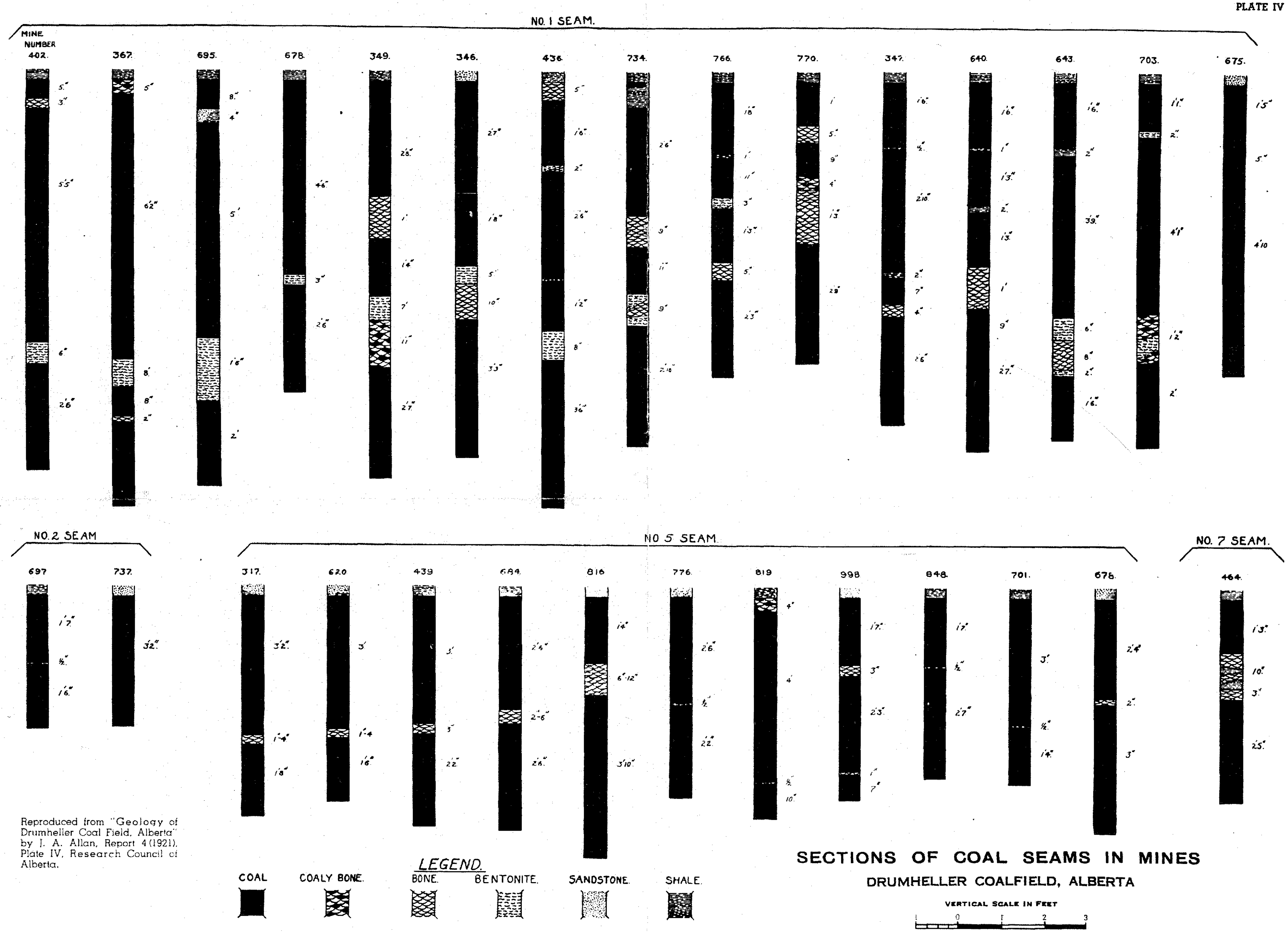
*Geology by J. A. Allan and J. O. G. Sanderson*

MAP 9A — COMBINATION OF MAPS NOS. 8 AND 9 TO ACCOMPANY REPORT NO. 13




ARC 9A c.1


STRATIGRAPHIC SECTIONS
RED DEER AND ROSEBUD SHEETS
Letters Refer to Locations Shown on
Maps 8 and 9, Report 13,
Scientific and Industrial Research Council of Alberta,
1925
by
J. A. ALLAN and J. O. G. SANDERSON
LEGEND
Glacial beds (Undifferentiated)
Sandstone
Shale
Shaly sandstone
Silty shale
Coal seams
Volcanic tuff
Carbonaceous shale and ss.
Ss. nodules Cross-bedding
Clay—ironstone
COLOR NOTE: Yellow denotes Paskapoo formation; Green—Edmonton formation.
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
T
U
V
3150
3100
3050
3000
2950
2900
2850
2800
2750
2700
2650
2600
2550
2500
2450
2400
2350
2300
2250
2200
Note: No. 14 seam appears to be slumped down 40'-60' at this locality.
(This section replaced by coarse, cross-bedded ss., 400 yards west.)




Reproduced from "Geology of Drumheller Coal Field, Alberta" by J. A. Allan, Report 4 (1921), Plate IV, Research Council of Alberta.

## SECTIONS OF COAL SEAMS IN MINES
### DRUMHELLER COALFIELD, ALBERTA

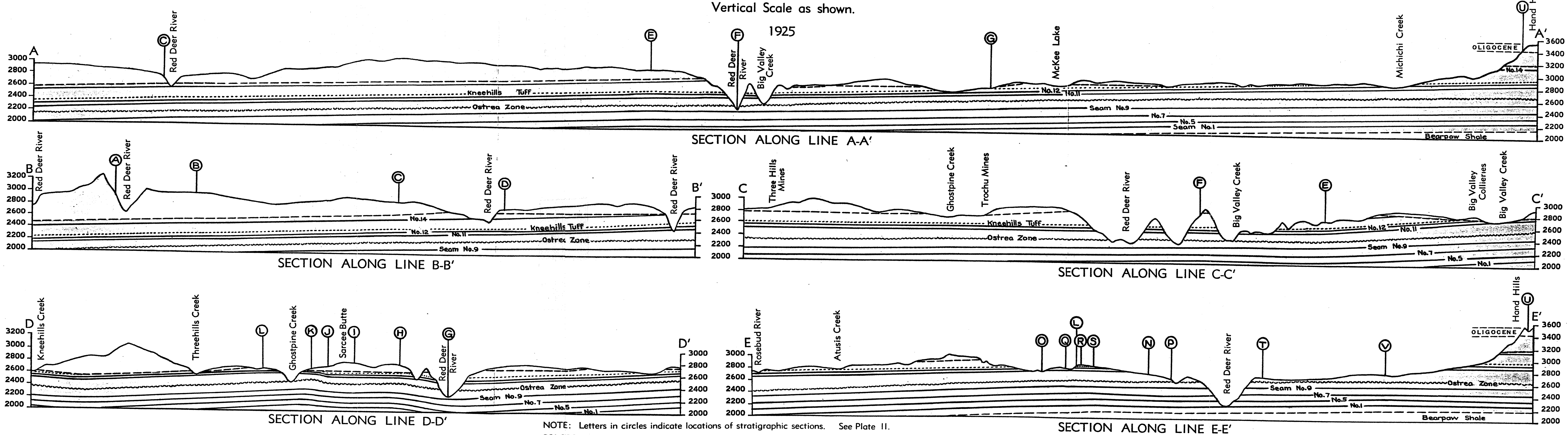
The number at the top of each section refers to the mine number given by the Alberta Mines Branch.

Drawn by J. O. Sanderson.

# STRUCTURE SECTIONS
# RED DEER AND ROSEBUD SHEETS
# ALBERTA

Horizontal Scale: 1 inch to 3 miles,
Vertical Scale as shown.

1925




NOTE: Letters in circles indicate locations of stratigraphic sections. See Plate II.

COLORS: Yellow denotes Paskapoo formation; Green—Edmonton formation.

Scientific and Industrial Research Council of Alberta, Report 13. DETAILED SECTIONS, COAL SEAMS MIDDLE AND UPPER EDMONTON. PLATE III.