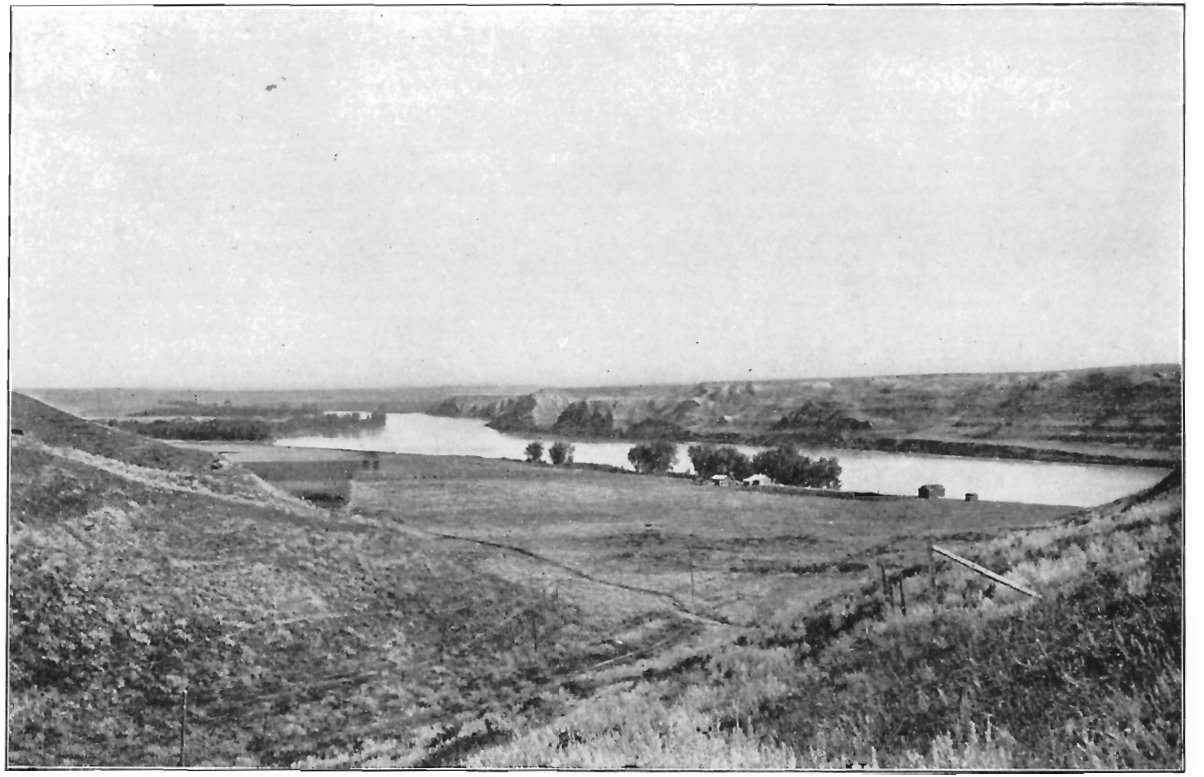
MEMOIR 93

THE SOUTHERN PLAINS OF ALBERTA

BY

D. B. DOWLING

GEOLOGICAL SURVEY
DEPARTMENT OF MINES
OTTAWA
1917



The Grand Forks. Oldman river enters on the left and Bow river in the middle distance. These form South Saskatchewan river, middle foreground, flowing to the right. (Pages 17, 103.)

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CHAPTER I.

INTRODUCTION.

The classic description of the southern plains of Alberta is to be found in the report by Dr. G. M. Dawson on the region in the vicinity of the Bow and Belly rivers.[1] This report gives a wonderfully true interpretation of the geology of the region; and later and more detailed work has served to confirm in the main the earlier conclusions. In a few cases fuller information derived from sections encountered in bore-holes and from other sources has shown that minor modifications should be made in the correlation. It is the purpose of this report, mainly, to bring the facts recorded by the earlier observers into accord with the results of more recent work and with this purpose in view very full extracts from the old reports are reproduced.

The rocks grouped under the name Belly River series were definitely determined to be beneath the Pierre shales, though in appearance and on account of the fossils they contained they seemed to belong to a series of transition beds at the top of the Cretaceous. The Judith River rocks in Montana had been called Laramie and Foxhill but were supposed by Dawson to be the representatives of the Belly River series. The examination of this series by Stanton and Hatcher for the United States Geological Survey proved that Dawson's contention was correct; but the United States geologists restricted the name Judith River to an upper series, correlated, by tracing surface outcrops northward to Alberta, with the pale and yellow beds of the eastern escarpments of Milk river.[2] Since the series described in Dawson's report as the Belly River has been found to consist of at least three main members, the division correlated with the

[1] Geol. Surv., Can., Rept. of Prog., 1882–83–84, pt. C.
[2] Bull, U.S. Geol. Surv. No. 257, p. 62.

Judith River formation is only a part of the series. Attention is drawn to this threefold division since it has been suggested that the name given by Dawson should be dropped, as it was considered to be synonymous with Judith River, which had priority. It is shown in the descriptions quoted that the series in Alberta can be correlated with fair certainty, with the group in Montana consisting of Judith River, Claggett, and Eagle formations. It is necessary, therefore, to retain the group name Belly River series for the undifferentiated Alberta equivalent of the three Montana formations.

Now that the Montana series has been subdivided and it has been shown that one of its members is the equivalent of the lower Pierre shale, it becomes necessary to revise the earlier descriptions of the Alberta deposits and to subdivide them in a way that will permit of the differentiation of the portions that may be of economic value.

The examination of the western area in greater detail has shown that the earlier interpretation of the structure and correlation by Dawson must be modified. It was assumed at the time the first reports were written that there was only one Pierre shale horizon and a certain amount of confusion necessarily followed; sandy shale exposed in the ridge near Milk River station, holding Pierre fossils, was considered to be an extension of the beds carrying coal seams near Lethbridge and to represent, therefore, the lower part of the upper Pierre; the measures overlying these at the summit of the ridge, were taken to be the equivalent of similar beds exposed on Milk river below the forks, which, to the south and east, overlay certain light-coloured shales and sandstones (Milk River sandstones) then thought to represent the pale and yellow beds at the top of the Pierre; these supposed pale and yellow beds were observed to rest on Benton shales in Rocky Spring plateau and, therefore, certain shales underlying the true pale and yellow beds east of Pakowki coulée were assumed to be Benton.

Thus it was that shales that are now known to lie between the upper and lower divisions of the Belly River series were in one instance placed above that series and in the other below it.

CHAPTER II.

GENERAL CHARACTER OF THE DISTRICT.

TOPOGRAPHICAL FEATURES.

The area covered by the accompanying map and report may be described as a plain sloping gently northward from an elevated region near the International Boundary to the wide depression occupied by the waters of the Oldman and South Saskatchewan rivers. To the southwest of this plain rises the elevation known as Milk River ridge, part of an outlying series of hills in front of the foothills; to the south and just across the boundary line, in Montana, rise the three intrusive masses known as the Sweet Grass hills; and to the east lies the elevated plateau country crowned by the Cypress hills.

River Valleys.

This plain, surrounded on three sides by higher country is scored by three valleys that have formed part of a drainage system not dependent on the present surface conditions and that are assumed to have been formed during the period of the recession of the Glacial ice-sheet. These valleys, known as Chin, Etzikom, and Verdigris coulées, are now dry. Other valleys, including Milk River valley and the trench cut by the waters of Oldman and South Saskatchewan rivers, are now occupied by streams. All, with the exception of part of the Milk River valley, bear evidences of youth, and some of them have had only a short period of use before being abandoned. They point to a temporary diversion of the waters of the St. Mary, Belly, and Oldman rivers eastward across the plain by successively lower outlets. Thus, for a short time the water reached Milk river by Verdigris coulée but later flowed across the plain in an eastern direction to the Pakowki Lake depression and during this period carved out Etzikom coulée. The drainage during these two periods of diversion appears to have reached the Missouri by way of the lower part of the Milk River valley.

The channel known as Chin coulée seems to indicate that the further recession of the ice barrier caused another diversion of the water and its return to the south Saskatchewan by the northward trending channel known as Sevenpersons coulée. The channel along this diversion is eroded in general to a greater depth than that by way of Etzikom coulée, so that it probably was occupied for a longer time than was Etzikom; and as it enters higher country and is cut to an even grade through it, the inference is that it drained a lake basin. A lowering of the water to a second stage, owing to an ice dam east of the mouth of Bow river, is indicated by an old channel showing a lower outlet to Sevenpersons coulée by way of Fortymile and Grassy Lake depressions. During this period the united streams above the glacially dammed lake commenced cutting the present channel through boulder clay and stratified deposits which back filled the former valley at Lethbridge, and no doubt much of the debris was collected in a lake formed in the depression above the junction of Oldman and Bow rivers. There is in the country just south of the river here, an extra deposit of sand on the surface, forming distinct sand hills, The lake does not seem to have been of long duration, and the removal of the ice dam allowed the stream to follow a shorter course, somewhat as at present. The channel now in use bears evidence in its canyon-like character of rapid excavation (Plate IV).

Milk River valley in Canada consists of two distinct parts historically: a pre-Glacial valley (Plate VI), starting in Milk River ridge, and following a northerly course through Pakowki lake to the Saskatchewan by way of Sevenpersons coulée; and a post-Glacial valley (Plate V), excavated when the increased drainage was forced south by an ice dam which occupied the lowlands to the north. The newer channel is gorge-like in the portion to the east of Pakowki coulée; and as the rocks cut through are soft it may be inferred that it quickly attained the general grade of the old valley, so that on the removal of the diverted northern drainage, a small stream occupying the old upper part of the valley continued the occupation of the new course to the Missouri.

Plains.

The following descriptions of the plains, written by Dawson in 1884, gives a clear picture of the field under consideration.

[1]"The plains proper may be considered as extending westward to the foot-hills near the St. Mary River in the vicinity of the 49th parallel, but further north, find their western limit at the base of the Porcupine Hills. Their surface is generally undulating or rolling, though in some localities considerable tracts occur which are almost perfectly level. The undulations vary much in amount locally, but are seldom—and then only in limited areas—entitled to be called hills. Deep, trough-like valleys, occupied by rivers, or, in some cases, by quite inconsiderable streams, and then denominated 'Coulées' trench the plains at intervals, but wide intervening areas are entirely destitute of drainage channels, the rainfall collecting in lakes, or in the innumerable small pools and sloughs which dot the surface, but which frequently dry up completely during the summer. Rising above the general level are a number of elevations which are generally called 'ridges,' but are properly speaking plateaus. The heights of these seldom exceed by more than one hundred or two hundred feet that of the surrounding plain, and their slopes are usually very light. As viewed from a distance, however, in this flat country, they are frequently conspicuous objects, and are generally in close and evident connection with the geological structure. The more important of these may be enumerated as follows:—Milk River Ridge, west of the MacLeod-Benton trail and north of the Milk River, average elevation 4,100 to 4,200 feet. Belly Butte and associated ridges between the St. Mary and Upper Belly Rivers, running eastward into Wild Turnip Hill. The Chin, on Chin Coulée, forming the western end of a diffuse plateau. Plateau south-east of Lake Pakowki, and high ground stretching eastward from the Three Buttes. Bull's Head, east of Seven Persons River, forming the southeastern front of the Peace Buttes. Black Spring Ridge, elevation 3,550 feet. The Thigh Hills. Buffalo Hills, 3,850 feet. The Rocky Buttes, about 3,100 feet. Spy Hill, Carcase

[1] Geol. Surv., Can., Rept. of Prog., 1882-83-84, pt. C, pp. 8-9.

Hill, Spring Hill, and Little Rolling Hills. Outer and Inner Rainy Hills, about 2,700 feet. Wintering Hills, about 3,000 feet. The Hand Hills, with, according to Dr. Hector, an elevation of 3,400 feet.

"The general uniformity of the surface of the country is largely due to the covering of boulder-clay and other drift deposits. These have been apparently laid down in greatest thickness in the pre-existing hollows, while the higher plateaus are comparatively thinly covered; and the result has been the general levelling up of the surface, and the production of wide flat plains in the less elevated tracts. The underlying Cretaceous and Laramie rocks are seldom seen except in the scarped banks of rivers and streams. The same circumstance has caused a remarkable uniformity in the general character of the soil, which, below the sod, is usually composed of the rearranged materials of the boulder-clay. It may be described generally as a clayey loam, of brown or grey tint, and mingled locally with a varying proportion of gravel. Gravel is most usually found in the subsoil in the higher tracts, and is almost or altogether wanting in many of the lower, which are characterized by fine water-deposited loam. No large areas of loose sandy soil, or sand-hills, have been observed in this district, the most extensive covering only a few square miles, of these the following may be noted:—Sand hills north and east of Lake Pakowki. About forks of Bow and Belly Rivers. In the south bend of the Belly east of Little Bow. Near the mouth of the Little Bow. The Drifting Sand Hills, and the Peigan Sand Hills west of Blackfoot Crossing and near the Bow River.

"In a few places the surface is pretty thickly strewn with boulders, but these areas are quite inconsiderable, and the prominence of the boulders is generally to be traced to the removal by denudation,—owing to some local circumstance—of a considerable depth of the finer materials of the drift. The general absence of boulder-strewn tracts thus shows how small must have been the effect of denudation since the deposition of the boulder-clay and other glacial materials.

"Speaking generally, the soil may be described as fertile, and in some places is eminently so, but over a large part of these

plains the rainfall is probably too scanty for the successful growth of crops. The surface is almost uniformly grassed, and no tracts of an absolutely barren or desert-like character occur. The grass is usually the short crisp variety known as "buffalo grass," which becomes to all appearance dry about midsummer, but is still green and growing at the roots, and forms nutritious pasture both winter and summer. In some particularly dry areas about the lower Bow River, the grass becomes scanty, but on almost all the plateaus above enumerated it is particularly good, while a heavy growth of grass suitable for hay is found in many of the river bottoms, and surrounding the numerous lakes and sloughs. This whole region, a few years since, contained numerous herds of buffalo, and though these have now practically disappeared, it will not be long before they will be replaced by cattle and horses.

"The entire region of plain included on the map may be characterized as treeless, and except in the river valleys, or here and there in some steep-sided coulée, no arboreal or shrubby growth of any kind exists.

Milk River and Country in its Vicinity.

[1]"Milk River rises in the foot-hills south of the 49th parallel and, crossing that line near the 113th meridian, pursues a course not far north of the parallel for a distance—without taking into consideration its minor flexures—of one hundred and three miles, within the limit of the present map. A short distance beyond the eastern edge of the map, it recrosses the 49th parallel on its course to join the Missouri. It is known as Kenuhsisuht or Little River by the Blood Indians and possesses some peculiar and interesting features. In that part of its course above defined it receives besides the South Branch which is about equal to the main river or North Branch, a few small tributaries from the south, of which Red Creek is the most important, and probably holds running water at all seasons. The tributaries from the north are all very small brooks, even at times of high water. The river cannot be considered as navigable even for canoes.

[1] Ibid., pp. 13–20.

It is rapid and in some parts of its course very tortuous on a small scale, but in many places difficult to cross on account of quicksands. In the season of 1874—a more than usually dry year—we found its bed completely dry in some places a few miles south of the 49th parallel, a short distance east of the limit of the present map. Between the 113th and 112th meridians, the country has a general northward slope, which, on the MacLeod-Benton trail, from the high southern edge of the Rocky Spring Plateau to the 49th parallel—a distance of twelve miles—amounts to 405 feet, or about thirty-four feet to the mile. The wide clayey and barren plain southeast of this plateau has an elevation several hundred feet less than that of the bed of the Milk River in the same longitude. Between the MacLeod-Benton trail and the flank of the West Butte, near the 49th parallel, are several wide irregular trough-like valleys, holding very small streams, or entirely without flowing water, for which the present conditions of the country fail to account. The drainage of the northern flanks of the Buttes, which is very small in amount, also finds its way to the Milk River by a system of valleys, some of which are of considerable depth.

"In the report on the Geology and Resources of the 49th Parallel, I have described the general aspect of the country south of the Milk River, and west of the West Butte in the following terms:—As compared with the tract east of the Butte and south of the Cypress Hills, it improves in appearance, and shows evidence of a greater rainfall, and the cactus, grease-wood and *Artemisia* cease to appear. It is generally much broken, but shows evidence of a former more elevated surface, in somewhat extensive flat-topped hills, which, when ascended, are found to be nearly of equal height, and show much drier and more gravelly soil than elsewhere found in the region. There is usually a close thick growth of grass, and the swamps and sloughs, which are numerous, generally hold grasses and *Carices* to the exclusion of the rushes formerly most abundant.

"Three wide valleys join the Milk River from the north—the Lonely Valley, Verdigris Coulée, and the Lake Pakowki Coulée. The two first carry very small streams and the latter is dry. In fact, at a distance of a few miles north of the Milk

River, the whole country is below the level of its bed. Thus, five miles northwest of the point at which it first crosses the 49th parallel, the plain is fifty-seven feet lower than the nearest part of the river. Twelve miles north-west of the mouth of Lonely Valley, beyond the Milk River Ridge, it is one hundred and seventy feet lower, eight and a half miles north-west of the MacLeod-Benton trail-crossing, nearly on the course of the trail thirty-two feet lower. The most remarkable instance is found, however, in the Lake Pakowki Coulée, where the south-western arm of the lake reaches to within three and a half miles of the river but is eighty feet lower than it. Here, by a small cutting, the river might be turned into the lake, and would then flow round by Many Berries Creek, returning to the present valley near its intersection with the 49th parallel.

"The Milk River thus actually occupies the central line of a long broken plateau region, of which the Milk River Ridge, the Rocky Spring Plateau and other elevations, constitute the higher parts, and its waters at the point at which it first crosses the 49th parallel are at a greater elevation than those of any of the other large streams in the district, except when these are in the immediate vicinity of the mountains. The greater part of the Milk River Ridge, and a considerable portion of the Rocky Spring Plateau exceed 4,000 feet in elevation.

"The country in the immediate vicinity of the river-valley from the 113th meridian to the point at which the MacLeod-Benton trail crosses, may be described as generally affording fair to good pasturage. The lower tracts and valleys are invariably covered with good grass, while some of the higher tracts are gravelly and rather bare. The valley itself probably averages about a mile in width—though narrow and about 300 feet deep for a few miles below Lonely Valley—and invariably produces very fine grass, of which a considerable portion is sufficiently long to be cut as hay. The Milk River Ridge, to the North, is elsewhere more fully described. Its surface though high, is well grassed, and dotted with numerous sloughs and pools. It will constitute a fine summer grazing ground. No arboreal or shrubby vegetation is met with except a few bushes in one or two deep coulées.

"For about seven miles east of the trail-crossing, the valley is remarkably wide with low sloping banks in many places, but is equally destitute of wood. Thence to the mouth of Verdigris Coulée it seldom exceeds half a mile in width, and the pasturage to the north for some distance is rather short and indifferent. No wood occurs in the Verdigris Coulée, which is a trough-like valley about three-quarters of a mile wide, and holds several lakes in its course. From this point, for eight miles, the Milk River valley expands, and is about a mile wide north of the West Butte. The bottom is well grassed, and small groves of cottonwood occur in it. Sandstones, which weather into monumental and fantastic forms, elsewhere fully described, border its sides. The pasturage in the plains immediately to the northward may be characterized as fair, though occasional patches of cactus occur.

"The river next turns abruptly to the north, in a comparatively narrow valley, while a wide trough, evidently that formerly occupied by the stream, and known as Dead Horse Coulée, continues in the main direction for six miles when it is rejoined by the river. Thence to the Pakowki Coulée the valley is at least fifty and sometimes over one hundred feet deep. It continues wide, and the edge of a low diffuse plateau runs nearly parallel to it some miles to the north. The country between the river and the plateau-edge affords fair to good pasturage, and pools and swamps are in some places frequent. The level of the plateau further to the north slightly exceeds 3,000 feet, with an undulating surface, and generally affords a good close growth of buffalo-grass. It is diversified by numerous small pools and swamps, most of which become dry before the end of the summer.

"Near Pakowki Coulée the valley again holds a few trees. The Pakowki Coulée between the river and arm of the lake is wide and flat-bottomed with patches of sage brush and some good grass. From this place to the edge of the map, the Milk River valley continues wide, but is deep and forbidding in aspect, with high bare clay-banks and a few groves of trees. Thence to the point at which it finally crosses the 49th parallel, it is in

some places very deep and difficult of access but is never without well grown cottonwood trees.

"Pakowki is the largest lake in the district embraced by the present report. It is very irregular in shape, holds several islands, and is evidently shallow. The north-west and south-west arms are bordered by high banks, and doubtless represent old drainage channels, but the country on the north-east side is low, and as viewed from a distance presents wide areas of bare sand hills. The water is of a greyish milky colour and slightly saline.

"The following description of the Three Buttes and their vicinity is again quoted from my report on the Geology and Resources of the 49th parallel:—The isolated mountains called by the half-breed hunters *Montagnes du Foin de Senteur*, are known to the traders of the Missouri region as the 'Sweet Grass Hills.' They are roughly indicated on most good maps of the west, and are there found under the geographical appellation of the 'Three Buttes.' As indicated by the latter name there are three distinct mountain masses. A line passing from the peak of the eastern through the central mass of the West Butte, would have a direction of about N. 70° W., the central Butte lying between them, but some miles to the south. The highest summits are those of the eastern and western Buttes, which are about twenty miles apart, and rise nearly 3,000 feet above the level of the plains at their base. The height of the summit of the East Butte, as ascertained by the aneroid barometer, and taking the mean of two readings separated by about an hour, is 6,200 feet. That of the West Butte was found to be 2,746 feet above the depot camp at its base, by comparison with nearly simultaneous readings there; and taking the height of the latter locality at 3,737 feet, the height of the West Butte above the sea would be 6,483 feet.

"The central masses of the Buttes are composed of eruptive trappean rock, and around them the previously horizontal beds of the plains have been tilted up, those immediately surrounding the igneous masses resting at very high angles. The West Butte is the most important, and forms quite a little mountain region, having numerous peaks and ridges, with round or blunted tops,

and deep, almost precipitous, valleys. The East Butte is next in importance, and consists of four main peaks, arranged nearly as the angles of a square. The north-western of these is the most prominent and conical; the south-western is round-topped and connected with the north-western by a ridge, and not far below it in height. The north-eastern and south-western summits are nearly equal in elevation, but considerably less than the others. The central Butte was not ascended, but appears to be notably smaller than the others. It has, however, an exceedingly symmetrical conical form, as viewed from almost every direction, and its slopes must form an angle of nearly 45° with the horizon. Like the East and West Buttes it is surrounded by grassy foothills, which are especially prominent on its northern slope.

"The height and mass of the Buttes is sufficient to cause the formation and arrest of clouds in their immediate vicinity, where the rainfall is in consequence much more copious. These mountains and the broken ground around them form a favourite haunt of the buffalo (in 1874) where they find abundance of food and water. The springs arising from some parts of the Buttes are very copious, and form streams, which, on leaving the shelter of the wooded valleys and issuing on the plains are rapidly absorbed by the dry soil and atmosphere, at least in the summer season. One of these was observed to be a rapidly flowing brook during the night and morning hours, but in the afternoon became quite dry. The timber of the Buttes is chiefly pine; much of it has been burned, but it shows a tendency to renew itself. The trees are not of great size and generally in somewhat inaccessible parts of the mountains but cannot be considered unimportant in a country so treeless. A few of the plants found at elevations above 6,000 feet in the Rocky Mountains appear also on the summits of the Buttes.

"The following paragraph, though written in 1874 and referring to conditions obtaining at that time, may also still have some interest:—The country surrounding the Buttes is said to have been for a long time a neutral ground between various tribes of Indians. That it has been so is evidenced by the almost complete absence of buffalo bones in the neighbourhood, and the rare occurrence of the circles of stones marking camping places.

The region is at present a debatable ground between the Blackfeet, Peigans, and Bloods of the west; the Sioux and Assiniboines of the east, and the Crows and other tribes of the Upper Missouri. It is not passed through save by war parties strong in numbers and travelling rapidly. Ten miles north of the Middle Butte the bodies of over twenty Crow Indians were found, unburied, on the scene of a conflict.

Plains between Milk River and Oldman River.

"Beyond the region of plateau and high plain which borders Milk River valley on the north, the whole surface of the country slopes gradually northward toward the Belly River, till, between Coal Banks and the Chin the elevation is about 3,000 feet, and between Seven Persons River and the South Saskatchewan about 2,500 feet only. It must not be supposed, however, that the surface is quite uniform. Besides the valleys of some important coulées, several low plateaus appear, of which the Chin, and that midway between Seven Persons River and the Saskatchewan are most important. The Bull's Head constitutes the most prominent portion of a still more elevated plateau at the extreme east of the map known as the Peace Buttes. Ten miles southeast of Coal Banks a limited tract, characterized by irregular low hills, is crossed on the MacLeod-Benton trail. The region south of the Belly, between Driftwood Bend and its mouth, is rolling or rather hilly, with intervening pools and lakes. Some small sandhills also occur immediately south of the confluence of the Bow and Belly. South of the crossing of Seven Persons River by the Cypress trail, is another broken hilly tract, apparently composed of drift materials, and strewn with numerous boulders. To the south of this is a valley three miles wide, not resembling that of a river or related to that of any existing stream. The bottom slopes gently southward, but the main course of the valley is nearly east and west. This is again bordered to the south by a well-marked hilly ridge, which separates it from the Lake Pakowki valley, and it is also about three miles wide.

"The Chin Coulée is the most remarkable of the valleys traversing this part of the plain, and from the Chin to its junc-

tion with Peigan Creek at the eastern crossing of the Cypress trail, has a length of nearly seventy miles. It is a trough-like valley from half a mile to a mile in width, and depressed from 150 to 250 feet below the prairie level. A number of small lakes lie in the valley and are connected by a little flowing water at seasons of flood, but during the summer some of them dry up completely. Boulders are quite abundant in some places, having been concentrated by the removal of the finer portion of the drift deposits, and the underlying Cretaceous rocks are exposed in a number of places in its banks. On the south side a little scrub occurs, and in the bottoms occasional thickets of sage brush. The Forty-mile Coulée which joins it from the northwest is similar in character, but both this and the upper part of the Chin Coulée appear to die out entirely before reaching the bank of the Belly River.

"The Peigan Creek above alluded to, is really the upper part of the Seven Persons River. Its valley is narrow and evidently of more recent origin than the Chin Coulée, and when the stream reaches the latter it immediately adopts it, and flows in it to the South Saskatchewan River. The valley of the Seven Persons River, north of the Cypress trail, therefore, constitutes the continuation of Chin Coulée, and is wide and important. It holds, at least in its upper part, a few small trees.

"South of the Chin Coulée is a second and very similar valley, which runs in a nearly parallel direction at a distance of from six to eleven miles, and may be noted by its Blackfoot name Etzi-kom. This valley also holds several small lakes, and at its eastern end contains a small stream which flows into the north-west arm of Lake Pakowki. The coulée originates in the region east of the Fifteen-mile Butte on the MacLeod-Benton trail. Kipp's, Middle, and Ed. Mahan's Coulées—crossed south of this point by the same trail—were, by the exploration of 1883, found to be branches of Verdigris Coulée, the mouth of which has already been referred to in connection with the description of Milk River. There are in all seven lakes in Verdigris Coulée east of the MacLeod-Benton trail. Of these the largest is about seven miles in length. This coulée in its steep banks and flat bottom resembles those above described,

and like them cannot be accounted for by the present conditions. Not only do the small streams now flowing into it lose themselves in its lakes so completely that not even a permanent flood-channel connects the lakes in its upper part, but its bed is almost absolutely flat from the trail-crossing of its upper branches to its mouth on the Milk River.

"As a grazing country, the region of plains between Milk River and the Belly may be described generally as of fair quality. It varies from indifferent, to fair and good, and may be classed as very good in a few limited tracts. The best and most extensive areas of grazing land are found in the vicinity of the MacLeod-Benton trail and westward, including the Milk River Ridge region; between Cherry Coulée and the Seven Persons River north of the Cypress trail; south of the Cypress trail near the 111th meridian; and west of Lake Pakowki, in the angle between it and the Milk River.

"The cairn on the south side of the Saskatchewan near the confluence of the Bow and Belly is regarded with much veneration by the Indians who call it Omaxokotok, but I have been unable to discover any reasonable explanation of its origin or meaning. It is a pile of rough boulders about six feet in height, with a breadth of base of about fifteen feet, and occupies a commanding situation on the brow of the hill overlooking the river. A few other small cairns occur in this district, but are probably only landmarks. Ten miles south of the Cypress trail on the 111th meridian, and in a few other places, some old stone-piles, now nearly imbedded in the sod, appear to cover shallow graves. In the Etzikom Coulée, a couple of miles from Lake Pakowki, a cairn, apparently of pretty recent date, probably marks the scene of a fight, as some rough low breastworks of boulders were also noticed there."

Oldman and South Saskatchewan Rivers.[1]

[2]"The Oldman river with the upper part of the South Saskatchewan occupies the centre of a wide depressed area,

[1] The lower portion of Belly river of Dawson's report is now known as a part of Oldman river.

[2] Ibid., p. 23.

which runs across the entire district with a course a few degrees north of east. This important feature originates at the mountain precisely opposite the remarkable gap in the Palæozoic rocks of the outer ranges, and both are doubtless due to some general structural circumstance not yet clearly ascertained."

[1]"At Coal Banks ferry, (Lethbridge of the present maps) the high water channel of the river is 437 feet wide. From this point it runs northward for twelve miles to Big Island Bend. The prairie level is 300 feet above the river, and scarped banks occur with fine sections, occasionally over 200 feet high. The valley is of the usual trough-like form, about a mile in average width in the bottom, with the river meandering from side to side and still evidently actively engaged in widening the trough by the constant waste of the cliffs at its convex bends. The flats are generally covered with fine cotton-wood and luxuriant foliage, in which the choke-cherry bushes are prominent, and several of the bottoms are adapted to agriculture.

"On turning eastward the valley becomes somewhat more confined, and is still nearly as deep as before, but with the banks more gently sloping and grassy, and fewer good sections, to the mouth of the Little Bow. From its first bend below Big Island to within a mile and a half of the Little Bow, there are no trees. The country evidently becomes dryer in this direction, and the low cactus abounds on southward-facing banks. About the mouth of the Little Bow are wide bottoms with some timber and probably a thousand acres of cultivable land.

"From the Little Bow to the mouth, there are practically no trees or shrubs, with the exception of those on a few islands. The bottom of the valley averages scarcely more than half a mile in width, and the banks are from one hundred to one hundred and fifty feet in height. They are often for considerable distances grass-grown, and the sections of the rocks are not nearly so good as before. Wolf Island, nine miles above the mouth of the river, is the largest in this part of its course, being half a mile long. It supports some cottonwoods on its lower end.

"A mile and a half from the mouth of the river is a flat with a grove of cottonwood and thickets of large *Artemisia* bushes.

[1] Ibid. pp. 25–26.

Opposite this point the river is 720 feet wide, with a velocity of 3·6 miles per hour, being here rather less swift than in most places on its lower course.

"The height at the confluence of the Belly and Bow is 2,212 feet, giving a difference from Coal Banks of 520 feet. The distance, measured in two mile stretches, is seventy-six miles, and the average slope is at the rate of 6·8 feet in a mile, though considerably more in the upper part and less in the lower. In the autumn the volume of the river is much decreased, and it would not be easy to descend some parts of it in a large flat-bottomed boat. During high-water, in the early summer it would probably be possible to make a few trips with a small stern-wheel steamer, as far up as Coal Banks, but it cannot be counted on as a means of carrying eastward any large quantity of coal from the fine seams in that vicinity.

"In 1881 no sign of habitation existed below Mr. Sheran's house at Coal Banks, and in descending the river we saw but a single Indian.

"The island at the confluence of the Belly and Bow[1] supports a few cottonwood trees (Plate I), but from this point to the edge of the map, wood is extremely scarce along its course. Between the confluence and Cherry Coulée, high, scarped, desolate banks occur on both sides of the South Saskatchewan, and the general level of the prairie is nearly 250 feet above the river at the latter point (Plate IV). At the same place the width of the stream was found to be 1,013 feet, and the current three miles an hour only. This river is generally tranquil to Medicine Hat at the eastern border of the accompanying map, but the valley is narrow, and in places almost cañon-like with banks 250 to 300 feet high."

CLIMATE.

[2]"A few words may be added in regard to climate. We are yet without full and trustworthy observations of the temperature and rainfall, but these will doubtless be supplied ere long by the meteorological service. The climate of that part of the district included under the general title of Plains, probably

[1] Oldman and Bow of present maps.
[2] Ibid., pp. 12–13.

closely resembles that of a large portion of the southern part of the great plains of the North-west Territory. The total annual precipitation of moisture is evidently small, the summer heat is frequently great during the day, and is quite sufficient in intensity and duration for the ripening of all ordinary grains, wherever sufficient moisture is found for their healthy growth. The winter is severe and the exposed and treeless character of the country causes its rigour to be more keenly felt, but there is no reason why tree-planting should not succeed at least in the river valleys and on broken ground, even in many of the dryer portions of the plains; and wherever the rainfall is sufficient for crops, the growth of trees with proper precautions is undoubtedly possible. It is stated that the winter climate in the neighbourhood of Fort MacLeod is milder than elsewhere, and though little instrumental proof of this can yet be adduced, it may probably be the case, and arise from the less elevation of that part of the district, combined with its vicinity to the mountains. The snow-fall is light over the entire district, and in the Porcupine Hill region and foot-hills, its amount and persistence is largely a matter of elevation, the higher tracts receiving and bearing much more snow than those with a less altitude. The country in the neighbourhood of the mountains has undoubtedly a milder climate than that remote from them, and this—up to a certain point—notwithstanding its greater average height. The set of the aerial currents from the westward and particularly the strong westerly winds known as "Chinooks" play an important part in this amelioration. It is not the case that low passes in the mountains account for the influence of the westerly winds. It is on the contrary the fact that the passage of these winds over a high mountain barrier, and their subsequent descent into low ground in a comparatively dry and warm state, in correspondence with well-known physical laws, enable them to affect the rapid dissolution and evaporation of the snow. This result is most perfectly attained where the descent from the summits of the range to the valleys below is greatest, and as the lowest tracts are generally in the river-valleys, is there most marked."

In an earlier report Dr. Dawson makes a further reference to the cause of the warmth and dryness of the Chinook winds:

[1]"The complete explanation is to be found in the great quantity of heat rendered latent when moisture is evaporated or air expanded in volume, but which becomes sensible again on condensation of the moisture or compression of the air.

"The pressure in the upper regions of the atmosphere being so much less than in the lower, a body of air rising from the sea-level to the summit of a mountain range, must expand, and this, implying molecular work, results in an absorption of heat and consequent cooling. The amount of this cooling has been estimated at about 1° Centigrade for 100 metres of ascent when the air is dry, but becomes reduced to ½ degree when the temperature has fallen to the dew-point of the atmosphere, and precipitation of moisture as cloud, rain or snow begins; the heat resulting from this condensation retarding to a certain degree the cooling due to the expansion of the air. When the air descends again on the further side of the mountain range, its condensation leads to an increase of sensible heat equal to 1° C. for each 100 metres.[2] It is owing to this circumstance that places in the south of Greenland, on the west coast, during the prevalence of south-easterly winds, which flow over the high interior of the country, have been found, in winter, to experience for a time a temperature higher than that of North Italy or the south of France, though the North Atlantic Ocean from which the winds come, can, at this season, be little above the freezing-point. The wind well known in the Alps as the foehn, is another example of the same phenomenon.

"The data are wanting for an accurate investigation of the circumstances of our west coast in this regard, but a general idea of the fact may be gained. We may assume that the air at the sea level is practically saturated with moisture, or already at its dew-point, that in crossing the mountainous region the average height to which the air is carried is about 2,000 metres (6,560 feet), and that it descends to a level of about 700 metres (2,296 feet) in the Peace River country. The loss of sensible heat on elevation would, in this case, amount to 10° C. (18° F.), the

[1] Geol. Surv., Can., Rept. of Prog., 1879–80, pt. B, pp. 77–78.

[2] The figures are Dr. Hann's, quoted by Hoffmeyer in the Danish Geographical Society's Journal, and reproduced in Nature, August, 1877.

gain on descent to the level of 700 metres to 13° C. (23·4° F.). The amount of heat lost by the air during its passage across the mountainous region, by radiation and contact with the snowy peaks, cannot be determined. It is of course much greater in winter than in summer, and depends also on the speed with which the current of air travels. Taking the mean summer temperature of the coast at about 12° C. (54° F.) and allowing several degrees for loss by radiation, it becomes easy to understand how the western prairies may be flooded with air nearly as warm as that of the coast, though it has travelled to them over a region comparatively cold.

"Owing to the great width of the mountain barrier, the main result is complicated by local details, regions of considerable precipitation occurring at each important mountain range, with subsidiary drier regions in the lee. The last of these regions of precipitation is that of the Rocky Mountain Range properly so-called. In descending from this, a further addition of heat is made to the air, which then flows down as a dry and warm current to the east."

CHAPTER III.

GENERAL GEOLOGY.

The rocks exposed on the plains of southern Alberta are of Upper Cretaceous age. The swell in the crust caused by the protrusion of the igneous masses found in the Sweet Grass hills, just across the boundary in Montana, brings to the surface the upper members of the Palæozoic; so that the whole Mesozoic section may be studied. The portions of the Upper Cretaceous which are exposed on the plains consist of marine shales, brackish water sands and clays, and freshwater deposits—an association indicating that while the general plains region was covered by the sea the western part, including the area under consideration, was for a time elevated above sea-level and instead of marine deposits near-shore and land deposits were laid down.

The conditions of sedimentation are more fully explained in a paper by the writer published by the Royal Society of Canada.[1] The deposits of the area under discussion which belong to the shallow water period following the marine invasion marked by the Colorado deposits, have been described by Dr. G. M. Dawson as the Belly River series, and his descriptions of the rocks have been largely used in the present report. The table on page 22 includes, besides the formations that are exposed at the surface in Canada, others that outcrop south of the International Boundary and presumably underlie the Canadian plains.

SUPERFICIAL DEPOSITS.

Glacial deposits form a thin mantle over the whole area under review. Morainic hills may possibly in time be traced across portions of the plains to indicate halting stages for the ice-sheet. In the general description of the surface it was assumed that the change in the drainage was due to the shifting of the ice

[1] "The Cretaceous Sea in Alberta", Trans. Roy. Soc., Can., 3d. ser., vol. IX.

Table of Formations.

	WESTERN MONTANA.	BOW AND BELLY REGION. (Dawson 1882–84).	SOUTHERN ALBERTA.	CENTRAL MONTANA.	MANITOBA.	SOUTH DAKOTA.
Montana group	Bearpaw shale (marine)	Pierre-Foxhill (marine)	Bearpaw shale, 622 feet (marine)	Bearpaw shale (marine)		
	Two-Medicine formation (Fresh water and brackish water)	Belly River series (fresh water and brackish water)	Pale beds, 651 feet (mostly fresh water)	Judith River formation (mainly fresh water)	Odanah and Millwood shales (marine)	Pierre shales (marine)
			Foremost beds 200 to 300 feet (brackish water)			
			Pakowki shales, 300 feet, thicken eastward (marine)	Claggett shales (marine)		
	Virgelle sandstone		Milk River sandstone, 316 feet in west 200 at Taber (fresh water and brackish water)	Eagle sandstone (marine at top and bottom)		
Colorado group	Benton shales (marine)	Lower dark shales of Rocky Spring ridge (marine)	Benton, exposed in northern Montana, 1,776 feet in Sweet Grass hills (marine)	Niobrara-Benton shales (marine)	Niobrara shales	Niobrara shales
					Benton shales	Benton shales
Dakota group			Shales and sands exposed in Sweet Grass hills		Dakota sandstone	Dakota sandstone

front. Under this assumption records of the halting stages of the ice should be found between the shifted channels. One of these was noted to the north of Etzikom coulée south of Foremost and seemed to indicate that the continuation of the southern drainage was due to an ice dam, running east and west, north of this channel.

In the vicinity of the Oldman valley there is an accumulation of river-borne material that seems to belong to two periods, one that may be termed the retreating ice period and the other in many cases antedating Glacial time. The newer sands and silts are spread over the surface at some distance from the valley and seem to have been deposited in lakes lying along the ice front. The deposits of the Lethbridge-Raymond area seem to belong to the period when all the western drainage found a passage by Verdigris and Etzikom coulées, successively, into a lake basin below. Farther down the river the sand hills near the mouth of the Bow suggest the energetic cutting of new channels in both the Bow and the Oldman above this point, and the scattering of the debris in a lake drained by Fortymile coulée. The older stream deposits are found to have filled an old river valley. The present stream follows a somewhat erratic course and in places is in the old valley, but on account of a steepening of grade, has cut below it. Sections of over 200 feet of these stream deposits are found in the Oldman valley near Lethbridge and several other sections are obtained from well records. The northwestern edge of this old valley is limited by the high ground northwest of the present river. To the east little evidence has been found to outline the valley. In the vicinity of the coal mines on the west side of the river the following sections were obtained in drillings near Chinook. The thickness of these deposits appears to be about 220 to 230 feet. At the head of Piyami coulée the deposit is 153 feet thick. On the slopes of Black Spring ridge and at its base there are gravels and sands deeply covered by drift from these hills, but at a much higher level than farther south. The following sections serve to illustrate the character of the deposit referred to in several papers and reports under the name of Saskatchewan gravels.

Section on Section 12, Tp. 10, Range 22, W. 4th Mer.

	Feet	Inches
Yellow clay and sand	87	0
Dark blue clay	22	0
Sand and rocks mixed	16	0
Gumbo	10	0
Sand	3	0
Clay	6	0
Sand	4	0
Clay	4	0
Sand	8	0
Clay	40	0
Sand and gravel	10	0
Sand and rocks	10	0
	220	0

Record from Well in S.E. ¼, Sec. 12, Tp. 10, Range 22, W. 4th Mer.

	Feet	Inches
Soil and subsoil	5	0
Sandy clay with few rocks	135	0
Sandy gravel and rocks	6	0
Sandy clay	26	0
Sand and boulders	3	0
Blue sandy clay	19	0
Hard hardpan	8	0
Gravel and sand (cemented)	6	0
Hard quartzite boulders	7	0
Hardpan	2	0
Yellow shaly clay	3	0
	220	0

Further discussion on these deposits is to be found in papers by Dawson and McConnell on the Saskatchewan gravels, published in the Bulletins of the Geological Society of America, vol. VII, pages 31–66, and further discussions by W. C. Alden in vol. XXIII, pages 687–708, and by Alden and Stebinger in vol. XXIV, page 557, of the same series of bulletins.

BEARPAW SHALE.

The portion of the area dealt with in this report, in which the marine shales of the Bearpaw formation are found, lies along the western limb of a broad anticline. In the Milk River ridge a thin sheet of these shales is found on the summit in range 19. To the west, owing to their westerly dip they are found in the

lower land near the mouth of St. Mary river (Plate II) and are thicker, since they have suffered less erosion. Concealed under a heavy mantle of alluvium and drift these shales are exposed along the banks of Oldman river from Ryegrass flat to Piyami coulée. The formation consists generally of dark shales holding a few ironstone nodules and a few fossils characteristic of the marine part of the Montana group. Its thickness seems to be less in this district than on the western slope of the Cypress hills and has been variously estimated. A former estimate, based in part on the record of a boring near Kipp station, placed the thickness at 615 feet, but uncertainty as to the exact position of the top of the well in the geological section made the estimate inconclusive. Another record obtained by diamond drill north and beyond the mantle of drift seems to place the thickness of the shale series at 622 feet. In this case the top of the formation was definitely fixed by the recognition in the record of a series of sandy beds similar to those at Ryegrass flat lying above the mass of the shale. These beds are probably the ones correlated with the Foxhill sandstones. The drilling record also reveals the presence of a sandy member in the shale series 208 to 227 feet below the sandstones at the top. The shales are generally of a lead-grey colour and are essentially an argillaceous formation containing hardly a trace of lime.

The complete section of this formation obtained from a boring near Scabby butte, sec. 9, tp. 11, range 22, W. 4th mer., shows sandstones at the top, which probably are the equivalent of those at Ryegrass flat (the so-called Foxhill). Beneath the sandstones is the general shale formation of the Bearpaw or upper Pierre, with, however, sandy beds at the middle which indicate shallow water conditions. The following section is found beneath the Foxhill beds:

	Feet	*Inches*
Soft, dark shale	27	0
Dark, sandy shale	150	0
Hard, tough shale	31	0
Sandy shale	17	0
Hard sandstone	2	0
Soft, grey sandstone	30	0
Soft, dark shale	19	0
Hard, dark shale	18	0

	Feet	Inches
Dark, sandy shale	119	0
Dark shale	93	2
Ironstone band	0	10
Dark shale	70	0
Dark, sandy shale	36	0
Ironstone band	0	10
Dark, sandy shale	7	6
Sandy shale	0	8
	622	0

Next underlying are the coal-bearing beds of the top of the Belly River series.

Fossil shells are not common in the formation but a few have been found at various places on the plains and suffice to show the general character of the fauna. The fossils are essentially marine, the zone of transition through brackish water to fresh at the base is very thin in section. The marine shales frequently rest upon an oyster bed that in some sections lies immediately above a coal seam. The transition beds include several small coal seams, and one of mineable proportions, and are generally placed with the Belly River series. In many of the lists published in former reports the marine fauna of this upper portion of the Pierre includes also forms from the brackish water beds that are found in thin beds above and below the marine shales.

The following list which has been compiled from determinations by J. F. Whiteaves and T. W. Stanton gives the species represented and their geographical distribution so far as known.

Fossils from Bearpaw (Upper Pierre) Shales.

BRACHIOPODA.

Lingula nitida M. and H. (Plate XXI, figures 1, 1a.)
Near Irvine station, north of Cypress hills, and on Notukeu creek (Old Wives), tp. 10, range 11, W. 3rd mer. *Con. Can. Pal., vol. I, p. 29.*

PELECYPODA.

Ostrea patina M. and H. (Plate XVIII, figures 1, 1a.)
Frenchman creek, tp. 1, range 10, W. 3rd mer. *Con. Can. Pal., vol. I, p. 30.*
Sage creek, south of Cypress hills. *Bull. U. S. G. S., No. 257, p. 53.*

Ostrea inornata M. and H. (Plate XVIII, figure 3.)
St. Mary river, near mouth. *Con. Can. Pal., vol. I, p. 30.*

Ostrea subtrigonalis Evans and Shumard. (Plate XVIII, figures 4–4c.)
Oldman river, mouth of St. Mary river. *Con. Can. Pal., vol. I, p. 30.*
Battle river, near the Elbow. *Ann. Rep. vol. II, p. 89 E.*
Milk River ridge. *Con. Can. Pal., vol. I, pp. 30 and 40.*

Chlamys nebrascensis M. and H. (Plate XXI, figures 2–2b.)
Rocky creek, sec. 6, tp. 1, range 6, W. 3rd mer., and on Notukeu creek, tp. 10, range 11, W. 3rd mer. *Con. Can. Pal. vol. I, p. 31.*
Willow creek, south of Cypress hills. *Bull. U. S. G. S. No. 257, p. 55.*

Pteria linguiformis Evans and Shumard. (Plate XXI, figures 5–5b.)
Elbow of South Saskatchewan and 15 miles west of mouth of Swift-current creek, near Bulls head, Alberta, and near Irvine station. *Con. Can. Pal., vol. I, p. 31.*
Blood Indian creek, north of Red Deer river. *Ann. Rep., vol. II, p. 81 E.*
Battle river, tp. 46, range 4, W. 4th mer. *Ann. Rep., vol. II, p. 153E.*
Willow creek, south of Cypress hills. *Bull. U. S. G. S. No. 257, p. 55.*
Upper Smoky river, in upper dark shales. *Rep. Prog. 1879–80, p. 124 B.*

Pteria (Oxytoma) nebrascana Evans and Shumard. (Plate XXI, figures 3, 3a.)
South Saskatchewan river, opposite mouth of Swift-current creek. *Con. Can. Pal., vol. I, p. 31.*
Athabaska river, 25 miles above Athabaska landing. *Ann. Rep., vol. V, p. 28 D.*
Willow creek, south of Cypress hills. *Bull. U. S. G. S., No. 257, p. 55.*

Pteria (Pseudopteria) fibrosa var. M. and H. (Plate XXI, figures 4–4b.)
Horseshoe bend, Bow river. *Con. Can. Pal., vol. I, p. 32.*

Inoceramus altus Meek.
East fork Milk river or Battle creek south of Cypress hills. *Con. Can. Pal., vol. I, p. 33.*

Inoceramus barabini Morton. (Plate XXI, figure 6.)
Twelve miles east of Frenchman creek, tp. 1, range 8, W. 3rd mer., and Elbow of South Saskatchewan river. *Con. Can. Pal., vol. I, p. 33.*

Inoceramus sagensis var. *Nebrascensis* Owen. (Plate XXI, figure 7.)
Near mouth of St. Mary river and South Saskatchewan river opposite Swift-current creek. *Con. Can. Pal., vol. I, p. 34.*
Near mouth of Vermilion river, North Saskatchewan river. *Ann. Rep., vol. II, p. 100 E.*
Near Moose hills, North Saskatchewan river. *Ann. Rep., vol. II, p. 120E.*
Nose creek, sec. 24, tp. 44, range 2, W. 4th mer. *Con. Can. Pal., p. 174.*
Sage creek, east of Milk river. *Bull. U. S. G. S., No. 257, p. 54.*

Inoceramus tenuilineatus Hall and Meek. (Plate XXII, figures 1, 1a.)
Blood Indian creek, range 9, W. 4th mer., and at Elbow of South Saskatchewan. *Con. Can. Pal., vol. I, p. 34.*

Inoceramus vanuxemi M. and H. (Plate XXII, figure 2.)
Mouth of Vermilion river, tp. 54, range 3, W. 4th prin. mer., and in next township east. *Con. Can. Pal., vol. I, p. 175.*

Gervillia recta M. and H. (Plate XXIII, figures 1, 1a.)
Bulls head, west of Cypress hills. *Con. Can. Pal., vol. I, p. 35.*

Gervillia recta var. *borealis* Whiteaves. (Plate XXIII, figure 2.)
Oldman river, west of and at mouth of St. Mary river, South Saskatchewan river opposite Swift-current creek, and at Lorne crossing, Red Deer river. *Con. Can. Pal., vol. I, p. 36.*
Berry creek, tp. 25, *Ann. Rep., vol. II, p. 79E.*
Blood Indian creek. *Ann. Rep., vol. II, p. 81E.*
Sounding creek, tp. 30, range 8, W. 4th mer. *Ann. Rep., vol. II, p. 154E.*

Modiola attenuata M. and H. (Plate XXIII, figures 4, 4a.)
St. Mary river near Belly river, and at Ross coulée near Irvine station. *Con. Can. Pal., vol. I, p. 36.*

Modiola (Brachydontes) dichotoma Whiteaves. (Plate XXIII, figure 5.)
Near mouth of St. Mary river, Alberta. *Con. Can. Pal., vol. I, p. 37.*

Nucula cancellata M. and H. (Plate XXIV, figures 1–1b.)
St. Mary river, 11 miles above mouth. *Con. Can. Pal., vol. I, p. 37.*
Upper Smoky river, in upper dark shales. *Rep. Prog. 1879–80, p. 124 B.*

Yoldia scitula M. and H. (Plate XXIV, figure 3.)
South of Wood mountain, about tp. 2, range 8, W. 3rd mer., and on east branch Rocky creek near Wood mountain, sec. 6, tp. 1, range 6, W. 3rd mer. *Con. Can. Pal., vol. I, p. 38.*

Yoldia evansi M. and H. (Plate XXIV, figures 2–2b.)
South Saskatchewan, 15 miles west of Swift-current creek, and on Notukeu creek, tp. 10, range 11, W. 3rd mer. *Con. Can. Pal., vol. I, p. 38.*
Burnt rapid, Athabaska river. *Ann. Rep., vol. V, p. 31 D.*

Lucina occidentalis Morton. (Plate XXIV, figures 5–5b.)
Bullpound creek, tp. 26, range 14, W. 4th mer., and on Notukeu creek, tp. 10, range 11, W. 3rd mer. *Con. Can. Pal., vol. I, p. 39.*

Lucina subundata Meek. (Plate XXIV, figures 4–4d.)
Willow creek, south of Cypress hills. *Bull. U. S. G. S., No. 257, p. 55.*

Tancredia americana M. and H. (Plate XXIV, figures 6–6c.)
Berry creek, sec. 31, tp. 25, range 12, W. 4th mer. *Con. Can. Pal., vol. I, p. 39.*
Sounding creek, tp. 30, range 8, W. 4th mer. *Ann. Rep., vol. II, p. 154 E.*
Willow creek, south of Cypress hills. *Bull. U. S. G. S. No. 257, p. 55.*
Twenty-five miles above Athabaska Landing in La Biche shales. *Ann. Rep., vol. V, p. 28D.*

Cyprina ovata M. and H. (Plate XXV, figures 1, 1a, 2.)
Belly river west of St. Mary river, Belly river below Horseshoe bend, Belly river near mouth, and on South Saskatchewan opposite Swift-current creek. *Con. Can. Pal., vol. I, p. 40.*
Battle river above elbow. *Ann. Rep., vol. II, p. 154 E.*
Sage creek south of Cypress hills. *Bull. U. S. G. S. No. 257, p. 53.*

Cyprina subtrapeziformis Whiteaves. (Plate XXV, figures 3–3b.)
Battle river, tp. 46, range 4, W. 4th mer. *Con. Can. Pal., vol. I, p. 176.*

Corbicula occidentalis M. and H. (Plate XIX, figures 5, 5a.)
Milk River ridge and St. Mary river. *Con. Can. Pal., vol. I, p. 40.*
Forks of Devils Pine and Three Hills creek, *Ann. Rep., vol. II, p. 75E.*

Protocardia subquadrata E. and S. (Plate XXVI, figures 2–2d.)
South Saskatchewan opposite Swift-current creek, Bulls head west of Cypress hills, Ross coulée near Irvine station, Battle river, tp. 38, range 12, W. 4th mer., and from Upper Smoky river. *Con. Can. Pal., vol. I, p. 41.*
Blood Indian creek, *Ann. Rep., Vol. II, p. 81 E.*
Sounding creek, *Ann. Rep., vol. II, p. 156 E.*
Elbow Battle river, *Ann. Rep., vol. II, p. 90 E.*

Protocardia borealis Whiteaves. (Plate XXVI, figures 3–3c.)
Near mouth of St. Mary river. South Saskatchewan river opposite Swift-current creek and from Ross coulée near Irvine station. *Con. Can. Pal., vol. I, p. 42.*
Willow creek south of Cypress hills. *Bull. U. S. G. S. No. 257, p. 55.*
Neutral hills west of Sounding lake, Alberta. *Ann. Rep., vol. II, p. 83E.*

Linearia formosa M. and H. (Plate XXVI, figures 4, 4a.)
Sounding creek, tp. 30, range 8, W. 4th mer. *Con. Can. Pal., vol. I, p. 177.*
Blood Indian creek north of Red Deer river. *Ann. Rep., vol. II, p. 81E.*

Callista (Dosiniopsis) deweyi M. and H. (Plate XXVI, figure 5b.)
Bulls head, west of Cypress hills and Big Plume creek, tp. 8, range 5, W. 4th mer. *Con. Can. Pal., vol. I, p. 42.*
Sage creek, south of Cypress hills. *Bull. U. S. G. S. No. 257, p. 53.*

Callista nebrascensis M. and H. (Plate XXVI, figures 5, 5a.)
Willow creek, south of Cypress hills. *Bull. U. S. G. S., No. 257, p. 55.*

Mactra (Cymbophora) warrenana M. and H. (Plate XXVI, figures 6–6c.)
South Saskatchewan river, 5 miles above Swift-current creek and Ross coulée near Irvine station. *Con. Can. Pal., vol. I, p. 43.*

Mactra (Cymbophora) gracilis M. and H. (Plate XXVII, figures 2, 2a.)
Rocky creek, sec. 6, tp. 1, range 6, W. 3rd mer. *Con. Can. Pal., vol. I, p. 43.*

Pholadomya subventricosa M. and H. (Plate XXVII, figures 3, 3a.)
North Saskatchewan river at Fort Pitt and near mouth of Moose river. *Con. Can. Pal., vol. I, p. 178.*
Elbow South Saskatchewan. *Con. Can. Pal., vol. I, p. 178.*

Liopistha (Cymella) undata M. and H. (Plate XXVII, figures 4, 4a.)
St. Mary river near Oldman river, South Saskatchewan opposite mouth of Swift-current creek, Bulls head west of Cypress hills, Berry creek, tp. 25, range 12, W. 4th mer., Battle river, tp. 38, range 12, W. 4th mer., and Ross coulée near Irvine station. *Con. Can. Pal., vol. I, p. 44.*
Neutral hills, west of Sounding lake. *Ann. Rep., vol. II, p. 83 E.*
Upper Smoky river in upper dark shales. *Rep. Prog. 79–80, p. 124 B.*

Solecurtus (Tagelus) occidentalis Whiteaves. (Plate XXVI, figure 1.)
Battle river, tp. 40, range 13, W. 4th mer. *Con. Can. Pal., vol. I, p. 179.*

Neæra moreauensis M. and H. (Plate XXVII, figures 5, 5a.)
Notukeu creek (Old Wives), tp. 10, range 11, W. 3rd mer. *Con. Can. Pal., vol. I, p. 44.*

Martesia tumidifrons Whiteaves. (Plate XXVII, figures 6, 6a.)
North Saskatchewan river, tp. 54, range 2, W. 4th mer. *Con. Can. Pal., vol. I, p. 180.*
Near Moose hills, North Saskatchewan river, tp. 56, range 6, W. 4th mer. *Ann. Rep., vol. II, p. 120 E.*

Panopæa subovalis Whiteaves. (Plate XXVIII, figures 1, 1a.)
Four miles south of Battle river, tp. 38, between ranges 11 and 12, W. 4th mer. *Con. Can. Pal., vol. I, p. 45.*

GASTROPODA.

Haminea occidentalis M. and H. (Plate XXVIII, figures 7–7b.)
Blood Indian creek, north of Red Deer river and 20 miles east of Hand hills.
South Saskatchewan river opposite Swift-current creek, and Notukeu creek (Old Wives), tp. 10, range 11, W. 3rd mer. *Con. Can. Pal., vol. I, p. 45.*

Hydatina parvula Whiteaves. (Plate XXVIII, figures 6, 6a.)
Sounding creek, tp. 30, range 8, W. 4th mer. *Con. Can. Pal., vol. I, p. 181.*

Actæon attenuatus M. and H. (Plate XXVIII, figure 9.)
Notukeu creek (Old Wives), tp. ? range 11, W. 3rd mer. *Con. Can. Pal., vol. I, p. 46.*

Cinulia concinna M. and H. (Plate XXVIII, figures 8–8b.)
Twelve miles east of Frenchman creek, elbow of South Saskatchewan river, Notukeu creek (Old Wives), tp. 10, range 11, W. 3rd mer., and at Two creeks, Assiniboine river. *Con. Can. Pal., vol. I, p. 46.*
Willow creek, south of Cypress hills. *Bull. U. S. G. S. No. 257, p. 55.*

Anisomyon alveolus M. and H. (Plate XXVIII, figures 11, 11a.)
Frenchman creek near Boundary line. *Con. Can. Pal., vol. I, p. 47.*

Anisomyon centrale Meek. (Plate XXVIII, figures 12–12b.)
Notukeu creek (Old Wives), tp. 10, range 11, W. 3rd mer. *Con. Can. Pal., vol. I, p. 47.*

Anisomyon patelliformis M. and H. (Plate XXIX, figures 1–1c.)
Upper Smoky river, upper shales. *Rep. Prog. 79–80, p. 124 B.*

Lunatia concinna Hall and Meek. (Plate XXIX, figures 4–4b.)
Elbow of South Saskatchewan and at Blood Indian creek, north of Red Deer river. *Con. Can. Pal., vol. I, p. 48.*
Bullpound creek, 8 miles above mouth. *Ann. Rep., vol. II, p. 79 E.*
Sounding creek, at Lorne crossing, tp. 30, range 8, W. 4th mer., and at Battle river, tp. 46, range 3, W. 4th mer. *Ann. Rep., vol. II, p. 159 E.*
Athabaska river above Athabaska Landing, *Ann. Rep., vol. V. p. 28 D.*

Anchura americana Evans and Shumard. (Plate XXIX, figures 5, 5a.)
South Saskatchewan, collected by Hind probably near elbow. Ross coulée near Irvine station.
Notukeu creek (Old Wives), tp. 10, range 11, W. 3rd mer., and at Wood river, tp. 6, range 4, W. 3rd mer. *Con. Can. Pal., vol. I, p. 48.*
Willow creek, south of Cypress hills. *Bull. U. S. G. S. No. 257, p. 55.*

Vanikoropsis tuomeyana M. and H. (Plate XXIX, figures 2, 2a.)
North of Ross coulée near Irvine station. *Con. Can. Pal., vol. I, p. 49.*

CEPHALOPODA.

Baculites compressus Say. (Plate XXX, figures 1–1b.)
Twelve miles east of Frenchman creek south of Wood mountain, Rocky creek, sec. 6, tp. 1, range 6, W. 3rd mer., elbow of South Saskatchewan river, Bow river below Horseshoe bend, Oldman river 5 miles above Lethbridge, St. Mary river above mouth, Belly River western upturn, tp. 4, range 28, W. 4th mer., Milk River ridge, Ross creek near Irvine station, Bullpound creek, sec. 3, tp. 26, range 14, W. 4th mer., Red Deer river at Lorne crossing, Battle river tp. 38, ranges 12 and 13, W. 4th mer. and at Berry creek, tp. 25, range 12, W. 4th mer. *Con. Can. Pal., vol. I, p. 50.*
Sage creek, south of Cypress hills. *Bull. U. S. G. S. 257, p. 54.*
Vermilion river, north Saskatchewan. *Ann. Rep., vol. II, p. 100 E.*
Twenty-five miles above Athabaska Landing and at mouth of La Biche river. *Ann. Rep., vol. V, 28 D.*
Neutral hills west of Sounding lake, Alberta. *Ann. Rep., vol II, p. 83 E.*
Saskatchewan river, tp. 56, range 6, W. 4th mer. *Ann. Rep., vol. II, p. 120 E.*
Ribstone creek, tp. 37, range 9, W. 4th mer. *Ann. Rep., vol. II, p. 95E.*

Baculites grandis Hall and Meek.
East fork of Milk river, tp. 1, range 26, W. 3rd mer.
St. Mary river 11 miles above mouth, Oldman river near mouth of St. Mary river, South Saskatchewan river opposite Swift-current creek, and on Red Deer river, sec. 24, tp. 25, range 16, W. 4th mer. *Con. Can. Pal., vol. I, p. 51.*
Blood Indian creek. *Ann. Rep., vol. II, p. 81 E.*
Sounding creek, tp. 30, range 8, W. 4th mer. *Ann. Rep., vol. II, p. 160 E, and Con. Can. Pal., vol. I,* p. 182.

Baculites ovatus Say. (Plate XXX, figures 2, 2a.)
Ghost river, tp. 25, range 6, W. 5th mer. (may be Claggett), North Saskatchewan river near Moose Hill creek, North Saskatchewan river, tp. 54, range 2, W. 4th mer., tp. 56, range 6, W. 4th mer., and at mouth of Vermilion river. *Con. Can. Pal., vol. I, p. 182.*
Sage creek, south of Cypress hills. *Bull. U. S. G. S., No. 257, p. 53.*

Scaphites abyssinus Morton. (Plate XXXII, figures 1, 1a.)
Frenchman creek, near Cypress hills. *Con. Can. Pal., vol. I, p. 51.*

Scaphites Nicolleti Morton. (Plate XXXII, figures 2, 2a.)
Twelve miles east of Frenchman creek near Wood mountain and Notukeu creek (Old Wives), tp. 10, range 11, W. 3rd mer. *Con. Can. Pal., vol. I, p. 52.*

Scaphites nodosus Owen. (Plate XXXII, figure 3.)
South Saskatchewan river near Elbow and opposite Swift-current creek, and west end Cypress hills. *Con. Can. Pal., vol. I, p. 52.*
Willow creek, south of Cypress hills. *Bull. U. S. G. S., No. 257, p. 55.*
North Saskatchewan river, tp. 56, range 6, W. 4th mer. *Ann. Rep., vol. II, p. 120 E.*

Scaphites subglobosus Whiteaves. Plate XXXI, figures 1, 1a, 2, 2a.)
Rocky creek, sec. 6, tp. 1, range 6, W. 3rd mer., and on Notukeu creek (Old Wives), tp. 10, range 11, W. 3rd mer. *Con. Can. Pal., vol. I, p. 53.*
In Foxhills sandstone north of Wood mountain. *Ann. Rep., vol. I, p. 46 C.*

Placenticeras placenta Dekay. (Plate XXXIV, figures 1, 1a.)
South Saskatchewan river near Elbow and opposite Swift-current creek. Frenchman creek at International Boundary, Blood Indian creek north of Red Deer river, Berry creek, tp. 25, range 12, W. 4th mer., St. Mary river near mouth, Belly river above St. Mary river, and also on Red Deer river above Lorne trail, tp. 25, range 16, W. 4th mer. *Con. Can. Pal., vol. I, p. 54.*
Sounding creek, tp. 30, range 8, W. 4th mer. *Ann. Rep., vol. II, p. 81E.*
Battle river, tp. 39, range 12, W. 4th mer. *Ann. Rep., vol. I, pp. 80–90 E.*
Neutral hills, west of Sounding creek. *Ann. Rep., vol. II, p. 83 E.*
Large specimens formerly referred to this species are now known as *Placenticeras whitfieldi* Hyatt.

Placenticeras placenta var. *intercalare* Meek. (Plate XXXIII, figures 1, 1a.)
Sage creek, south of Cypress hills. *Bull. U. S. G. S. 257, p. 54.*
Berry creek, north of Red Deer river. *Ann. Rep., vol. II, p. 79 E.*

Placenticeras whitfieldi Hyatt.
Sage creek south of Cypress hills. *Bull. U. S. G. S., No. 257, p. 54.*

Many specimens listed under *P. placenta* are now recognized as *P. whitfieldi.*

Nautilus dekayi Morton. (Plate XXXIV, figures 2, 2a.)
Sage creek, south of Cypress hills. *Bull. U. S. G. S., No. 257, p. 54.*

CRUSTACEA.

Palæastacus (?) *ornatus* Whiteaves. (Plate XXXV, figure 2.)
Sounding creek, tp. 30, range 8, W. 4th mer. *Ann. Rep., vol. II, p. 161 E.*

BELLY RIVER SERIES.

The rocks that have been described as the Belly River series are as a general rule shallow water and shore deposits of the early Pierre sea. In the foothills they are shore and land deposits and are mainly fragmental. To the east they contain less coarse material and are more argillaceous. The character of the deposits indicates that there was an advance of the early Pierre sea during the early portion of the period represented, to probably the longitude of the western margin of the area under considera-

tion. The early shore deposits were covered by brackish water beds, succeeded by marine shales. The retreat of this early sea was slow and along the swampy margin deposits of lignite were formed. Thus the marine shales are covered by brackish water beds in which coal seams are common. The final series of deposits are mainly of freshwater origin and form a large part of the beds composing the series. The divisions that it seems possible to make in the series comprise, therefore, the following, in descending order:

Pale beds (mainly fresh water).
Foremost beds (yellow banded beds, brackish water).
Pakowki shales (mainly shales, marine).
Milk River sandstone (mainly fresh water, brackish water at the top).

In accordance with the belief that the material in these beds was derived from the newly elevated land to the west, there is found to be a general decrease in the fragmental rocks and an increase in the argillaceous material as they are followed eastward.

On this account the character of the rocks forming the divisions enumerated changes somewhat and it is difficult to be sure of their correlation on lithological grounds alone. In the western portion of the area it is probable that the marine shales are wanting, and thus the Belly River series is represented by a series of sandstones and clays in which no subdivisions can be clearly recognized; while to the east the increase in the thickness of the marine shales leaves the Belly River series represented only by remnants of shore formations—in many cases brackish water beds surrounded by marine beds. It is not known how far east the remnants of the series extend into the marine beds of the lower Pierre.

PALE BEDS.

Most of the rock exposures in the valley of the Oldman river from near Big Island bend (Plate III) to the mouth of the Little Bow river and others on Pothole river are pale beds. They are generally light coloured sandy clays and soft and irregularly hardened shales and sandstones. Dawson mentions the occurrence of typical exposures in Fossil coulée. The general

extent of the beds is outlined in the description of the outcrop of the coal-bearing zone at the base of the Pierre (Bearpaw) and is here reproduced.[1]

"As previously shown in detail in this report, one of the most constant features throughout the entire district is the occurrence of a coal-bearing or lignitiferous horizon at the base of the typical Pierre shales.[2]

"This is found in its usual position in the sections on Sage Creek above alluded to, and serves to assist in the definite correlation of the overlying shales with those above the coal at Coal Banks, Belly River. On Sage Creek a length of outcrop of two miles showed a southeastward slope of the base of the Pierre at the rate of twenty-five feet to the mile, though this may not represent the direction of greatest inclination here. Beyond this place, the general trend of the western or lower edge of the Pierre shales is a few degrees west of north for about forty miles, to the low hills near the Bull's head and north of Peigan Creek, the outcrop of its base nearly following a contour line at a height of 3,000 feet, but declining slightly to the north. East of Lake Pakowki the Pierre forms well marked plateaus, while the lower country between these and the lake, in the valley of Many Berries Creek and two streams north of it, shows fine sections of the upper or pale-coloured portion of the Belly River series. After a concealed interval, the base of the Pierre shales, with its usual carbonaceous character, is again seen in a tributary of Peigan Creek, south of the main stream. From the hills above characterized as near the Bull's Head, where the base of the Pierre shales is found distinctly overlying the pale beds, it appears to run north-eastward for about twenty-eight miles to Ross Creek,[3] near the line of the Canadian Pacific Railway, where its relation to the underlying beds and coaly base were again observed by Mr. McConnell. In this distance the level of the base decreases by at least three hundred feet, though the direction of dip is probably more nearly east than north-east."

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[1] Geol. Surv., Can., Rept. of Prog., 1882–83–84, pt. C, p. 122.

[2] This horizon I observed occupying the same position on the Missouri, where it is also described by Prof. Cope. Bulletin U. S. Geol. and Geog. Survey, Vol. VIII, p. 566.

[3] Near Irvine station, 16 miles east of Medicine Hat.

At the base of this portion of the Belly River series there is a fairly persistent coal seam, and as may be seen by the distribution of the coal indicated on the accompanying map, a thin covering of these pale beds is very general over the plains of southern Alberta. The total thickness of the formation is present only on the limbs of the anticline, for instance, at Lethbridge and in the Milk River ridge on the west side. On the east it is also present on the western slopes of Cypress hills but no records from that locality are available.

The section along the river channel east of Lethbridge is not continuous and the thickness must be estimated in part from the dip of the beds. The calculation indicates the presence of nearly 700 feet of beds in this section. From the record of a well drilled at Lethbridge there seems to be good reason to estimate that the beds have a thickness of 651 feet at that locality. Eastward, as noted before, there is reason to believe that there is a decrease in the thickness of the beds.

As to the character of the beds, the fossils found point to freshwater deposition but near the top of the division marine or brackish water molluscs[1] are occasionally found, for example in the exposures near Lethbridge, on Oldman and Pothole rivers, and in Fossil coulée. The coal seam mined at Lethbridge is at the top of the formation, and associated with the beds both above and below it there are distinctly brackish-water fossils.

Fossils from the Coal Horizon at Top of Pale Beds.

Ostrea inornata M. and H. (Plate XVIII, figure 3.)
St. Mary river, near mouth. *Con. Can. Pal., vol. I, p. 30.*

Ostrea subtrigonalis E. and S. (Plate XVIII, figures 4–4c.)
Above coal seam mouth of St. Mary river and on Milk River ridge. *Con. Can. Pal., vol. I, p. 30.*

Modiola (Brachydontes) dichotoma Whiteaves. (Plate XXIII, figure 5.)
St. Mary river, near mouth. *Con. Can. Pal., vol. I, p. 37.*

Corbicula occidentalis M. and H. (Plate XIX, figures 5, 5a.)
In base of Upper Pierre group on Milk River ridge. *Con. Can. Pal., vol. I, p. 40.*

[1] In an adjoining district to the north the beds for a thickness of over 300 feet from the top have been explored for remains of vertebrates and many skeletons of very large wading reptiles or dinosaurs have been discovered. The descriptions of these form the subject of many memoirs by both Canadian and United States authors.

Fossils from Pale Beds (Upper Portion of Belly River Series).

Ostrea glabra M. and H. (Plate XVIII, figure 2.)
Near Bulls head. *Con. Can. Pal., vol. I, p. 56.*

Ostrea subtrigonalis E. and S. (Plate XVIII, figures 4–4c.)
(Forms resembling) collections of 1915, from near Taber.

Anodonta propatoris White. (Plate XV, figure 1.)
Big Island bend, Milk River ridge, South Saskatchewan near Red Deer river. *Con. Can. Pal., vol. I, p. 58.*

Unio primævus White. (Plate XVI, figures 1, 1a.)
Boundary line, range 27, W. 3rd mer., and collections of 1915 near Taber. *Con. Can. Pal., vol. I, p. 59.*

Unio danae M. and H. (Plate XV, figure 5, 5a.)
Near Coal Banks. *Con. Can. Pal., vol. I, p. 59.*
Driftwood bend. *Con. Can. Pal., vol. I, p. 65.*

Unio consuetus Whiteaves. (Plate XVI, figure 4.)
Milk River ridge, Red Deer river.
Bow river, near Grassy island. *Con. Can. Pal., vol. I, p. 60.*

Unio senectus White. (Plate XV, figure 3.)
Forms resembling, collections of 1915, near Taber.

Anomia micronema Meek. (Plate XIX, figures 6–6c.)
Forks of Bow and Oldman rivers. *Con. Can. Pal., vol. I, p. 64.*

Sphaerium formosum M. and H. (Plate XVI, figures 5, 5a.)
Ed. Mahans coulée, and Oldman river above Lethbridge. *Con. Can. Pal., vol. I, p. 61.*

Corbicula occidentalis M. and H. (Plate XIX, figures 5, 5a.)
Forms resembling, collections of 1915, Big Island bend.

Mactra (Cymbophora) alta M. and H. (Plate XXVII, figures 1, 1a.)
Milk River ridge. *Con. Can. Pal., vol. I, p. 62.*
Fossil coulée. *Rep. Prog., 82–83–84, p. 51c.*

Corbula subtrigonalis M. and H. (Plate XIX, figures 2, 2a.)
Piegan creek, tp. 7, range 6, W. 4th mer. *Con. Can. Pal., vol. I, p. 62.*
Collections of 1915, near Taber.

Corbula perundata M. and H. (Plate XIX, figures 1–1b.)
Piegan creek and East Fork Milk river. *Con. Can. Pal., vol. I, p. 62.*

Physa copei White. (Plate XVII, figures 7–7c.)
South Saskatchewan near Red Deer river and near Bulls head. *Con. Can. Pal., vol. I, p. 63.*
Several undescribed species of gasteropoda are also mentioned resembling forms such as *Aporrhais* or *Anchura*, *Goniobasis tenuicarinata* and probably *Viviparus Conradi.*

FOREMOST BEDS.

The separation of the upper part of the Belly River series into the pale and the yellow beds and sombre beds beneath was not carried by Dawson to the stage of mapping. The presence of several coal seams in the lower beds is thought to render them of sufficient importance to warrant their being outlined in a general way on the map. This division furnishes most of the exposures on the upper part of Verdigris, Etzikom, and Chin coulées, and is also exposed on Milk river east of Pakowki coulée and along the South Saskatchewan (Plate IV). The upper part, described by Dawson as consisting of a carbonaceous zone, is very variable in character. In an exposure north of Winnifred there is fully 100 feet of beds in which small coal seams are found; at other places the coal horizon seems to be thinner. It is quite evident, then, that if the coal horizon is of variable thickness, the thickness of the formation as an entirety must vary in like manner. The top of the formation is placed generally as a certain coal seam that in various places is important enough to be mined. As the seam is not confined to any exact position in the upper part of the formation this horizon marker is not strictly the top of the formation and the apparent thickness of the division may for this reason appear variable. The following is a generalized section:

Yellowish sands and clays with coal seams	100
Grey sands and clays, yellow streaks	95
Oyster beds, yellow sands	15
Dark grey clays, ash coloured, streaks of sand and coal	50
Sandstone and shale with some coal	50
	310

The subdivision called "Foremost beds" seems to include along with the "Yellow beds" certain dark shales beneath, which, but for the presence in them of coal seams would probably be placed in the Pakowki shales.

The coal seam in the top beds, from which the thickness of the formation is generally estimated, occupies a higher place in the series in the west than in the east; that is, if the coal horizon, or what we may call the yellow beds, is 100 feet thick the seam

at Taber is well up near the top; the seam at Bow Island is probably near the middle; and the seam east of Winnifred well down in the series. Following the measures toward Medicine Hat it is not clear that this horizon is represented, and the coal seams there may represent the coals of the lower part of the Foremost beds. The sections which would give the thickness of the formation are to be found on the Saskatchewan and in the dry coulées to the south. At Verdigris coulée there is about 200 feet of beds exposed, including, at least, all of the lower part of the formation, the yellow beds of the upper part underlying some of the country on each side. In the Lethbridge well section there is about 350 feet of beds that possibly should be included in the formation; but at Taber, where the section is much more definite, the thickness is only 300 feet at most. Going east, as mentioned before, the assumed datum line for the top of the formation is probably lower in the section: thus from the coal seam at Foremost down to the shale series below is about 200 feet, but as may be seen in the sections on the Saskatchewan to the north the main seam is overlain by 100 feet of measures containing poor coal seams which are probably included in the 300-foot section at Taber. Over most of the central part of the area mapped, for example, along Etzikom, Chin, and Fortymile coulées the section shows a thickness of about 200 feet for the brackish water deposits. The transition beds at the top, representing swamp deposits laid down at sea-level, are probably 100 feet thick and were formed during a period of rest after a slight elevation, the only movement apparent being a slight depression caused probably by a shifting of load owing to the transportation of material from the mountain areas by the streams. Thus, apparently, a slow advance of the sea took place just before the general uplift that is indicated by the overlying freshwater beds of the pale series.

Fossils from the Foremost Beds.

Anomia micronema Meek. (Plate XIX, figures 6–6c.)
South Saskatchewan, one-half mile below Bow river. ***Con. Can. Pal.,*** *vol. I, p. 64.*
Chin coulée north of Foremost, 1915 collections.

Ostrea subtrigonalis E. and S. (Plate XVIII, figures 4–4c.)
Woodworth mine, Medicine Hat. *Con. Can. Pal., vol. I, p. 56.*
Hughson's mine, sec. 10, tp. 3, range 11, W. 4th mer., 1915 collections.
Fortymile coulée, Bow River highway, 1915 collections.

Ostrea glabra M. and H. (Plate XVIII, figure 2.)
South Saskatchewan, 1 mile below mouth of Bow river and 6 miles below Bow river, north bank of Milk river 5 miles below Pakowki coulée, and south bank of Milk river above Pakowki coulée, 40 and 100 feet above water level. *Con. Can. Pal., vol. I, p. 64.*
Coal mines at Medicine Hat. *Con. Can. Pal., vol. I, p. 56.*
Etzikom coulée, sec. 30, tp. 5, range 10, W. 4th mer., 1915 collections.
Mouth of Fortymile coulée and near Crow Indian lake. *Rep. Prog. 82–84, p. 53 C.*
Chin coulée, north of Foremost, 1915 collections.

Anodonta parallela White. (Plate XV, figure 2.)
One mile below mouth of Bow river. *Con. Can. Pal., vol. I, p. 64.*

Modiola tenuisculpta Whiteaves. (Plate XXIII, figures 6, 6a.)
Fortymile coulée, south of Bow river, 1915 collection.

Unio priscus M. and H. (Plate XV, figures 4–4e.)
Two miles above Woodpecker island. *Con. Can. Pal., vol. I, p. 65.*

Unio danæ M. and H. (Plate XV, figures 5, 5a.)
Northwest angle Driftwood bend. *Con. Can. Pal., vol. I, p. 66.*

Unio deweyanus M. and H. (Plate XVI, figures 3, 3a.)
One mile below mouth of Bow river. *Con. Can. Pal., vol. I, p. 66.*

Unio supragibbosus Whiteaves. (Plate XVI, figure 2.)
One mile below mouth of Bow. *Con. Can. Pal., vol. I, p. 66.*

Unio senectus White. (Plate XV, figure 3.)
One mile below Bow river. *Con. Can. Pal., vol. I, p. 67.*

Corbicula occidentalis M. and H. (Plate XIX, figures 5, 5a.)
North side Milk river, 5 miles below Pakowki coulée. *Con. Can. Pal., vol. I, p. 67.*

Corbicula cytheriformis M. and H. (Plate XIX, figures 4–4b.)
Verdigris coulée near Warner. *Rep. Prog. 82–84, p. 52 C.*

Sphærium formosum M. and H. (Plate XVI, figures 5, 5a.)
East side Driftwood bend and one mile below mouth of Bow river. *Con. Can. Pal., vol. I, p. 68.*

Corbula subtrigonalis M. and H. (Plate XIX, figures 2, 2a.)
East side Driftwood bend and near mouth of Bow, 6 miles below mouth of Bow from lower beds. North side Milk river 5 miles below Pakowki coulée and 40 feet above water level 1 mile west of Pakowki coulée. *Con. Can. Pal., vol. I, p. 68.*
Chin coulée north of Foremost road to Bow river, 1915 collection.

Corbula perangulata Whiteaves. (Plate XIX, figures 3–3b.)
Etzikom coulée, and Hughson's mine, sec. 10, tp. 3, range 11, W. 4th mer., 1915 collection.

Corbula perundata M. and H. (Plate XIX, figures 1–1b.)
Associated with *C. subtrigonalis*. Near mouth of Fortymile coulée. *Rep Prog. 82–84, p. 53C.*
Etzikom coulée. *Rep. Prog. 82–84, p. 53C.*
Verdigris coulée west of Verdigris lake. *Rep. Prog. 82–84, p. 53C.*

Corbula pyriformis Meek.
Near mouth of Fortymile coulée. *Rep. Prog. 82–84, p. 53C.*

Rhytophorus glaber, Whiteaves. (Plate XVII, figures 4–4b.)
East side Driftwood bend, near mouth of Bow river, on Milk river one mile above Pakowki coulée. *Con. Can. Pal., vol. I, p. 70.*

Planorbis paucivolvis Whiteaves. (Plate XX, figure 4.)
Mouth of Bow river and 6 miles below 35 feet above the water level. *Con. Can. Pal., vol. I, p. 71.*

Physa copei White. (Plate XVII, figures 7–7c.)
Mouth of Bow river and 6 miles below. *Con. Can. Pal., vol. I, p. 71.*

Thaumastus limnæiformis M. and H. (Plate XVII, figures 6–6c.)
Six miles below mouth of Bow river, 35 feet above water. *Con. Can. Pal., vol. I, p. 72.*

Velatella baptista White. (Plate XX, figures 3–3d.)
East side Driftwood bend, near mouth of Bow river; Milk river near Pakowki coulée. *Con. Can. Pal., vol. I, p. 73.*
Etzikom coulée, 1915 collection.

Melania insculpta Meek (Plate XX, figure 1.)
South Saskatchewan near mouth of Bow river. *Con. Can. Pal., vol. I, p. 74.*
Chin coulée north of Foremost, 1915 collection.
Fortymile coulée, sec. 17, tp. 8, range 11, W. 4th mer., 1915 collection.

Goniobasis subtortuosa M. and H. (Plate XVII, figure 3.)
Two miles above Woodpecker island and on east side Driftwood bend. *Con. Can. Pal., vol. I, p. 75.*

Hydrobia subcylindrica Whiteaves. (Plate XX, figure 5.)
East side Driftwood bend, Oldman river; north side Milk river 5 miles below Pakowki coulée. *Con. Can. Pal., vol. I, p. 76.*

Viviparus conradi M. and H. (Plate XVII, figures 5–5b.)
Six miles below mouth of Bow river. One mile above mouth of Pakowki coulée and one mile below mouth of Bow river. *Con. Can. Pal., vol. I, p. 76.*

Campeloma multilineata M. and H. (Plate XVII, figures 1, 1a.)
East side Driftwood bend, and also 6 miles below Bow river.
Milk river 5 miles below Pakowki coulée. *Con. Can. Pal., vol. I, p. 77.*

Campeloma producta White. (Plate XVII, figures 2–2c.)
South Saskatchewan one mile below Bow river. *Con. Can. Pal., vol. I, p. 77.*

PAKOWKI SHALES.

A short note seems necessary to explain the seeming confusion that has arisen in respect to the position of the *Lower Dark shales* of G. M. Dawson's classification. The series to which he gave the name *Belly River* is found by later examination to consist of two sheets of shallow water and continental deposits separated by a wedge-like sheet of marine sediments of Pierre age, underlain by marine shales of Colorado age, and overlain by another sheet of marine Pierre shales. The upper, sandy series is, therefore, underlain by a Pierre marine shale and the lower sandy series by a Benton marine shale. As the two sandy formations and the two underlying shales are respectively quite similar to one another, no discrimination was made between them in the descriptions and the sandy members were mapped as the Belly River series. In the region near Pakowki the shales which underlie the upper sandy series were examined and compared with those beneath the lower sandy series in the flanks of the Sweet Grass hills and on the slope of Rocky Spring ridge in Montana. The marine deposits between the two parts of the Belly River were seen higher up Milk River valley also, near the railway crossing, where they are quite thin and sandy and were seen to be above the lower sandy beds. Owing to the presence of lignite in them these beds were correlated with the lignite zone at the top of the pale beds of the Pierre, and consequently in the mapping, a band of Pierre shales was shown running along the top of Milk River ridge and down to the International Boundary, capping the northern part of Rocky Spring ridge, and the shale that is now recognized as of lower Pierre age was mapped as upper Pierre in the Milk River ridge and farther east near Pakowki as Colorado.

Fossils were collected from these beds at several localities, and in some cases were taken from one set of beds and in some cases from the other set. The mixture of fossils is referred to by Dr. Whiteaves in the following note:[1]

"These are obviously Cretaceous but their exact horizon in the upper division of that formation has not yet been ascertained with much certainty.

[1] Con. to Can. Pal., vol. I, p. 78.

"Of the eleven species of fossils which have, so far, been collected from them, seven or eight seem to be identical with forms that are elsewhere regarded as characteristic of the Fort Pierre or Fox Hills Group, but the presence in these shales of *Scaphites Warreni* var. *Wyomingensis*, and possibly of *Ostrea congesta* may indicate that they occupy a slightly lower position in the series."

The shales on the slopes of the Sweet Grass hills and in the Rocky Spring ridge contain a typical Benton fauna, and are beneath the series of shore deposits referred to above. The marine shales of the Milk River valley at Pakowki coulée contain Pierre fossils and are, therefore, higher in the series and without doubt form part of the series of deposits called Claggett shales on the Missouri.

These shales it is claimed do not occur in the sections on the headwaters of Cut Bank and Milk rivers; but in the sandy deposits which make up the lower part of the Montana series, a zone has been found containing marine forms which may represent the near-shore deposits of this marine series. In the sections on Milk river and Verdigris coulée sandy shales with lenses of sand, containing a marine fauna, probably represent the thin edge of the deposit which is here so closely associated with the brackish water, lignite-bearing Foremost beds as to be almost a part of the series.

The section near Milk River station consists of the lignite-bearing beds with brackish water fossils overlying beds containing brackish water as well as marine fossils. The underlying series repeats the beds above in reverse order excepting that it contains no important coal beds and has at the bottom a fresh-water sandstone. The Pakowki shales represent the marine sands and clays of the middle of this section. Marine shales like the Claggett occur east of Police creek on the ridge running north of West butte. The first exposure in Milk river occurs a short distance below the mouth of Dead Horse Coulée where the shales are brought up by faults or fractures and are underlain by sandstones. The mouth of Pakowki coulée is the type locality for these shales which form the lower part of the section exposed there. The Foremost beds in the same section are of almost

the same colour and character but are marked by great beds of oyster shells.

The red colour which characterizes the Claggett in Montana seems to be confined in Canada to beds at the base of the formation. The upper beds in the Milk River region and on the South Saskatchewan have been referred to as the sombre shales since they seem to lack any definite colour, but are dark grey with a brownish to yellow-brown tint.

The position of the shales in the series has been demonstrated by the well sections and in this way the relative thickness at different points may also be predicted. The edge of the deposit as before noted is somewhere in the vicinity of the foothills.

In the well section at Lethbridge there is about 215 feet of shale deposits at this horizon and in the well section at Taber about 311 feet. Farther east the formation probably thickens. At Foremost the thickness is given as 420 feet and in the boring in Etzikom coulée 385 feet. At Medicine Hat the enclosing formations are largely shales, so that the thickness is doubtful, but may be about 500 feet if the light sandy shales beneath, which run to 300 feet, are classed as the off-shore representatives of the Milk River sandstones.

Fossils collected from the beds near south branch Milk river include the following:

Nucula cancellata, Mactra (Cymbophora) gracilis,
Liopistha undata, Entalis paupercula.

From the shales near the mouth of Pakowki coulée the following forms also have been collected:

Ostrea glabra, Pteria (Oxytoma) nebrascana,
Nucula cancellata, Tancredia americana,
Mactra gracilis, Liopistha undata, Melania whiteavesi,
Corbula perundata, C. subtrigonalis,
Cardium speciosum, Entalis pauperperculum,
Lunatia subcrassa, Tancredia americana,
Vanikoropsis huomeyana, Rhytophorus glaber,
Baculites asper.

The deposits in Montana which were described under the name Claggett by Stanton and Hatcher are thought to be

continuations of the beds here discussed. A summary of Stanton's description is here inserted:[1]

"*Claggett formation.*—The beds to which the name Claggett formation has been given lie above the Eagle formation and below the Judith-River beds. In the neighbourhood of Judith (old Fort Claggett), where they are well exposed, they have a total thickness of about 400 feet and consist largely of dark clay shales with variable intercalated bands and beds of sandstone, especially in the upper half. The dark shales of the lower part of the formation contain many calcareous concretions which yield *Gervillia borealis*, *Baculites ovatus*, *Baculites compressus*, and a few other forms, elsewhere regarded as characteristics of the Fort Pierre. The yellowish sandstone beds higher in the formation, especially one about 200 feet from the top and another near the summit, are often locally very fossiliferous, and bear an invertebrate fauna, of which the most conspicuous species are the following:

Species from Upper Part of Claggett Formation.

Tancredia americana
Cardium speciosum
Sphaeriola ? endotrachys
Tellina equilateralis
Thracia gracilis
Liopistha (Cymella) undata.
Mactra formosa
Mactra alta
Lunatia subcrassa
Vanikoropsis tuomeyana
Baculites sp.

"This has long been considered a typical 'Fox Hills' fauna, and a number of its species do recur at the top of the marine Cretaceous immediately below the Laramie in Colorado and elsewhere. It is now known that some of them also occur as low as the Eagle formation. The shale exposures of this formation in the neighbourhood of Judith have been identified as Fort Pierre in previous publications. The 'lower dark shales' mapped by Dawson on Milk River near Pakowki Lake, Assiniboia, are the upper part of the Claggett formation. There is usually a gradual transition upward into the Judith River beds, so that it is often difficult to determine the exact boundary."

Fossils from beds correlated with the Pakowki shales in localities outside the region to which this report refers have been included in this list for purposes of comparison.

[1] Bull. U.S.G.S., No. 257, p. 13.

Fossils from the Pakowki Shales and Correlated Beds.

Lingula subspatula Hall and Meek.
Reported in the Claggett shales of Moose mountain. *Mem. 61, p. 52.*

Ostrea glabra M. and H. (Plate XVIII, figure 2.)
Eight miles below mouth of Pakowki coulée. *Bull. U. S. G. S. No. 257, p. 53.*

Inoceramus mytilopsis Conrad.
Upper Smoky river. *Rep. Prog. 1879–80, p. 124B.*

Pteria nebrascana Evans and Shumard. (Plate XXI, figures 3, 3a.)
In La Biche shales, 25 miles above Athabaska Landing. *Ann. Rep., vol. V, p. 28 D.*
Milk river, west of Milk River station. *Con. Can. Pal., vol. I, part I, p. 79.*
Upper Smoky river. *Rep. Prog. 1879–80, p. 124 B.*
Moose Mountain area. *Mem. 61, p. 52.*

Pteria linguiformis E. and S. (Plate XXI, figures 5–5b.)
Upper Smoky river. *Rep. Prog. 1879–80, p. 124 B.*

Tancredia americana M. and H. (Plate XXIV, figures 6–6c.)
Athabaska river, 25 miles above landing. *Ann. Rep., vol. V, p. 28 D.*
Milk river below Pakowki coulée, *Bull. U. S. G. S., No. 257, pp. 52–53.*

Corbicula cytheriformis M. and H. (Plate XIX, figures 4–4b.)
Verdigris coulée. *Rep. Prog. 1882–84, p. 52 C.*

Volsella like *V. Meeki* E. and S. (Plate XXIII, figures 3, 3a.)
Upper Smoky river, *Rep. Prog. 1879–80, p. 124 B.*

Limopsis parvula ? M. and H. (Plate XXVIII, figures 2–2b.)
Upper Smoky river. *Rep. Prog. 1879–80, p. 124 B.*

Nuculana bisulcata M. and H. (Plate XXVIII, figures 4, 4a.)
Upper Smoky river. *Rep. Prog. 1879–80, p. 124 B.*

Nucula cancellata M. and H. (Plate XXIV, figures 1–1b.)
Milk river west of Milk River station, and at mouth of Pakowki coulée. *Con. Can. Pal., vol. I, p. 79.*
Milk river at R. N. W. M. P. station, Pend-d'Oreille, 1915 collection.
Upper Smoky river. *Rep. Prog. 1879–80, p. 124 B.*

Protocardia subquadrata Evans and Shumard. (Plate XXVI, figures 2–2d.)
Upper Smoky river. *Con. Can. Pal., vol. I, p. 41.*
(Referred to *P. rara* in Rept. of Prog., 1879–80, p. 124 B.)

Modiola sp.
La Biche shales, 25 miles above Athabaska Landing. *Ann. Rep., vol. V, p. 28 D.*

Goniema americana M. and H. (Plate XXVIII, figure 3.)
Upper Smoky river. *Rep. Prog. 1879–80, p. 124 B.*

Liopistha (Cymella) undata M. and H. (Plate XXVII, figures 4, 4a.)
Upper Smoky river. *Rep. Prog. 1879–80, p. 124 B.*
Milk river, west of Milk River station. *Con. Can. Pal., vol. I, p. 80.*
Milk river at mouth of Pakowki coulée. *Bull. U. S. G. S. No. 257, p. 52.*
Milk river near R. N. W. M. P. station, Pend-d'Oreille, 1915 collection.

Mactra (Cymbophora) gracilis M. and H. (Plate XXVII, figures 2, 2a.)
Milk river at mouth of Pakowki coulée. *Con. Can. Pal., vol. I, p. 79.*
Verdigris coulée, sec. 23, tp. 3, range 16, W. 4th mer., 1915 collection.

Melania whiteavesi Stanton. (Plate XX, figure 2.)
Milk river, 8 miles below Pakowki coulée. *Bull. U. S. G. S., No. 257, p. 53.*

Corbula perundata M. and H. (Plate XIX, figures 1–1b.)
Forks of Bow and Belly rivers, and 6 miles below Milk river near Pakowki coulée. *Con. Can. Pal., vol. I, p. 69.*
Verdigris coulée, collection of 1915.

Corbula subtrigonalis M. and H. (Plate XIX, figures 2, 2a.)
Forks of Bow and Oldman rivers, Milk river south side 6 miles below, 5 miles below, and one mile above Pakowki coulée. *Con. Can. Pal., vol. I, p. 68.*
Eight miles below Pakowki coulée. *Bull. U. S. G. S., No. 257, p. 53.*

Cardium speciosum M. and H. (Plate XXVIII, figures 5–5b.)
Mouth of Pakowki coulée. *Bull. U. S. G. S., No. 257, p. 52.*

Entalis paupercula M. and H. (Plate XXVIII, figure 10.)
Milk river at mouth of Pakowki coulée. *Con. Can. Pal., vol. I, p. 81.*

Anisomyon patelliformis M. and H. (Plate XXIX, figures 1–1c.)
Upper Smoky river. *Rep. Prog. 1879–80, p. 124 B.*

Lunatia subcrassa M. and H. (Plate XXIX, figures 3–3b.)
Mouth of Pakowki coulée. *Bull. U. S. G. S., No. 257, p. 52.*

Lunatia concinna Hall and Meek. (Plate XXIX, figures 4–4b.)
Athabaska river above Athabaska Landing. *Ann. Rep. vol. V, p. 28 D.*

Aporrhais biangulata M. and H. (Plate XXIX, figures 6, 6a.)
Upper Smoky river. *Rep. Prog. 1879–80, p. 124 B.*

Vanikoropsis tuomeyana M. and H. (Plate XXIX, figures 2, 2a.)
Milk river, 8 miles below Pakowki coulée. *Bull. U. S. G. S. No. 257, p. 53.*

Rhytophorus glaber Whiteaves. (Plate XVII, figures 4–4b.)
Forks of Bow and Belly rivers and Milk river near Pakowki coulée, *Con. Can. Pal., vol. I, p. 69.*

Baculites asper Morton. (Plate XXX, figures 3–3c.)
Milk river at mouth of Pakowki coulée. *Bull. U. S. G. S. No. 257, p. 52.*

Baculites compressus Say. (Plate XXX, figures 1–1b.)
Athabaska river, 25 miles above Athabaska Landing and below La Biche river. *Ann. Rep., vol. V, p. 28 D.*
Moose Mountain area. *Mem. 61, p. 52.*
Ghost river. *Ann. Rep., vol. II, p. 123 E.*

Scaphites ventricosus M. and H.
Reported from Upper Smoky river. A Benton species which may prove to be loose. *Rep. Prog. 1879–80, p. 124 B.*

Hemiaster humphreysianus M. and H. (Plate XXXV, figures 1–1c.)
Upper Smoky river. *Rep. Prog. 1879–80, p. 124 B.*

MILK RIVER SANDSTONE.

The Milk River sandstones, as the name implies, are found exposed on Milk river (Plate VI). They have long been recognized as a well-marked horizon in the Cretaceous and in the "Report on the Geology of the Forty-ninth Parallel" by Dawson exposures in the vicinity of Coutts and on the headwaters of Red creek were so designated. The outstanding peculiarity that characterizes these beds is their habit of weathering into castellated forms, a feature that is shown in an illustration of the beds on Milk river north of West butte published by Dawson in the Report of Progress of the Geological Survey for 1880–81–82. In the section on Milk river a series of transition beds at the top of the castellated sandstones resemble in almost every particular the series of Pale beds at the summit of the Belly River series. This resemblance is well shown in the exposures just south of the station at Sweetgrass in Montana just across the International Boundary.

In the earlier reports it was recognized that the sandstones on Milk river were the same as those on the summit of Rocky Spring ridge and were above the shales of the lower slopes. Also they were recognized as rising to the south toward West butte and overlying the shales exposed there. The assumption that these sandstones rose in the banks of the Milk river eastward from Dead Horse coulée and overlay the shales at Pakowki has little field evidence to support it and is, in fact, disproved by well records and the sections to the north of the river. The Milk River sandstones dip under the Pakowki shales and are penetrated in the wells bored in Etzikom coulée and in the Milk

River valley east of Dead Horse coulée. The sandstone is of varying thickness decreasing toward the northeast. It is porous and acts as a container for natural gas in the Medicine Hat area and farther south is saturated with water which acts as a seal to the natural gas. The beds dip to the north with the general surface, but being covered by close-grained beds the contained water is confined and acquires sufficient head to become a potential artesian supply for a large area. Gas is being used from this horizon in Medicine Hat. Small flows were also obtained at Bow Island but are closed off. In Verdigris coulée it is found that there are about 316 feet of beds partly exposed and partly bored through that belong to this division. Another test of the thickness is obtained from the record of the boring in sec. 1, tp. 1, range 12, W. 4th mer., where it is thought that the shales and sands just below the Pakowki shales form the surface. The sandstone series is here about 295 feet thick. The sandstones were penetrated in another boring in the valley to the north, but the record of the well is not available. Another section was obtained from the drillings in Etzikom coulée and Foremost. The thickness given in the log of the United Oil Company's well was from 130 to 170 feet, and at Foremost the Canadian Pacific Railway's well drilling was stopped at 140 feet in the sandstone. Farther north at Lethbridge 88 feet of sandstone is credited to this division and at Taber, where the record is reliable the sandy beds are interleaved with shales, and the thickness of the formation seems to be maintained at about 202 feet.

At Medicine Hat the sandstone is reduced to layers varying from a few feet to 20 feet. The representative of the shallow water deposits corresponding to the thicker land deposits farther west may be represented by the brown beds about 300 feet in thickness that lie above the sands.

Plant impressions have been found in these beds, and freshwater molluscs have been found in the upper portion. The main body of the sandstone in the exposures south of Milk river appears to be of continental origin and contains hardly a trace of any material other than the sand grains. The shaly beds at the top and bottom of the formation were probably deposited in water, and, indeed, the greater part of the formation

to the eastward may well have been assorted in brackish or even marine waters.

COLORADO GROUP.

Almost all the rocks of this group in Canada are marine deposits. There is possibly one place in the area discussed where these beds come to the surface. Not far south of the International Boundary they are exposed on the flanks of the Sweet Grass hills and in Rocky Spring ridge. The beds underlying the Belly River series are, generally speaking, dark shales that cannot be distinguished from the Benton shales and are found to carry the same characteristic fauna. Fossils collected on the Sweet Grass hills and Rocky Spring ridge include: *Ostrea congesta*, *Pteria nebrascana*, *Corbulamella gregaria*, *Pyrifusus newberryi*, *Baculites asper*, and *Scaphites warreni*. Details of the sections are given in the chapter devoted to descriptive geology. Estimates of the thickness of the formation are far short of the results obtained in the well sections. The well section in sec. 1, tp. 1, range 12, W. 4th mer., gives a thickness of 1,745 feet for the shale series. This is checked by the results of the boring in Etzikom coulée southeast of Foremost where the measurement is 1,776 feet including calcareous clays 370 feet in thickness at the top but excluding the vari-coloured shales beneath that have been regarded as rearranged Dakota material. The record of the Taber well shows 1,390 feet of the shale beds but there is probably a slight thinning to the north and east, as at Medicine Hat there is reported to be about 1,000 feet of these lower shales.

DAKOTA GROUP.

No exposures of Dakota rocks occur nearer the region under consideration than the slopes of the Sweet Grass hills, where sandstones of this division, with probably some of Lower Cretaceous age, are found to have a total thickness of about 535 feet. Sections of the Dakota sandstones are also obtained in some of the oil bearing records and S. E. Slipper, who has been watching the boring operations for the Geological Survey, states

that these sands may be distinguished from all others met in this Cretaceous section by the red, green, and grey, variegated colouring of the top beds. The highly coloured beds seem to be variable in thickness and probably occupy basins in the sandy surface. The well in Etzikom coulée penetrated 440 feet of these oxidized shales. Since these sands occur in an almost continuous sheet under the marine shales there is in each roll or anticline a prospective reservoir of oil or gas. The formation in the lower measures is probably saturated with salt water. The upper sandy beds are in the Milk River-Bow Island anticline, apparently filled with a dry natural gas and constitute the supply beds for the Bow Island gas wells. Lower down the anticline, at Medicine Hat, the gas seems to be replaced by salt water.

The deposit is supposed to be mainly of freshwater origin, and holds occasional plant remains. It can hardly be called a coal formation in Alberta. The inrush of the Cretaceous sea rearranged some of the top beds of the series and possibly marine shells may be found in these beds. The emergence of this portion of the continent above the sea was accomplished with little disturbance to the beds under the plains, so that it is probable that the Dakota formation has long retained its basin-like form and also the water of saturation below the lowest outcrop around the margin.

CHAPTER IV.

DESCRIPTIVE GEOLOGY.

The natural exposures and sections in this portion of the plains occur as a rule along the sides of valleys and as many of them were examined by Dawson and McConnell the descriptions in the report of 1884 are here repeated, supplemented by a few sections obtained from deep well records and prospecting operations for coal. The descriptions are arranged in a series from south to north as in the original report.

SECTION ON MILK RIVER AND IN THE VICINITY OF THE 49TH PARALLEL.

[1]"From the point at which the Milk River crosses the 49th parallel, for about ten miles north-eastward, the rocks observed are chiefly sandstones of brownish and yellowish-grey tints. These, in several of the lateral ravines, assume monumental forms from the unequal resistance of the several layers to weathering. At the point last defined, rather massive beds of these sandstones are found, on the south bank of the river, to be underlain by the blackish shales of the Pierre, and they may therefore be assumed to represent the Fox Hill series, but possibly also include the lower beds of the St. Mary subdivision. The discovery of the Pierre shales, which, owing to the rounded character of the banks are here very poorly exposed, is due to Mr. R. G. McConnell. These shales are here, probably, much thinner than further north, and cross the valley with a width of less than three miles. They appear to form the southern edge of the plateau of the Milk River Ridge, which here borders the valley to the north, for about seven miles, or nearly to the point at which the Lonely Valley enters. Beyond this point, for about five miles, the river flows south-eastward and cuts through a higher tract of country, forming a narrow and almost cañon-like valley, three hundred feet in depth and less than a mile in width from rim to rim.

[1] Geol. Surv., Can., Rept. of Prog., 1882–83–84, pt. C., pp. 37–43.

The rocks here shown belong to the pale upper protion of the Belly River series, and underlie the Pierre shales[1] above referred to. They consist chiefly of greenish-grey sands and sandy clays, and thin layers of soft sandstones with calcareous or ferruginous concretions. They are to all appearance horizontal, and no fossils were observed. These rocks and the Pierre shales were more carefully studied in the Milk River Ridge to the north, and their relations are described on a succeeding page.

"South of the Milk River, and near the 49th parallel, about six miles west of the South Branch, rocks belonging to the same area of the Belly River series were observed by me in 1874, though at that time erroneously supposed to belong to the "Lignite Tertiary" of my report. As this locality has not since been visited and the volume referred to is now out of print, the following description of these rocks is quoted from it:—

"The best exposures are found in a group of small hills, which assumes in miniature the appearance of badlands, and stands like an island of older rocks among the drift deposit which lap around its base. It is an outlier of a plateau, which, with irregular edge, runs northward with a little easting where it crosses the line. The beds are horizontal, and are exposed for a thickness of about sixty feet. The lower portion of the section is of pale greenish-grey clays, while above, the greenish colour is not so marked, and there are somewhat massive sandstones. In some places the latter are almost conglomerates, and hold many small pebbles, the majority of which are of greenish shale. They also hold fragments of reptilian bones and large *Unio* shells. Small nodules occur abundantly in some layers of the lower greenish clays, of a tint similar to the matrix. The bones are found in considerable abundance in all parts of the section, but are much crushed and fissured. When embedded in the bank they are purplish-black in colour, but on weathering assume whitish and rusty tints. It is very difficult to dig the bones out of the bank itself, from the great hardness of the dry clay relatively to that of the fossils, and where washed out by the rains they are found only as broken fragments, difficult to re-

[1] Bearpaw.

construct. From specimens obtained here, however, in the course of a few hours, Prof. Cope finds, besides many broken fragments of Dinosaurians, new species of *Cionodon* and *Compsemys*, which he has called *C. stenopsis* and *C. agmius*, respectively.

"The greenish clay beds are doubtless formed of the disintegrated material of beds of green shale, similar to those represented by the pebbles in the conglomerates. A microscopic examination of the clay did not reveal any recognisable fragments of green mineral or rock, the colour apparently residing in the very fine argillaceous matter, through which a few large partly rounded grains of transparent quartz are scattered.

"The South Branch of Milk River where examined by me near the 49th parallel in 1874, shows drift deposits only. Between this point and its mouth, the valley shows at one point yellowish-weathering sandstones irregularly hardened and bedded and holding some ironstone. These appear to be practically horizontal. Several miles further down, near the confluence of this with the North Branch, these beds re-appear, with much the same aspect, but are overlain by beds of a different character, which, from analogy with those seen in the Milk River Ridge and elsewhere, with little doubt represent the base of the Pierre.[1] These are well shown in a scarped bank about one hundred feet high, a mile and a quarter up the South Branch, and consist of greyish and blackish well bedded shales and shaly sandstones, containing one highly carbonaceous layer which almost resembles a coal. The bedding of the whole is very uniform but no regular direction of dip could be determined. A few fragments of shells, among which is a *Unio*, occur.

"In following down the main valley of Milk River below the mouth of the South Branch, sections occur at frequent intervals for some miles, of beds quite similar to, and evidently on the same horizon with, those last described. The carbonaceous character of the beds here, however, becomes more pronounced, and they hold three or four coal seams which occasionally attain a thickness of over six inches. After a concealed interval of about a mile and a half, at a point about four miles west of

[1] Foremost beds.

the MacLeod-Benton trail-crossing, yellowish and grey sandstones of variable hardness and appearance, again appear. These were at the time regarded as probably overlying the Pierre shales last described, but as more fully shown on a succeeding page, reasons have since been found to show that they probably represent those described as occurring at the mouth of the South Branch, and really underlie these shales.[1]

"Sandstones of the character of those just described were the only rocks seen in the Milk River valley from this point eastward for many miles, but the exposures are infrequent and small on this part of the river. East of the trail-crossing, occasional outcrops occur in low bluffs. At a point four miles east, (near Milk River station), a small section of grey, yellowish-weathering sandstones with intervening yellowish-grey and blackish shaly beds, holding *Nucula cancellata*, was examined. There is here an appearance of light northerly dip which may, however, be merely a local undulation.

"Ten miles south of this part of Milk River, very similar rocks are again exposed in the valley of Red Creek, where it crosses the 49th parallel. In a bank about seventy feet high the following succession of beds[2] was observed, though no exact measurement of them was made:—

Gravel and boulders, underlain by obscurely stratified drift	10 feet.
Greyish and yellowish, sandy shales Yellowish, soft clayey sandstone Purplish-grey shale Yellowish sandstone Yellowish, shaly sandstone Irregular, harder, yellowish sandstone Greyish sandy shales, with thin layers of blackish carbonaceous clay as base	30 feet.

"The beds are here believed to have a low northerly dip, and rise southward and eastward with the general surface of the country to the summit of the Rocky Spring Plateau, south of the 49th parallel, where they are probably represented by those forming the upper layers in the section in the eastern escarpment of this plateau, referred to on a succeeding page.

[1] Sandy margin of Pakowki shales.
[2] Upper part of the Milk River sandstone.

"From the point on Milk River last alluded to—four miles east of the trail-crossing—to the mouth of Verdigris Coulée, sandstones not dissimilar to those above described are seen at intervals, but generally in small exposures, and presenting no points of especial interest. They appear throughout to be horizontal, or affected by light indefinite undulations only, but the sections are so inconsiderable that it is by no means certain that sandstones really preponderate among the rocks of this part of the river. It is frequently the case throughout this district that the harder sandstone layers alone appear in the rounded and grassy banks, while other and more characteristic beds, owing to their inferior induration, are concealed.

"The rocks exposed on Verdigris Coulée are described subsequently, in connection with those of Milk River Ridge. At its mouth, a peculiar series of castellated or monumental sandstones first appears,[1] the summit being here not much above the level of the Milk River, and overlain to the north by the beds seen further up Verdigris Coulée. From this point to that part of the river immediately north of the West Butte (nine miles) and beyond into Dead Horse Coulée, these sandstones appear almost uninterruptedly, and disregarding minor undulations, they rise persistently eastward and attain a greater height in the banks. They often characterize both sides of the valley, and though occasionally forming vertical cliffs, generally weather out into fantastic monumental forms (Plate VI), one group of which has already been illustrated in connection with the preliminary note on the geology of this district.[2] The greater part of the sandstone is soft and whitish, but certain harder, finely stratified or false-bedded layers, generally yellowish in color, have served as protective cappings, or project in cornice-like forms, which in some of the lateral ravines give rise to very remarkable instances of weathering. At a point three miles east of Verdigris Coulée, the sandstones were observed to be roughly false-bedded and to include blackish shaly intercalations and rolled fragments of shale, indicating proximity to, and some local denudation of, the underlying series. This,

[1] Milk River sandstone.

[2] Frontispiece to Part B, Report of Progress 1880-82.

about a mile further east, was observed in small exposures below the sandstones, and doubtless represents the upper part of the shaly series of the Rocky Spring Plateau and that of the mouth of Pakowki Coulée.[1] The thickness of these sandstones is rather variable, but where greatest is about seventy feet. The beds overlying them are not well shown till that part of the river north of the West Butte is reached. Here, about one hundred feet of softer brownish and greyish sandy beds, which at times becomes blackish from the addition of carbonaceous matter, appear, and are interbedded with friable sandy clays holding occasional nodularly hardened layers of sandstone or ironstone, in which no fossils could be found. The same sandstones, with the last mentioned overlying beds, continue in the banks through Dead Horse Coulée to its east end, though in consequence, apparently, of the absence of calcareous matter, the castellated forms here become less characteristic and eventually cease to appear.

"In going from the Milk River, near the west end of Dead Horse Coulée, to the west flank of the East Butte—eight miles south-westward—the country gradually rises, and the beds above described appear to follow the slope and are seen in isolated exposures in some of the valleys. The massive sandstone observed on the west flank of the Butte, elsewhere described, is doubtless the same which forms the castellated rocks on the Milk River.

"The tract south of the Milk River and between the West Butte and Red Creek was examined by me in 1874, and has not been revisited. Though numerous exposures occur in the various coulées, they are as a rule small and unsatisfactory. Westward from the Butte, the beds are found to assume a gentle synclinal form. About six miles from the base of the Butte, a zone of sandstone appears, which seems to hold a position much higher in the series than that on its flank, above referred to. This sandstone, two miles further west, was again seen, with a light eastward dip, the two outcrops forming the eastern and western escarpments of a low plateau. A short distance west of this

[1] This correlation should omit "the mouth of Pakowki coulée."

synclinal, sandstones evidently representing the castellated beds of Milk River appear, and are doubtless also the same with those capping the eastern edge of the Rocky Spring Plateau. These beds are thus described in the report already several times referred to:—

"In a system of ravines south of the line, about twenty miles west of the Butte, these sandstones are again well exposed, and have an estimated thickness of thirty feet. In these valleys they occur not much below the general level of the prairie, and forming the upper parts of the banks, give them a most picturesque and remarkable appearance. The lower layers of the sandstone are generally very regularly bedded, and some of them are exceedingly fine and thin, and show worm-tracks and other obscure markings. The upper beds are more massive, and have a nodular character, which causes them to weather out into castellated forms, resembling in some places those of the Roche Percée. Underlying the sandstones are less permeable clays, or arenaceous clays, of light colours, of which I did not succeed in finding good exposures, but which turn out numerous springs of a highly saline character. The beds appear to be quite horizontal in this locality."

"The escarpment mentioned in the succeeding paragraph of the Boundary Commission report is that of the Rocky Spring Ridge or plateau. Originating near the place last described, it runs south-eastward, gradually increasing in elevation, till, where crossed by the MacLeod-Benton trail, at a distance of fourteen miles, it has a height above the plains at its eastern base, of over 800 feet. The following section, in descending order, was measured near the point at which the trail descends from the plateau:

	Feet	*Inches*
1. Beds imperfectly exposed, but evidently soft, and wherever seen greyish, shaly sandstones, or sandy shales, thinly bedded.	90	0
2. Sandstones, one rather massive bed of thirty to fifty feet near the top. Other beds flaggy sandstones, passing in some places into sandy shales. The bedding of all the sandstones regular, and surfaces often showing ripple-marks and annelide tracks. Two series of jointage-planes, causing the beds to weather into castellated forms. General colour on weathered surfaces, dark brownish.....	135	0

	Feet	Inches
3. Pale greyish, and in places yellowish-grey sandy shales, all finely bedded, and occasionally holding calcareous nodules	90	0
4. Grey, finely-bedded sandy shales, rather hard. (Fossil bed No. 2.) *Baculites*, *Inocerami*, etc.	20	0
5. Lead-grey, soft sandy shales	55	0
6. Ferruginous ripple-marked sandstone. (Fossil bed No. 1.)	0	6
7. Lead-grey and blackish, thin sandy shales, with lenticular masses of dark argillaceous limestone, and calcareous concretions[1]	70	0
	460	6

"From the base of this section, the beds are concealed for a thickness of about 300 feet, when the surface of the lower plain is found to be composed of blackish shales, which continue southward to the Marias River.

"The Sweet Grass Hills and country immediately adjacent to them, are described together on a subsequent page. From the point to which the description of the rocks on Milk River has been carried, that stream bends abruptly to the north, following a narrow valley which is evidently of comparatively recent origin, while a wide trough-like valley, now dry, and above alluded to as Dead Horse Coulée, runs through eastward, and is again joined by the river six and a half miles further on. On the river to the north of this valley, a few exposures of sandstones and sandy-clays with ironstone were seen, and at one place,[2] three miles north of the river, in the front of the low plateau which here runs parallel to it, a bed of lignite-coal, three feet six inches in thickness and of fair quality, occurs. This is underlain by a few feet of whitish soft sandstone, but the exposure is small. For a mile or more further north, similar pale sandy beds are occasionally seen, and there is some reason to suspect a light southerly dip."

The Milk River sandstones exposed in Dead Horse coulée are overlain by a transition series of clays and sands containing a few small layers of coal and on Milk river east of the mouth of

[1] 1 and 2 Milk River sandstone; 3 to 7 Benton shales.

[2] Foremost beds (Yellow beds of the 1882–84 report) overlying the Pakowki shales.

the coulée the clays and sands appear to pass upward into rusty shales that have been called the Pakowki shales. The actual contact was not seen by Dawson but the superposition of the shale on the sandstones may be observed on the ridge running north from West Butte. In the Milk River valley the sandstones disappear eastward under the shales owing mainly to an easterly dip but assisted probably by some faulting, as is indicated in sec. 24, tp. 2, range 12, about 2 miles east of Dead Horse coulée, where sandstones in thin yellow beds are exposed for a short distance dipping to the east and showing small local fractures. This eastward dip probably continues across the next township, causing the shales to outcrop in the banks of the valley to a point beyond the mouth of Pakowki coulée. Sandstones similar to the underlying Milk River sandstones appear in the top of the banks at that point and were formerly mistaken for them. The transition beds above the Milk River sandstones hold important coal seams in places and their position in reference to the sandstones has been established by tracing them to points where they evidently overlie them.

In a prospecting bore in the valley, in sec. 24, tp. 2, range 11, W. 4th mer., the Pakowki shales as well as the transition beds above the sandstone were penetrated and a porous sandstone saturated with water encountered at 165 feet. This appears to be the Milk River sandstone and to represent the continuation of one of the northward sloping beds of Dead Horse coulée. From it a heavy flow of water of nearly 200,000 gallons per day is diverted to the Milk river.

Continuing Dawson's description of the valley: [1] "At a point five miles west of the Pakowki Coulée, they (sandy beds) are found capping the high bank of the river on the north side, of which the greater part is composed of the dark shales.[2] These sandstones are yellowish in general tint, hold a few valves of *Ostrea* and are the same with those more fully described as occurring at the mouth of Pakowki Coulée. East of the point last referred to, in consequence of a light anticlinal or perhaps merely owing to the decreased height of the bank, the shales

[1] Geol. Surv., Can., Rept. of Prog., 1882–83–84, pt. C, pp. 43 and 44.

[2] Lowest member of Foremost beds lying on the Pakowki shales.

alone are seen for about two miles, when grey and yellowish generally soft sandy clays and sandstones again form the summit of the section, and continue with increased thickness, due to a light-easterly dip, to Pakowki Coulée.

"It is probable that a light narrow anticline crosses the Milk river and runs into the mouth of Pakowki Coulée. The coulée is, in any case, in pretty evident connection with the existence of a subordinate intrusion of the igneous rocks of the Sweet Grass Hills. A small mass of dark mica-trap appears in the middle of the coulée near the point at which it joins the river. This includes fragments of hardened blackish shale, and is much cracked and fissured. Calcite, pyrites and some zeolitic mineral occur in small quantities. A similar little trappean projection whichmay be connected with this, is seen about two miles off to the south-east on the opposite side of the river. The dark shales[1] and shaly sandstones occur on both sides of Pakowki Coulée at its mouth. They form about eighty feet of the lower part of the bank to the west, but are not so well exposed to the east (Plate V), owing to the persistent light easterly dip which here affects the strata. In both places the overlying rocks[2] are grey sandstones and sandy clays, some layers of which are charged with innumerable well-preserved specimens of *Ostrea glabra*. On the opposite or south side of the valley of the river the shales are not seen. In the spot first referred to, they hold a few badly preserved fossils, among which fragments of *Nucula cancellata* and *Liopistha* (*Cymella*) *undata* were detected.

"For some miles eastward from the Pakowki Coulée there are fine exposures of the banded sandstones and clays above referred to. These beds are evidently the same with those observed on the Lower Belly (Oldman) and Bow, and on the South Saskatchewan, and belong to the Belly River series of this report. They include, east of the coulée, some beds rich in molluscs, among which *Corbula subtrigonalis*, *Corbula perundata*, *Neritina baptista*, (?) *Melania insculpta*, a *Rhytophorus*, *a Viviparus* and a *Goniobasis* have been determined. The following

[1] Pakowki shales.
[2] Foremost beds.

section[1] was obtained about five miles below the mouth of the coulée in the north bank of the valley of the river:—

	Feet	*Inches*
1. Greyish, sandy clays	6	0
2. Laminated, carbonaceous shale, with four-inch seam of lignite	6	0
3. Brownish and greyish, sandy clays	6	0
4. Shell-bed, with rusty, ferruginous cement. *Corbula perundata*, &c.	1	6
5. Lignite (variable)	0	4
6. Brownish and greyish clays, *Corbula*, &c.	12	0
7. Brown, thinly bedded, ripple-marked sandstone	0	6
8. Greyish, sandy clay, regularly bedded	4	0
9. Oyster bed	3	0
10. Brownish and greyish, banded sandy clays	70	0
11. Brown, hard sandstone	1	0
12. Greyish, sandy clay	10	0
13. Laminated, carbonaceous shale	1	6
14. Brownish-grey, sandy clays, many small *Ostreae*. Similar beds poorly exposed. To water of river	132	0
	253	10"

SECTION SOUTH OF MILK RIVER.

"[2]The rocks displayed in and about the remarkable isolated mountains known as the Sweet Grass Hills or Three Buttes are of great interest, but owing to the constant danger of having our horses stolen by wandering parties of Indians in this vicinity, and the fact that these mountains lie to the south of the International Boundary line, it was not deemed expedient to remain long in the neighbourhood. A general description of the Sweet Grass Hills, in which the main features of their geological structure are referred to, has already been given. Since my examination of the East and West Buttes in 1874, the only point revisited has been the flank of the latter mountain, and the following description is, therefore, almost literally quoted from my report on the Geology and Resources of the 49th parallel.

"On approaching the East Butte from the north to within ten or twelve miles, the hitherto nearly horizontal beds are found to assume a distinct dip away from its central mass. In the valleys of the streams which seam the flanks of the hills and furrow the surface around them, numerous more or less extensive

[1] Lower part of the Foremost beds.

[2] Geol. Surv., Can., Rept. of Prog., 1882-83-84, pt. C, p. 45.

exposures of rocks evidently representing the Belly River series of this report, occur, which it is unnecessary to describe in detail.

"Dykes of eruptive material traverse the sedimentary rocks surrounding the Buttes, in some places, and appear generally to have a direction radiant from the higher peaks. In a valley about ten miles north of the summit of the East Butte, one of these is well exposed. By the wearing away of the softer surrounding base, it stands up like a massive partly ruined wall, the resemblance being increased by the fact that the rock has been broken up by the weather into quadrangular blocks. Its observed course is nearly east and west. The rock is a mica-trap of dark greenish-grey colour, and not very hard, in which small tabular crystals of a brown mica are thickly scattered. It may probably originally have been of the same nature with the central masses of the Buttes, but has become more basic by the incorporation of portions of the surrounding sedimentary rock, and has acquired a different mineralogical character from this circumstance and from more rapid cooling. The clays and sandstones on either side are nearly horizontal, except immediately in contact with the dyke, where they are contorted and much altered. Valves of *Ostrea* are abundant in some of the surrounding beds, and specimens of *Corbula perundata* were also recognized.

"On ascending the East Butte, the harder beds are found constituting more or less continuous ridges round the central mass, while the softer intervening strata are not usually well exposed. The total thickness of the beds seen is not very great, as the ground rises almost equally with the increasing dip. The sedimentary rocks, in some places, rise to within about one thousand feet of the summit, and are then found much hardened and altered, and dipping very steeply away from it. They are here traversed, like the igneous rock itself, by many small seams of crystalline quartz, in which a careful examination failed to detect a trace of any metallic material.

"Nearest the igneous mass, and lowest in the series, on the East Butte, occur beds of hardened sandstone, not of great thickness.[1] On these rests a considerable thickness of hard, blackish,

[1] Probably Dakota sandstone.

fissile shale, in which no characteristic fossils were found, but which doubtless represents those subsequently described as occurring at the West Butte. Above this is a rather important sandstone series, much of which is regularly bedded, but which in some places is nodular, and gives rise in the valleys which cut through it to castellated step-like and fluted rocks of picturesque appearance.[1] These, with little doubt, represent the castellated sandstones described on Milk River, and are followed by the beds above alluded to as probably referable to the Belly River series.

"The igneous material composing the higher peaks and central masses of the mountains, though very hard and compact, is seldom seen actually *in situ*, the solid rock being concealed under a great depth of its own fragments. These fragments are very irregular in form, but generally angular, bounded by plane faces, and vary in size from a few inches to about two feet in greatest diameter. The rock is very uniform lithologically, in appearance and composition. Mr. F. D. Adams has examined microscopic sections of it, and states that it may be called a hornblende-trachyte, rich in plagioclase. Mr. Adams writes: 'it is composed of orthoclase and plagioclase, both present in large amount, and some hornblende. It is therefore intermediate in composition between andesite and trachyte, and to which class it may best be referred can only be ascertained by a partial analysis.'

"The highest peak of the West Butte, is at its eastern side, and is a large blunt-topped mountain, which to the east presents vertical rocky cliffs. West and north of this summit lie several important peaks and ridges, enclosing a rugged, pine-clad and rocky area of some extent. The foot-hills of the West Butte are also on a larger scale than those of the others. The sedimentary rocks are, as in the East Butte, found to dip away from the central igneous intrusion on all sides, but a considerable mass of stratified rock has here been, as it were, caught up by the eruptive material, and occupies the depressed central portion of the group of mountains. A great part of these beds dip south-eastward

[1] Milk River sandstone.

at a rather high angle. They have been considerably altered and now consist of slaty shales, and hard, thin-bedded sandstones in which no fossils were found. The trappean nucleus of this Butte is indistinguishable lithologically from that of the East Butte, and it forms shattered and rubbly hill-tops in the same way.

"The clearest sections of the rocks surrounding this Butte were met with on its western side, where a considerable brook issues from the central valley. Dark, somewhat indurated shales, precisely resembling those described on the East Butte, here occur, with a light westward dip. The sections are not such as to admit of exact measurement, but the thickness of the shales was roughly estimated in 1874 at 800 feet.[1] A few fossils were found in sandy and nodular layers associated with these shales, which were at the time supposed to represent the Pierre group. In consequence of the importance of deciding their relations, the locality above described was again visited in 1881, and additional collections obtained, in which the following species have been determined:—

"*Ostrea congesta*, *Pteria Nebrascana*, *Pyrifusus Newberryi*, *Aporrhais biangulata*, *Scaphites Warreni*, *Baculites ovatus*, var., etc.

"Underlying these clay shales in some places, are rather massive sand-stones tilted at high angles against the flanks of the eruptive rock, which evidently represent those found occupying a similar position on the East Butte. Overlying the shales, are massive sandstone beds, yellowish in colour, which, from their superior hardness, generally form a prominent ridge at a little distance from the base of the Butte. On the west flank of the Butte these dip away at an angle of about 12°, and a thickness of over forty feet is exposed. The investigations of 1881–83 appear to show that the shales here described represent those of the Rocky Spring Plateau and Milk River north of the Buttes,[2] while the overlying sandstones are those referred to as the castellated series on the same river.

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[1] Bore-hole records of 1915 seem to definitely increase this estimate to 1,776 feet.

[2] The shales represent those of Rocky Spring plateau but not those of Milk river.

"With regard to the age of the isolated igneous masses here so prominently displayed, all that the sections prove is that they are later than the surrounding Cretaceous rocks, which have been disturbed by them and are cut by their dykes. They are probably protrusions quite local in character, though with possible deep-seated connection with the similar intrusive masses near the Missouri to the south. They have not, however, at all the character of modern volcanic cones, and no rocks were ever seen in connection with them which had even probably cooled at the surface. If of the nature of volcanoes they must be very ancient ones, of which the cones or stumps now only remain, and from about which the whole of the ejected material has been removed. The denudation affecting the rocks tilted up around the Buttes has been very great, and must have occurred for the most part in Tertiary time and before the glacial period."

SECTIONS IN THE SWEET GRASS HILLS.

Measured by S. E. Slipper in 1915.

A partial section only of the rocks below the Milk River sandstones was obtainable since all the exposures have been disturbed by intrusive dykes and small secondary plugs. The best results were obtained along the valley at the head of Sage creek on the northeast side of East butte. Here the lowest stratified rocks are bluish limestones containing crinoids and other obscure fossils evidently of Carboniferous age. Lying conformably on the limestone is a hard flaggy sandstone 10 feet thick. The next exposure 60 feet above is of impure limestone and calcareous shales 95 feet thick containing Jurassic fossils. *Belemnites densus* and *Gryphea calceola* are common forms. Others collected include *Perisphinctes* sp. (?), *Astarte dakotensis*, and *Tancredia inornata*. Above these calcareous beds are found about 130 feet of green and dark-coloured shales and sandy shales in which one 10-foot sandstone bed occurs containing clay pellets and plant fragments. These beds and an overlying massive sandstone are the lower part of the Dakota formation. The rocks above this were so disturbed that although the entire

Dakota and Benton are represented no measurements were attempted and the section given in the boring in sec. 1, tp. 1, range 12, W. 4th mer., has been incorporated as giving a truer interpretation. The following columnar section is submitted.

Well Section.

	Thickness feet
Cretaceous.	
Milk River sandstone	295
Benton formation.	
Bluish-grey argillaceous shales with thin sandstones	1,745
Dakota formation.	
Light grey and green sandstone with greenish and red shales	370

Exposed Section.

Cretaceous.		
Dakota formation.		
Green and chocolate brown clay shale	20	
Flaggy sandstone	15	
Hard massive grey sandstone	40	
Light green sandy shale turning bluish grey at top	80	
Greenish-grey coarse sandstone with clay pellets and plant remains	10	
		535
Jurassic.		
Green soft shales with dark stains, no fossils	40	
Dark blue calcareous shale with *Belemnites densus*	50	
Dark blue impure limestone containing *Gryphea calceola Perisphinctes*, etc	45	
Probably dark greenish sandy shales, concealed	66	
		201
Permian-Triassic.		
Hard grey flaggy sandstone	10	10
Carboniferous.		
Bluish massive limestone generally crystalline with *crinoids* ..		

Section of Well on Sec. 1, Tp. 1, Range 12, W. 4th Mer. (Drilled by the Grand Trunk Pacific Development Company.)

		Thickness feet	Depth from surface, feet
Milk River sandstones.....	Sandstone and sandy clay.....	295	295
Benton 1,745 feet.	Shale blue grey.....	325	620
	Shale blue grey with some lighter sand.....	60	680
	Shale blue grey.....	670	1,350
	Shale and white bentonite.....	260	1,610
	Shale with some sand.....	90	1,700
	Shale blue grey.....	340	2,040
Dakota and Lower Cretaceous 535 feet.....	Sand light greenish and grey...	90	2,130
	Shale green and red.....	50	2,180
	Gap in section.....	560	
	Compare previous section. The beds are probably sandstones.....395		
	shales.....165		
Jurassic 195 feet...	Blue black calcareous shale....	10	2,750
	Green grey shale.....	20	2,770
Permo-Triass. 30 feet.....	Light grey brown calcareous sandstone.....	10	2,780
	Grey brown shale and sand, calcareous.....	10	2,790
	Green tinted sand.....	10	2,800
Carboniferous.....	White limestone.....	100	2,900

SECTIONS IN MILK RIVER RIDGE.

The paucity of exposures at the east end of Milk River ridge is responsible for a misconception in the earlier correlation. The marine shales of the Pierre were found superposed on the freshwater beds of the Belly River series in the western part and at the top of the ridge. A very similar series of marine shales were found at the mouth of Pakowki coulée; and although the fossils were of Pierre type their position below the yellow beds of the Belly River series led Dawson to correlate them with the

Benton exposures in Montana. That they constitute, as they do, a lower member of the Pierre was not then recognized; and, where this marine member was discovered at the eastern end of the Milk River ridge, its sandy character prevented a correlation with the Benton. Accordingly it was mapped from its fossils as a continuation of the Upper Pierre and a hypothetical anticline was introduced in order to connect the two members. At the base of the Upper Pierre there is a coal seam (Lethbridge seam) and there are also coal seams both above and below the Lower Pierre though the lower ones are unimportant; so that correlation by means of the coal seams is of little or no value. That there was uncertainty even at the time the earlier reports were written as to the correlation of the Pakowki shales with the Benton is shown by the following statement by Mr. J. F. Whiteaves who described the fossils:[1]

"Of the eleven species of fossils which have so far been collected from them, seven or eight seem to be identical with forms that are elsewhere regarded as characteristic of the Fort Pierre or Fox Hills group, but the presence in these shales of *Scaphites warreni* var *Wyomingensis* and possibly of *Ostrea congesta* may indicate that they occupy a slightly lower position in the series."

In the collection examined by Dr. Whiteaves the last two species were collected from a lower shale in Montana so that the last remark can be disregarded, and the Pierre age of these lower shales admitted. Between these two marine shales are interleaved the pale and yellow divisions of the Belly River series which occupy the mass of the eastern part of Milk River ridge. Around the base of the ridge and along the irrigation canal, just to the west of Milk River station, the yellow beds are exposed. They are of brackish water origin, and contain coal seams, and are between freshwater deposits above and marine sediments below. They bear a distinct resemblance to the beds at the top of the Belly River series and were at one time mistaken for them.

The coal seam at the top, as exposed along Milk river, is apparently of small thickness, but at the eastern end of the hill and in the hill east of Milk River station the seam, or one just

[1] Con. Can. Pal., vol. I, p. 78.

below it in the section, is thick enough to mine. On sec. 26, tp. 2, range 16, there is a small mine supplying local demands. In the northeast corner of this township Oborn's mine is on the same seam which is there split up by clay partings. The following is the general section in this mine:

	Feet	*Inches.*
Coal	1	0
Bone	1	3
Coal	1	0
Clay	0	3
Coal	0	5
Clay	0	3
Coal	0	5
	4	7
Coal	2	10

Other lignite exposures may be seen on the road between sections 7 and 8, tp. 3, range 16, but none is of sufficient thickness to mine. The coal-bearing series is best exposed in Chin coulée at Foremost and is referred to in this report as the Foremost beds. Continuing Dr. Dawson's description:[1]

"Milk River Ridge is a rough irregular plateau varying in width from six to twelve miles, and extending from near St. Mary River, eastward parallel to the Milk River for about forty miles. Its northern edge is rather abrupt, and rises in some places as much as 600 feet above the plains. Its southern border is not so well defined and is worn into a succession of deep bays by small streams which flow into Milk River. The Lonely Valley cuts completely through its western portion, and there are several similar but less important gaps running through it from the Milk River valley near its intersection with the 49th parallel. The plateau to the south-east of the South Branch of Milk River, is evidently a portion of the same area of high land which constitutes the Milk River Ridge proper. As already stated on a previous page of this report, the plains to the north of the ridge are at nearly the same level as—and in many places even lower than—the water of Milk River to the south.

[1] Geol. Surv., Can., Rept. of Prog., 1882-83-84, pt. C, pp. 48-52.

"Milk River Ridge is remarkable on account of its complex geological structure. Its western portion, composed of beds of the Willow Creek subdivision of the Laramie has already been noticed in connection with the description of sections on the upper Milk River. In proceeding eastward the St. Mary River subdivision, the Fox Hill, Pierre and Belly Rivers beds, are found to outcrop successively, in consequence of a light westerly dip, which, though locally interfered with by light undulations, appears on the whole to be persistent. The last named series, though well displayed in the eastern part of the ridge, was in no place observed to form the surface of the plateau. The high land above alluded to as existing south-east of the South Branch, is probably chiefly composed of Pierre shales[1]; and in bare plateaus connected with it to the south-west, some miles south of the 49th parallel, these were seen from a distance overlying the pale beds of the Belly River series. The central and eastern portion of the plateau is composed of the[2] Fox Hill, Pierre and Belly River beds. The sandstones of the Fox Hill, are well exposed about seven miles north of the plateau, in a low hill which is cut through by the Pot-hole River, where Mr. McConnell observed the following section:—

	Feet.
Yellowish-weathering, soft, coarse sandstone, showing branching fuccidal markings in many places	60
Black shales	15
Flaggy sandstones	20
Black shales (to base of section)	60
	155

"The massive sandstone forming the top of this section, and which undoubtedly represents the Fox Hill, forms a steep cliff facing the stream and extending up it about half a mile. Following the strike southward, it is again seen in conspicuous exposures about half way up the northern slope of Milk River Ridge, where the castellated and fantastic forms which this rock frequently assumes on weathering are well displayed.

[1] Later observations show many exposures of Milk River sandstones with marine beds of the lower part of the Pierre on the surface.

[2] This statement is correct for the central but not for the eastern portion of the plateau.

"In the valley of the west branch of Pot-hole River, where it leaves the plateau, the sandstones above described form the upper part of the section, and overlie about one hundred and fifty feet of black shales. The occurrence of this sandstone on the Milk River, south of the plateau, has already been alluded to. It is there about sixty feet in thickness.

"To the east of the outcrop of these sandstones, the Pierre shales come to the surface in a belt of which the width is extremely variable. North of the plateau the outcrop is about five miles in width, but in following it southward it is found to spread eastward over the entire summit of the plateau, and reaches probably to within a few miles of the MacLeod-Benton trail; while the western edge, or summit of the shales, appears to run almost directly across the plateau to the Milk River. In many places along the northern slope of the plateau, the valleys of small streams afford good sections of the base of the Pierre, and the clays, sandstones and sandy clays of the underlying Belly River series. Of these the best observed are in and near Fossil Coulée, about ten miles west of the Nine-mile Butte. The actual base of the Pierre is best shown in the head-waters of a small stream which flows into Middle Coulée Creek. The shales here to some extent lose their characteristic dark tint, become greyish or brownish and earthy looking, and hold several small seams of coal and carbonaceous shales. The most considerable coal seam is not more than eighteen inches thick, and the section here is closely comparable with that previously described in Milk River south of the ridge. An oyster-bed identical with that observed at the mouth of St. Mary River at the same horizon, occurs in association with the coals. In this, in some places, the calcite of the shells has been largely replaced by iron oxide. The exposures on the head-waters of Ed. Mahan's Coulée are small, but probably represent the top of the Belly River series. On Fossil Coulée, fine exposures of the series last mentioned occur, in bare, bad-land banks. The following is a section of the greater part of the beds there shown, in descending order:—

	Feet	Inches
Dark grey, soft sandy clay	6	0
Yellowish sand or soft sandstone	4	0
Grey, soft sands, with some bands of clay	15	0
Grey, soft sandstone	1	0
Greenish-grey clay	5	0
Grey, soft, shaly sandstone	1	0
Grey, soft, sand and sandy clay	4	0
Greenish-grey clay	5	0
Nodular layer of impure calcareous ironstone	1	6
Yellowish, fine sand, or soft sandstone	4	6
Dark grey, sandy clay	3	6
Greenish-grey sands, irregularly hardened and forming projecting cornice-like layers of sandstone	8	6
Greenish clay, with large impure septarian ironstone nodules	8	0
Greenish-grey, sandy clays and clays	10	0
Yellowish-grey, sandy clay, with layer full of small clay pebbles at top	10	0
Yellowish-grey, fine, soft sand	3	0
Brown-weathering, shaly sandstone, becoming conglomoritic with small clay pebbles in some places (locally developed)	1	6
Grey, soft, fine sand	3	0
Grey, fine-grained sandstone	1	0
Pale greenish-grey clay, slightly banded	15	0
Pale greenish-grey, soft, sandy clay	4	6
Grey, soft, clayey sand. The upper portion full of small soft ironstone concretions	3	0
Grey, soft sandstone	0	2
Greyish, soft, clayey sand	5	0
	123	2

"This section may be regarded as a representative one of the upper or pale portion of the Belly River series. Mr. T. C. Weston, who accompanied me (G. M. Dawson) to this locality in 1883, made here a considerable collection of fossils, which included *Unio* and other freshwater shells resembling those abundant in the lower yellowish portion of the Belly River series. These were unfortunately lost *in transitu*. Mr. McConnell collected from the same locality, in 1882, a few fossils which indicate that some of the beds are brackish-water or marine in character. Among these are : *Pteria Nebrascana*, *Cymbophora alta* (?) *Volsella*, *Natica* (fragment), *Anchura*, *Spironema*, *Anodonta* and *Unio*.

"The eastern edge of the Pierre shales on the Milk River Ridge, owing to the lack of exposures, can only be very approximately defined. It probably crosses the ridge nearly opposite the head-waters of Ed. Mahan's Coulée. These shales are,

wherever seen in this region, very uniform in appearance. With the exception of the lower beds above alluded to, the mass of the series appears to be made up of very dark shales, in which sandstone beds, which in some other localities form a prominent feature, scarcely occur. Thin layers of red-weathering ironstone however, are occasionally found, and numerous concretionary masses of the same material are scattered throughout. The only fossils observed in these beds in this neighbourhood were fragments of an Inoceramus, of an Ammonite and of a Baculite.

"The exposures in Ed. Mahan's, Middle and Kipp's Coulées, north of the slopes of the ridge, are comparatively insignificant, and not sufficiently continuous to form a good connection between the rocks of the ridge and those of Verdigris Coulée. At the trail-crossing of Ed. Mahan's Coulée, a thin seam of lignite or shaly coal occurs in a bank of greyish sandy clays, the whole being underlain, in the bed of the stream, by a hard nodular calcareous layer, much fractured, and showing crystals of calcite lining the irregular crevices. The horizon of these beds is somewhat uncertain, but they may possibly represent the base of the Pierre.[1] Two or more species of *Sphaerium* and fragments of *Goniobasis* and *Viviparus* were obtained here. Near the junction of this coulée with Middle Coulée, yellowish soft, irregularly bedded sandstones appear, which possibly underlie the beds just described. On the south bank of Middle Coulée, between this point and the trail-crossing, a carbonaceous layer, probably representing that above mentioned, occurs, but the exposures are poor. West of the trail-crossing on Middle Coulée, are occasional banks showing yellow sandstones and grey clays, for about three miles, where beds of the same character and on about the same horizon with those of Fossil Coulée appear, and are well shown in scarped banks west of the entrance of Middle Coulée Creek. Similar inconsiderable exposures occur both east and west of the trail-crossing on Kipp's Coulée. These doubtless represent the Belly River series. In a narrow valley which connects Middle and Kipp's Coulées, west of the trail, scarped banks afforded the subjoined section:—

[1] They form part of the pale and yellow beds and lie at the top of the yellow beds, below the pale portion.

	Feet	Inches
Greyish, flaggy sandstone	10	0
White, arenaceous clay	20	0
Yellowish sandstone (to base of section)	8	0

SECTIONS IN VERDIGRIS COULÉE.

"Verdigris Coulée, already referred to in connection with the description of sections on the Milk River, affords almost continuous sections, for many miles, of the Belly River series; though from their character it is difficult to decide whether they represent its upper or lower portion. In the lower part of the coulée, near McConnell's Lake, the banks show a tendency to bad-land weathering and are in general tint greenish or purplish-grey. Yellowish sandstone beds are prominent and very irregularly hardened. Silicified wood is very abundant in some of the banks, but no other fossils were observed. The beds are to all appearance, perfectly horizontal. Similar beds at the same or nearly the same horizon, continue to and along the shores of Verdigris Lake, but are generally poorly shown. In the valley of a small stream which enters the lake from the south, near its north-west end, there are considerable sections of grey and yellowish shales and shaly sandstones,[1] thin-bedded and rather hard; these appear to have a very light westward dip.

"About a mile west of Verdigris Lake, in the north bank,[2] a thin bed very rich in well-preserved fossil shells of a few species, was found. Among these are *Corbula perundata*, *Corbicula cytheriformis* (?) *Ostrea* and *Unio*, but the specimens were unfortunately lost, with other collections from this district. The rocks in the vicinity are more thinly bedded than those near the mouth of the coulée. Thin yellowish and reddish sandstones occur, with pale or dark grey shales, which occasionally become impure lignite. Similar rocks, but in very imperfect exposures, in which the sandstones as a rule alone appear, occur on both sides of Tyrrell's lake and westward to Suds Lake. Their horizontal attitude, wherever observed, and the absence of slope in the bed of the valley, would indicate that nearly the same horizon is represented throughout. Some of the beds on the

[1] Pakowki shales.

[2] Part of the Foremost beds.

higher part of the coulée present a marked resemblance to those seen at the trail-crossing of Ed. Mahan's Coulée, but it is impossible to trace out minor subdivisions of the series in this region."

Observations made in 1915 show that there is a distinctly northern dip to the beds in this valley. Castellated sandstones similar to those described on Milk river are well exposed near the mouth of the valley and from some of the beds fine examples of palm leaves were collected by Mr. C. H. Sternberg. Freshwater shells are also reported to occur in them. Nearing Verdigris lake the sandstones are not so prominent, and softer sandy shales appear which represent a transition to marine conditions of deposition and are the westward continuation of the Pakowki shales. The following marine fossils, provisionally identified, were collected from these beds, mainly from sandy lenses in the shales: *Mactra gracilis*, *Crenella sericia*, and *Tellina equilateralis*, a fauna of marine type.

To the north of Verdigris lake and about due east of Warner (Plate XIV) the rocks are those of the next higher series and represent a transition back to brackish-water conditions with, probably, intercalations of freshwater or land deposits. The series is coal-bearing, and apparently the seam at the base just above the marine beds is of importance. The section in the bank includes nearly the whole of the division called the Foremost beds. At the top of the bank yellow sands are exposed together with brown shales with streaks of lignite. These beds contain unios, one variety resembling a large form of *Unio priscus*. A thickness of about 50 feet is exposed in the upper part of the banks, the lower part being concealed by surface wash. The northerly dip of these beds is shown by a comparison of their elevation with that of their representatives near Milk River station. About a mile to the south and 180 feet below the top of the exposure noted above, a coal seam has been mined on both sides of the valley. The seam is about 5 feet thick and is made up mostly of shale with streaks of coal. Near the top there is 12 inches of soft lignite, and near the floor there is 12 inches of what seems to be fairly good lignite. Lower down there is another 12 inches of lignite of which the quality is not known.

A deep well was being drilled during the summer of 1915 by the Stokes-Stevens Oil Company on or near sec. 22, tp. 2, range 14, W. 4th mer., in the bed of the coulée. The exposures about the well are of the thick-bedded, greyish, castellated sandstones of Milk river (Plate VI). Near the top of the bank the beds are particoloured and thin and are interleaved with shaly layers. In appearance they are very similar to those forming the top of the pale beds in the upper part of the Belly River series, showing the recurrence of similar conditions of deposition. The thickness of the beds exposed as determined by aneroid readings is 140 feet. Beneath these beds the drill penetrated 176 feet of sandstone before entering shale. This gives an estimated thickness of 316 feet for the sandstone series. A sandstone bed from 5 to 10 feet thick was encountered about 200 feet below the top of the shale, and another at a depth of 1,700 feet from the top of the well.

SECTIONS IN LUCKY STRIKE PLATEAU.

In the region north of Milk river and south of Etzikom coulée there are few rock exposures between Verdigris coulée and the rising ground of the Lucky Strike plateau. From the appearance of the surface it seems probable that the sandy beds containing coal seams have been largely destroyed by erosion over the area extending for some distance north of Milk river, and that the marine sandy shales floor a large part of the region. The eastern edge of this eroded strip forms the western edge of the plateau and runs northwest through tp. 3, range 12.

This broad valley probably formed a second and lower drainage outlet when Verdigris coulée was abandoned, following the new channel to the north of Dead Horse coulée. On the edge of the Lucky strike plateau several coal seams have been found and the coal mined for local consumption. Coal-bearing measures appear to underlie the plateau and to be connected with the Foremost beds along Etzikom coulée where their position directly above the marine shales of the Pakowki coulée establishes their equivalence with the coal-bearing beds of Verdigris coulée north of Verdigris lake.

West of Goddard post-office in section 20, near the northern edge of the plateau a coal seam was cut in a well at 60 feet from the surface. South of this a seam outcrops on the road allowance between secs. 15 and 16, tp. 3, range 12, W. 4th mer., and has been mined to a small extent by stripping and undermining. The coal is overlain by boulder clay and is reported to occur in two seams, an upper seam 30 to 34 inches thick and a lower seam 3 feet thick separated by a clay parting 3 feet thick. The coal horizon is exposed to the southeast at about the same elevation, in a small ravine running towards Milk river. One of the upper seams is reported to contain 3 feet of good coal in sec. 1, tp. 3, range 12, and has been worked for several seasons. Farther east, at Bembridges coal mine (Plate XI) in sec. 6, tp. 3, range 11, a lower seam, 27 inches in thickness, is mined by entry into the face of the banks of a small ravine. The next exposure of this coal is at Hughson's mine, in sec. 10, tp. 3, range 11, W. 4th mer., in a ravine at the southern face of the plateau. The seam worked is probably one of the lower ones. The coal at this point also is in two seams, an upper 1 foot 4 inches thick and a lower 1 foot 6 inches separated by a clay parting 1 foot thick. Light-coloured sandstones and clays overlie the seam. The following fossils were found in a bed at the top of the bank 50 feet or more above the coal: *Mytilus subarcuatus*, *Unio priscus*, *Ostrea glabra*, *O. subtrigonalis*, *Corbula perangulata*, *Panopæa* or *Tellina equilateralis*. The plateau slopes to the east and northeast where it forms part of the general prairie surface. To the east it slopes gradually to the Pakowki depression. In the southern and western borders of the plateau the location of the edge of the coal-bearing beds is indicated by a change in the slope of the surface but to the east the change is not so pronounced. A slight step may be noticed near Faith in the southern part of tp. 4, range 9, crossing northward towards the northwest corner of the township. There are no exposures of the coal-bearing rocks, but a few streaks of coal have been encountered in farm wells in the vicinity, below the overlying surface shales. In sec. 15, tp. 5, range 9, W. 4th mer., Mr. McKenzie drilled 100 feet and found no coal. The water from this well tastes of soda and is derived, without doubt, from the Pakowki marine shales.

SECTIONS IN ETZIKOM COULÉE AND NORTHWARD.

In the upper part of Etzikom coulée there are very few exposures and it is probable that the underlying rocks are principally light-coloured clays and sands belonging to the freshwater portion of the deposits. The top of the brackish-water beds with the coal seams if exposed at all should first appear in the bottom of the coulée. The actual outcrop is no doubt concealed, but coal is reported to occur in sec. 34, tp. 5, range 15, W. 4th mer., and the exposures around Crow Indian lake show beds similar to those near the top of the brackish beds of Foremost. Dawson's description of these beds is very full and is here reproduced.[1]

"In Etzikom Coulée about the meridian of the west Butte, sections were examined about fifty feet in thickness, which evidently represent the yellowish or lower portion of the Belly River series. The rocks seen were soft whitish sandstones and sandy clays, yellowish sandstones, and carbonaceous purplish-grey shales, which in some places approach lignite. They are apparently horizontal, *Ostrea glabra* (?) and a few other shells in a very poor state of preservation were observed.

"Fourteen miles westward, on the same coulée, similar rocks, again associated with lignitic shales, and holding fragments of *Unio*, were noted by Mr. McConnell. A few miles west of Lake Pakowki on the same coulée, yellowish sandy-clays and sandstones, holding *Corbula perundata* were observed in 1881. This long coulée was not followed throughout its course, though Chin Coulée, running parallel to it a few miles to the north, was pretty carefully examined, and the horizontality of the beds leaves little room for doubt that practically the same horizon is represented on both."

In the SW. ¼ of sec. 31, tp. 5, range 10, W. 4th mer. (Plate XIII), dark yellow sands and drab coloured shales show in cuttings along the road allowance, and a band made up mostly of oyster shells is found at a height of about 80 feet above the road bridge, in the coulée. Specimens of *Velatella*, *Corbula*, and

[1] Geol. Surv., Can., Rept. of Prog., 1882–83–84, pt. C., p. 52.

Ostrea were collected from the band. Higher up, near the top of the bench and probably over 100 feet above the bottom of the coulée, streaks of lignite form a small seam. This outcrop perhaps represents one of the upper beds of the series that is exposed on Chin coulée. To the east of the road bridge the United Oils of Alberta, a prospecting company, have penetrated most of the marine beds of the Cretaceous, according to the record of their boring which follows:

Log of United Oils Well No. 3, Etzikom Coulée, S. W. ¼ Sec. 31, Tp. 5, Range 10, W. 4th Mer.

Formation.	Strata.	Thickness in feet.	Depth below surface in feet.
	Surface deposits brown clay.....	130	130
Pakowki shales, 385 feet.....	Fine sand, greenish grey	50	180
	Shale, dark greenish.....	20	200
	Sand, dark green	50	250
	Shale, greenish	67	317
	Sand, greenish black	33	350
	Shale, greenish black	50	400
	Soft shale, greenish black	115	515
Milk River sandstones, 170 feet.	*Coal*.....	5	520
	Soft shale.....	6	526
	Coal and black shale.....	6	532
	Sand with streaks of coal.....	11	543
	Fine sand, top of water-bearing beds (Flow at surface 16,000 gals. per day, water fresh).....	7	550
	Fine sand, bottom of water-bearing beds.....	75	625
	Fine sand, light grey	60	685
Benton shales, 1,776 feet..	Shale, blue black.....	65	750
	Shale, dark greenish.....	20	770
	Shale, blue black.....	350	1,120
	Shale, blue black.....	500	1,620
	Shale, blue black.....	43	1,663
	Grey sand (gas 50,000 ft.).....	2	1,665
	Shale, blue black.....	275	1,940
	Fine sand, steel grey (salt wat er)..	2	1,942
	Shale, blue black.....	38	1,980
	Fine close sa nd.....	20	2,000
	So\t shale (Bentonite).....	15	2,015

Formation.	Strata.	Thickness in feet.	Depth below surface in feet.
Benton shales, 1,776 feet..	Sand (gas 10,000,000 c.f.).....	5	2,020
	Sandy shale.....	10	2,030
	Blue shale.....	40	2,070
	Pebbles.....	15	2,085
	Sand.....	25	2,110
	Black sand.....	20	2,130
	Sandy shale.....	30	2,160
	Black shale.....	40	2,200
	Sandy shale (at 2,250 feet salt water 7,000 bbls. per day).....	100	2,300
	Black shale.....	30	2,330
	Shale, bluish	15	2,345
	Shale and grey sand.....	5	2,350
	Shale, blue grey	10	2,360
	Shale, greenish	10	2,370
	Shale and sand, blue grey.....	5	2,375
	Shale, blue grey	5	2,380
	Shale and sand.....	5	2,385
	Shale, dark grey	10	2,395
	Shale and sand.....	15	2,410
	Shale, dark grey	10	2,420
	Shale and sand.....	15	2,435
	Shale, dark grey	26	2,461
Dakota and Kootenay 1,159 feet..	Sand, grey	9	2,470
	Shale, grey	15	2,485
	Shale, green and red	15	2,500
	Sand with red stains.....	5	2,505
	Shale, brick red.....	15	2,520
	Shale, green and red	15	2,535
	Sand, light grey	25	2,560
	Greyish white shale.....	155	2,715
	Fine compact grey sand.....	25	2,740
	Hard shale.....	10	2,750
	Pink coloured shale.....	150	2,900
	Black slate (shale).....	10	2,910
	Fine yellowish sand (salt water)..	20	2,930
	Grey shale.....	45	2,975
	Sand.....	10	2,985
	Sand *saturated with heavy oil*	65	3,050
	Sand generally grey.....	145	3,195
	Shale, blue grey	15	3,210
	Limestone, grey, cream, and buff.	410	3,620
	Shale, greenish grey	85	3,705

The upper part of the Benton of this section, that is from about 685 to 1,060 feet, is calcareous and on that account has been classified locally as Niobrara. The calcareous character

of the beds probably only indicates deposition in clear water, as farther east, at Moosejaw, there are calcareous streaks all through the Benton.

SECTIONS IN CHIN COULÉE AND NORTHWARD.

Two mines have been opened at the bottom of Chin coulée not far from Foremost which is located on the south bank of the coulée in range 11. The seams mined are near the base of the formation and a little work has been done on another seam higher up near the surface of the prairie. The section in the coulée resembles in its upper part that in Verdigris coulée and contains, besides coal seams, fossils of brackish-water and fresh-water types. In a sandy bed lying about 100 feet below the top of the bank on the south side there is a layer made up mostly of oyster shells, including *Ostrea glabra*, forms resembling *Melania insculpta*, and *Anomia micronema*, and fragments of *Pteria nebrascana*. In sands lying above the coal seam, near the bottom of the coulée, a few shells of *Corbula subtrigonalis* occur and many of the smaller *C. perundata*. From these fossils it may be inferred that the beds are transitional in character and mostly of brackish-water origin. The upper beds are not as well represented on the south as they are on the north side of the coulée where, on the road crossing 3 miles to the east near the top of the hill, a coal seam of 3 feet or over is exposed. An oyster bed lies just above the coal making a succession similar to that near Pend-d'Oreille; and a few feet above that a hard sandstone bed containing *Ostrea* of a broad type.

The Foremost beds where they are exposed to the south-west, contain many streaks of grey to white sandy deposits or sandy shales. In the exposures near Foremost a dark clay seems to have replaced the sand deposits and the rocks have a more sombre look, in that respect resembling those on the South Saskatchewan and in Pakowki coulée.

A well drilled on the north side of the railway reached the water-bearing sands at about 615 feet. The following log was obtained from the constructing engineer:

Well Section at Foremost.

Formation.	Strata.	Thickness in feet.	Depth from surface in feet.
Foremost beds 196 feet....	Yellow clay and stones.....	71	71
	Blue clay and shale.....	8	79
	Clay and stones.....	11	90
	Shale.....	8	98
	Sandstone.....	13	111
	Rock.....	2	113
	Clay and stones.....	4	117
	Rock.....	1	118
	Shale, blue sand, and *coal*.....	24	132
	Coal and hard shale.....	12	144
	Shale, *coal*, and blue sand.....	2	146
	Shale and *coal*.....	14	160
	Shale and sandstone.....	19	179
	Shale, sandstone, and *coal*.....	17	196
Pakowki shales 420 feet	Shale.....	66	262
	Sandy shale.....	68	330
	Sandy shale.....	29	359
	Hardpan.....	2	361
	Sandy shale.....	63	424
	Sandy shale.....	17	441
	Hardpan.....	1	442
	Shale.....	8	450
	Shale.....	165	615

The well was subsequently deepened, and at 615 to 625 feet penetrated sandy beds containing water which flowed from the top of the well. The supply of water increased with depth and at 760 feet, the deepest point reached, the flow was about 7,000 gallons daily.

McConnell has described Chin coulée as follows:[1]

"Chin Coulée runs entirely through rocks belonging to the Belly River series, good sections of which occur at many points. The Chin, a name given to a small plateau lying northeast from the crossing of the Cypress trail and abutting on the coulée, is composed of brownish-yellow coarse sandstones, thickly bedded, and overlying some brownish flaggy sandstone.

[1] Geol. Surv., Can., Rept. of Prog., 1882–83–84, pt. C, p. 53.

"Between the Chin and a point about twenty-seven miles further east the coulée was not examined. Below that point, the banks of the valley are usually more or less scarped, and show almost continuous sections nearly all the way down to its mouth; the rocks consisting mainly of greyish sands and sandy clays, yellowish and greyish sandstone, lignitic shales and ironstone. Near the mouth of Forty-mile Coulée, a darker band containing a number of beds of carbonaceous shale appears in the section. Fossils were found in many places, *Corbula perundata*, *Corbula pyriformis* and *Ostrea glabra* being the most abundant. The last named fossil forms in one instance the greater part of two beds, in the same section, each about three feet thick. North of Chin coulée, and near the point where the Cypress trail crosses Forty-mile Coulée, a small coal seam, about fourteen inches thick, occurs. This seam is probably about the same horizon as the coal at Medicine Hat."

The main road connecting Foremost and Bow Island crosses Chin coulée in sections 1 and 12, tp. 8, range 11, W. 4th mer. On the east bank near the top, a coal seam is mined by the stripping method. From information furnished by a resident of the neighbourhood it would appear that the coal occurs in two 14-inch seams, separated by a clay parting of 8 inches, lying just below a series of yellow beds. It is probable, therefore, that it occurs at the same horizon as the surface seam in Chin coulée to the south.

About 100 feet lower in the section near the bottom of the coulée there are several good exposures of the brackish-water beds, holding well preserved specimens of *Melania insculpta*, *Ostrea subtrigonalis*, *Modiola tenuisculpta*, and a specimen of *Lunatia*.

East of this point in Sevenpersons coulée, the exposures resemble the pale beds, and, if they really represent them, the Foremost beds must lie below the bottom of the coulée at this place. The coal seam dividing the two formations comes to the surface on the slope of the grassy escarpment (Plate XII), and is mined in two or three places in the vicinity. It is probably the same seam that is mined at the top of the bank

of Fortymile coulée. The seam, therefore, dips to the east, showing a fall of about 150 feet in 13 miles.

The coal horizon no doubt underlies the lake basins of the upper part of Fortymile coulée near Grassy lake, for it is mined at several points along the coulée. Near the road leading south from Bow Island in sections 14 and 15, tp. 9, range 11, two small coal hoists have been installed by which the coal is raised from 40 feet below the surface. The coal is sub-bituminous and well suited for ordinary domestic use. The seam is about 2 feet 6 inches in thickness, including a 4-inch band of shale, and slopes gently to the east. It outcrops at the head of Fortymile coulée and is mined also south of Grassy lake and underlies the town of that name. Several shafts and slopes have been sunk in the sides of the valley about 1½ miles south of Grassy Lake where the seam is reported to show 2 feet 6 inches of good coal. It is mined also in another depression about 6 miles farther south. The seam is mined also in sec. 23, tp. 9, range 13 W. 4th mer., where it has the following section: top coal 2 feet 6 inches; bone and clay 1 foot, increasing to 2 feet farther south; lower coal 1 foot 6 inches.

At a mine in sec. 25, tp. 9, range 13, W. 4th mer., the seam is of a similar character, showing: top coal 2 feet 9 inches; parting 1 foot; lower coal 1 foot 6 inches. At other mines, the seam is reported to be 2 feet 6 inches thick, a measurement that perhaps covers only the top bench.

In a well at Winnifred, according to the best information available, the coal-bearing beds of this horizon are cut; the first coal seam 18 to 24 inches thick was found at a depth of 150 feet; the second about 3 feet 6 inches thick at 180 feet; and the third, apparently a workable seam from 4 feet 6 inches to 5 feet in thickness, at a depth of 220 feet. The surface elevation is approximately 2,740 feet.

Other exposures of the coal of this horizon are referred to in the section of the report relating to the South Saskatchewan river.

SECTIONS ON ST. MARY RIVER.

In the lower part of the valley of St. Mary River are exposures of the Upper Pierre shales overlain by boulder clay. Near the

mouth and within the area of the present map the base of these shales and the coal seam at the top of the underlying Belly River bed comes above the water of the stream (Figure 1). The most westerly exposure of the seam on the river occurs in SE. ¼, sec. 2, tp. 7, range 22, W. 4th mer., where the beds are brought to the surface by a low anticline. Advantage has been

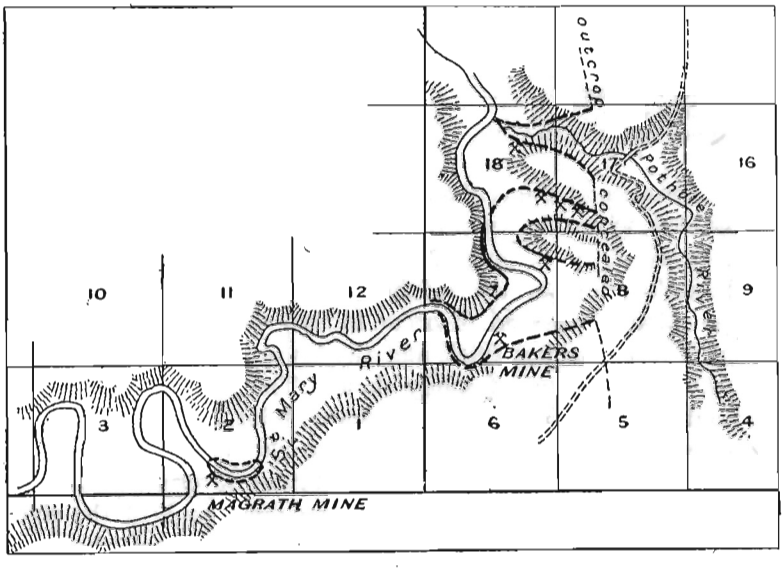

Figure 1. Outcrop of coal seam on St. Mary river.

taken of the accessibility of the coal at that point to open a mine known as the Magrath coal mine (Plate IX). In the bank of the stream at the crest of the anticline, near this mine, the section appears to be as follows, in descending order:

Section near Magrath Coal Mine.

	Feet	*Inches.*
Brown and grey shale	8	5
Sandy shale with some ironstone	0	2½
Greenish grey shale	1	11
Sandstone	0	6
Grey soft shale	6	0
Coal	0	6
Dark grey shale	8	8
Coal	0	6

	Feet	*Inches*
Clay	0	2½
Coal	0	8½
Soft shale	5	8½
Hard sandy shale	0	6
Soft grey shale	2	6
Coal	1	3½
Shaly coal	0	4
Coal	2	10
Carbonaceous shale	2	10
Shale	0	7
Coal	0	6
Shaly coal	0	11
Coal	0	6
Carbonaceous shale	0	5
Grey sandy shale	1	0
Grey sandstone, to water	1	6

Exposures of the coal seam occur also in the second section to the east, where the seam rises above water level at the western edge of sec. 7, tp. 7, range 21. It is mined on the south bank, at Baker's mine, in the southeast quarter section. The coal at the mine is reported to occur in two seams—the upper one about 3 feet 4 inches thick and the lower one 3 feet 8 inches, separated by 10 feet of sandy shale. The plane of the bed is undulating and evidently not in simple folds, but is affected by transverse waves. Small fractures are also found which affect the beds, and in the mines near Lethbridge several small faults are reported. One can be seen on the right bank of the river just above the road bridge with a displacement of about 15 feet, the upthrow being on the north side.

Near the mouth of Pothole river the coal seam dips below the level of the river, and rises to the surface at the mouth of Oldman river.

SECTIONS ON POTHOLE RIVER.

The coal-bearing zone at the top of the Belly River series is exposed at the waters edge at the mouth of Pothole river and rises in the banks for about half a mile to the east. It then disappears under the mantle of drift, and the line of its outcrop across country can only be conjectured. At the road crossing about a mile above the mouth of the river, the rocks exposed below the boulder clay consist of a broken mass of brown shale

mixed with clay and pebbles, and with some brown shale in place. Below the shale is a massive grey sandstone which is seen in the St. Mary River exposures to be very irregular in thickness and beneath the coal. Evidently the measures carrying the coal seam have been destroyed by erosion. Farther up the valley boulder clay seems to form most of the exposures. An exposure was found in sec. 20, tp. 6, range 21, which showed the boulder clay covering to be very much thinner than near St. Mary river. The beds exposed in this section belong to the top part of the Belly River series, below the coal seam. The fossils found are considered to represent freshwater species. The section in descending order follows:

Section in Sec. 20, Tp. 6, Range 21.

	Feet	*Inches.*
Boulder clay, light yellowish to grey, about	30	0
Brown and grey sandy clay shale, with plant remains	0	6
Rusty shale with *Viviparus Leai*	0	5
Coffee-coloured to blue-black, soft shale, *V. Leai* in upper part	1	10
Carbonaceous shale, with a thin streak of coal	1	5
Brown, carbonaceous shale	0	7
Soft shale, weathering light grey	0	10
Blue-grey shale	2	6
Blue-grey shale, softer than above	1	10
Sandy shale	1	3
Grey shale (3 inches sandy in middle)	3	0
Carbonaceous shale, unio shells at top	2	10
Coffee-coloured shale	0	2
Grey, soft sands, irregular in thickness, unios	0	3
Brownish-weathering grey clay	3	0
Carbonaceous shale	0	6
Dark clay, weathering light grey	1	2
Light, bluish-grey, sandy clay, with unios	1	0
Carbonaceous shales	1	0
Light-green, soft clays (yellow at top)	0	7
Carbonaceous shale	0	7
Dark, green-grey clay	17	0
Ash-coloured sandstone to waters edge	3	6
	75	9

SECTIONS ON OLDMAN RIVER.

From a point on Oldman river, about 2 miles above the mouth of the Belly river and just south of Monarch, eastward to the vicinity of Lethbridge, the underlying rocks are the marine shales of the Upper Pierre. They are very soft and easily eroded,

and probably had been planed to a low level previous to the advent of the continental glacier. The present surface does not show the depression caused by the erosion of those beds as it is filled by a great thickness of boulder clay. The tracing of the coal seam lying at the base of the Upper Pierre has shown that several minor warpings and slight faults occur in the measures; and borings to the east of the present mines have demonstrated that in that section the beds carrying the seams had been eroded previous to the deposition of the boulder clay covering. Dawson has described the exposures on the banks of this stream as follows[1]:

"The base of the Pierre shales is reached at the mouth of the St. Mary River, and the angle between the two rivers to the east, shows, in a scarped bank, the greyish and yellowish-grey shales and sandstones of the next subdivision of the Cretaceous in descending order, with the associated coal, which is considered as forming the base of the Pierre group. The section in this bank, as measured by Mr. McConnell, is as follows, the order being descending:—

	Feet	*Inches.*
1. Dark shales		
2. Ironstone	0	6
3. Brownish, shaly sandstone	2	0
4. Finely laminated dark shales	3	0
5. Oyster bed	2	6
6. *Coal*	0	10
7. Carbonaceous shales	0	9
8. Laminated dark shales	9	0
9. *Coal*	0	9
10. Carbonaceous shales	0	9
11. Laminated dark shales	10	0
12. Carbonaceous shales	1	1
13. *Coal* (3 ft. to 3 ft. 6 in.)	3	6
14. Carbonaceous shales	3	0
15. Laminated dark shales	2	0
16. Yellowish-weathering sandy shales	30	0
17. (Concealed)	5	0
18. Lignitic shales	3	0
19. Laminated dark shales	6	0
20. Brownish sandstone	3	0
21. Hard, greyish sandstone, topped with ironstone	1	2
22. Lignitic shales	5	0
23. (Concealed)	15	0
24. Soft, greyish and yellowish sandstone	25	0

[1] Geol. Surv., Can., Rept. of Prog., 1882–83–84, pt. C, pp. 69–73.

"From the mouth of the St. Mary, the (Oldman) river runs three miles eastward, and then turning sharply at right angles flows northward for about the same distance to the point known as "Coal Banks" or the "Colliery." This part of the river-valley is entirely excavated in the sub-Pierre rocks, a portion of the upper part of which has just been described, and which, from the fine sections which occur here and at other points further down the river, I have designated in a previous report as the Belly River series. The rocks of the Belly River series, though at first sight resembling those of parts of the Laramie, and particularly that portion of it which has been described as the St. Mary River subdivision, are found, on closer examination, to differ considerably in the more massive and irregular character of the beds, and their generally softer and more earthy condition. There is a marked absence of the regular and often flaggy sandstones which occur so frequently in the younger series, the sandstones of the Belly River subdivision being generally thicker, and almost always more irregularly hardened, while ironstone is much more abundant and occurs in larger masses. The scarped banks of the river in this part of its course are cut by numerous deep ravines or coulées, and frequently show bad-land weathering. In colour the beds are generally greyish, or yellowish or greenish-grey, but nearly always quite pale in tint. The ironstone nodules are often very large in the sections now described, and generally septarian, the internal fissures being filled with calcite or lined with that mineral in rhombohedral crystals. The only organic traces here met with were fragments of bones, doubtless reptilian, but so much broken as to yield very little information. In many cases the bones appear to have been rounded and water-worn before their inclusion. The beds are to all appearance flat, and the thickness exposed in the banks is about 200 feet.

"At the point known as Coal Banks (Plate VIII), the outcrop of the coal marking the base of the Pierre shales, which has run northward west of the river, again appears on the left bank. From this point to Big Island—a distance of twelve miles in a direct line—the river, though with numerous minor flexures, pursues a general north-north-eastward course and nearly follows

the out-crop of the coal-bearing horizon and base of the Pierre. The line of outcrop is, however, somewhat sinuous in outline. It crosses the river just north of Coal Banks, and making a sweep, the exact outline of which is uncertain owing to the thickness of the drift deposits which here form the whole surface of the country, re-crosses the river to the left or west bank, about six miles above Big Island. Thence, owing to the slight divergence of the line of strike and main course of the river-valley, the coal-bearing horizon may be observed gradually rising in the bank, till it is eventually cut off by the base of the drift deposits near Big Island, and is not again seen on the river. In consequence of the above described eastern sinuosity of the outcrops of the base of the Pierre, a portion of the valley extending nearly five miles northward from the coal crops near Coal Banks is entirely occupied by the Pierre shales. The light undulating character of the dips renders it impossible to estimate the exact depth below the bottom of the valley at which the coal would be found, but it is probably not over 500 feet midway between the northern and southern exposures. Besides the obvious method of working the visible outcrops of the coal seam on this part of the Belly River, it might thus also be reached with facility by shafts in the concealed interval, and the exact definition of the attitude of the beds becomes a matter of considerable importance.

"The (Oldman) valley, in that part of its course between Coal Banks and Big Island, is about 300 feet in depth, with an average width of nearly a mile, while the drift deposits underlie the surface of the plain to a depth of about 100 feet. The river-valley, therefore, cuts into the Cretaceous rocks to a depth of about 200 feet, and, with its ramifying coulées, presents remarkably fine sections of these.

"Having thus briefly described the general mode of occurrence of the coal on this part of the river, the following more detailed notes on the outcrops which occur will serve to show the actual character of the seam.

"The coal-bearing horizon embraces several associated seams, but only one of these is here of sufficient thickness to be worked. This, which is that opened at Coal Banks in "Sheran's mine," and subsequently in the North-Western Coal Com-

pany's mine, on the opposite or right bank of the river, may, for the sake of clearness, be referred to as the "main seam."

"At Sheran's mine, the coal has been extracted chiefly by quarrying along the natural outcrop, though during the summer of 1882 a small level was begun. The outcrop is situated in the front of a steep scarped bank facing the river, and the seam, which at the southern end of the bank is about thirty feet above the water, dips away below the water at the northern (Plate VIII). The following section shows the mode of occurrence, and association of the coal in the bank, but does not extend upward to the base of the drift deposits:

		Feet	*Inches.*	
	1. Finely laminated grey shale	8	0	
	2. *Coal* (shaly below)	1	6	
	3. Grey, thin-bedded shale	12	0	
	4. Ironstone	0	3	
	5. Grey shale	1	9	
	6. *Coal*	0	8	
	7. Grey shale and nodular sandstone, carbonaceous below	7	0	
Main seam	8. *Coal*	1	4	Coal 5′4″
Main seam	9. Shaly parting (often almost absent)	0	4	Coal 5′4″
Main seam	10. *Coal*	4	0	Coal 5′4″
	11. Carbonaceous shale	2	0	
	12. Grey shale	2	0	
	13. Ironstone	0	4	
	14. Greyish and brownish shale	3	0	
	15. Carbonaceous shale	3	0	
	16. Coaly shale	0	8	
	17. Grey shale	2	0	
	18. *Coal*	0	4	
	19. Carbonaceous shale (to water)	1	4	

"The dip at this place is about N. 60° W. (N. 83° W. mag., variation 22° 46′ E.), at an angle of five to eight degrees.

"On the opposite side of the river, at its next bend, the coal seam is again well shown. It is slightly undulating, and dips gradually away below the water-level at the northern end of the bank. It is near this point that the N. W. C. Company's mine has since been opened. This consists of a level run in on the strike, and is already well situated for a large output. The part of the section designated above as the main seam is here as follows:

	Feet	Inches
Coal	1	6
Shaly parting (1 to 3 inches)	0	2
Coal	3	3
Total coal	4	9

"About four inches in thickness at the base of the seam is here laminated in texture, but appears nevertheless to be of good quality. The general dip is about N. 27° W., at an angle of less than five degrees.

"From this point, for a distance of five miles down the valley, as above stated, the dark shales overlying the coal are alone seen. When the main seam again appears, on the west bank of the river, it shows the following section:—

	Feet	Inches.
Coal	1	6
Shale	0	3
Coal	4	6
Shale	1	6
Coal	2	9
Total coal	8	9

"The lowest division of the seam at this place, is apparently not represented in the sections previously described, The coal in it is somewhat laminated, but seems to be of good quality. The dip is here about N. 87° W. at an angle of five degrees.

"About three miles further north, extensive exposures of the coal are again found in the scarped bank or cliff facing the river, at a height of about one hundred feet above the water-level, the lower part of the bank being composed of the greyish and greenish-grey beds of the Belly River series. The dip is light and undulating, but on the whole westward, or away from the river. The main seam is here composed as follows:

	Feet	Inches.
Coal	2	6
Carbonaceous shale	0	7
Coal	2	2
Carbonaceous shale	1	0
Coal	1	3
Total coal	5	11

The coal here appears to be of good quality throughout.

"North of this point, the coal-bearing horizon is not again found well exposed on the river, the outcrop running to the west of the valley."

The coal seam referred to by Dawson as occurring at Coal Banks has since been extensively mined on both sides of the river, generally by shafts from the surface. The mines originally opened at the outcrops were not extensive. Sheran's mine (Plate VIII), on the west bank of the river south of the present railway bridge, is now practically abandoned, although in the past small amounts of coal have been taken out for local needs. No hoisting machinery was installed at the mine and the ascent to the level of the prairie above being about 300 feet, the haul by teams was expensive and slow. On the opposite bank the city of Lethbridge installed a pumping and filtration plant on a small flat near the river in connexion with the municipal water-works. The coal outcrop just behind the plant has been utilized for fuel and mining operations on a small scale have been carried on. North of the railway the Alberta Railway and Irrigation Company operate two mines known as the Galt mines, mainly to supply the needs of the more thickly settled areas to the east and north. No. 3 at the northern edge of the town raises the coal 340 feet by shaft. The section of the seam is, approximately: top bench 1 foot 6 inches; clay parting from 2 to 6 inches; bottom bench 2 feet 6 inches. The main workings extend under the bed of the Oldman river. No. 6 mine is situated about 2 miles farther north and reaches the seam by a shaft about 390 feet deep.

The Royal Collieries Limited operate another mine on the right bank, in section 32, almost north of the Galt mines. Under the adverse market conditions of the past year the mine was idle. The coal seam is exposed along the river side lying almost horizontally, and is mined by entry from the bank, with an outside slope to the level of the prairie. On the western or left bank the coal is mined at three places, namely: Coalhurst, Diamond, and Chinook.

Coalhurst. The Canadian Coal and Coke Company (Plate VII), Limited, has established a colliery in sec. 21, tp. 9, range 22,

W. 4th mer. The coal seam has been traced over a large area by borings, which show that it has a general westward dip but does not form a perfect plane and is affected by several small faults. At the shaft of the colliery, 128 feet of boulder clay—possibly an interglacial deposit of the age of the quartzite drift known as the Saskatchewan gravels—overlies stratified material which in turn lies on the Pierre shale of which there is 305 feet above the coal horizon. The following is the section at the shaft:

	Feet	*Inches.*
Clay	128	0
White sandy clay with layers of gravel	30	0
Very fine loose sand	14	0
Gumbo and boulders	18	0
Moist river sand	25	0
Gumbo	16	0
Gravel	26	0
Shale	305	0
Coal	0	8
Shale	2	2
Coal	0	10
Shale	20	0
Coal	5	6
	591	2

The location is in sec. 21, tp. 9, range 22, W. 4th mer., where the surface is about 3,030 feet above sea-level. The eroded surface of the shale is, therefore, about 2,778 feet above the sea and the top of the coal seam about 2,444 feet. To the north, in the southeastern part of township 10 of the same range, borings show that there is a change of almost 90 degrees in the dip of the coal seam and it is inferred that there is possibly a fault in the measures or a series of faults, as local faults occur in the Diamond and Chinook mines. Drill-holes in sections 11 and 12 of the township seem to indicate the occurrence of a hinge fault, with the westerly dip on the south side of the break steeper than on the north side. Other drillings, in tp. 11, range 22, show that, farther north, the measures dip to the west at a lower angle.

Diamond. Mining has been carried on rather extensively at the Diamond mine situated on the west bank of the river in sec. 6, tp. 10, range 21. The entry is on the outcrop of the seam in the bank, about 15 feet above the water, and the coal is hoisted up an outside incline.

Chinook. To the northwest, in sec. 12, tp. 10, range 22, is situated the Chinook mine, operating by shaft. The coal seam is about 400 feet below the surface, and the seam mined is about 5 feet in thickness.

The surface cover over the dark shales is thickest near the river and gradually thins as the river is left, showing that an old, very wide valley has been filled in. It is believed that the complete section of the marine part of the Upper Pierre has been penetrated in one of the borings in the neighbourhood which shows a thickness of about 622 feet from the so-called Foxhill sandstones down to the first small coal seam above the Belly River rocks. It shows a sandstone member near the middle of the section and sandy shales at various other levels, indicating the recurrence of a shore-line and, therefore, an unstable condition of the crust throughout this period of deposition. Many of the records of borings show sections of the lower part of this Pierre member. A record published in a previous memoir[1] showing an almost complete section of the Pierre, is here repeated.

Record of Well Drilled by the West Canadian Coal Mining Company on Sec. 35 or 36, Tp. 9, Range 23, W. 4th Mer.

Formation	Strata.	Thickness in feet.	Depth in feet.
Upper Pierre or Bearpaw.....	River silt.....	20	20
	Clay.....	12	32
	Shale.....	64	96
	Sandstone.....	19	115
	Shale.....	14	129
	Sandy shale.....	14	143
	Ironstone.....	1	144
	Shale.....	22	166
	Ironstone.....	1	167
	Shale.....	93	260
	Sandy shale.....	305	565
	Sandstone.....	27	592
	Coal.....	3	595
	Top of coal about 2,178 feet above sea-level.		
Belly River series...	Shale.....	5	600
	Sandy shale.....	15	615
	Shale and sandstone.....	43	658

Started 10 feet above water level and 50 feet below sandstone at the top of the Pierre. Ground level about 2,760.

Total thickness of upper marine part of Pierre about 615 feet.

[1] Geol. Surv., Can., Mem. 29, pp. 78–79.

Piyami coulée probably penetrates the boulder clay and the old river drift below it for a mile or more from the river and exposures of the coal seam may be expected to occur in the vicinity. A short distance to the east another coulée which runs through section 27 exposes the seam, and two mines of a primitive kind are established on the top of the bank at prairie level. They have outside slopes to the coal and the skips are hauled up by cable. The seam is reported to be 3 feet thick. This is the most easterly exposure of the seam on the river. It rises to the east and in a short distance outcrops on the old surface now covered by over 100 feet of boulder clay and river wash.

To the south the coal outcrop is concealed beneath material filling the pre-Glacial river channel, and to the east it probably does not extend far beyond the areas now being mined. In the record of a well drilled at Lethbridge in a search for water and gas, no mention is made of a coal seam so it is probably drilled to the east of the edge of the coal seam. A classification of the formations passed through in accordance with the divisions proposed in this report, gives the following results:

Record of Well Boring at Lethbridge.

Formation.	Strata.	Thickness in feet.	Depth in feet.
Surface deposits 299 feet	Sand	12	
	Gravel	40	
	Hard-pan and gravel	138	
	Hard-pan	20	
	Sand and gravel	59	
	Soapstone	25	
	Gravel	5	299
Pale beds of Belly River formation 651 feet	Shale	111	
	Sandstone	24	
	Soapstone and shale	46	
	Sandstone	30	
	Shale and sandstone	121	
	Shale	36	
	Soapstone and sandstone	10	
	Soapstone and shale	73	
	Black shale	12	
	Soapstone	15	
	Black shale	143	
	Sandstone	25	
	Limestone	15	950

Formation.	Strata.	Thickness in feet.	Depth in feet.
Foremost subdivision brackish water 350 feet	Black shale	36	
	Limestone	6	
	Black shale	158	
	Grey shale	30	
	Black shale	10	
	Sandstone	9	
	Black shale	20	
	Grey shale	9	
	Sandstone	9	
	Black shale	54	
	Sandstone	9	1,300
Pakowki shale, 215 feet	Dark shale	80	
	Lighter shale	70	
	Dark shale	60	
	Hard dark shale	5	1,515
Milk River sandstone 88 feet	Sandstone	5	
	Green shale, very hard	4	
	Soft shale	32	
	Sand rock	47	1,603 water bearing.
Colorado formation.	Greenish shale	100	
	Dark shale	142	
	Dark shale with streaks of white	95	
	Calcareous shale	125	
	Dark shale	80	
	Light grey shale	30	
	Dark shale	45	2,220

[1]"Opposite the lower end of Big Island, the drift deposits have a thickness of one hundred and sixty-five feet, and below them two coal seams of a few inches each are seen. These occupy a horizon a little below the main seam, and have a gentle dip westward or away from the river.

"At Big Island, the river resumes its eastward course, and the scarped banks continue for a distance of four and a half miles, in a direct line, to show fine exposures of the series underlying the Pierre. The banks generally show a thickness of about one hundred feet of these beds, which appear to be prac-

[1] Geol. Surv., Can., Rept. of Prog., 1882–83–84, pt. C, pp. 73–76.

tically horizontal. At the first bend to the south beyond Big Island (Plate III), a hard sandstone layer about fifty feet above the water, and in some layers charged with little greenish-grey rolled pellets of shaly clay, was observed to show also numerous casts of a large *Unio* with rounded fragments of bone. The inclusion of rounded pieces of the nearly contemporaneous clays in the sandstones is elsewhere found to be rather characteristic of the upper or pale part of the Belly River series, and taken in connection with the irregular bedding and scattered and broken character of the larger bones, would seem to show that the sheet of water in which the beds were laid down was a somewhat turbulent one. At this place a detached tooth was also collected, which Prof. Cope has been so kind as to examine, and pronounces to be that of a carnivorous Dinosaurian, which as it comes from below the Pierre shales may be a *Laelaps*, though it looks much like *Aublysodon* of the Laramie. At the next bend to the north, the scarped banks of the river are 275 feet in height. The upper one hundred feet consists of drift deposits, elsewhere described. Below there is a yellowish sandstone about twenty feet thick, irregularly hardened. This is followed to the water's edge by a series of bluish-grey and greenish-grey clays and sandy beds, which occasionally become hard sandstones. Below this point a gap of about a mile and a half occurs in the section of the river in which a few scarped banks show boulder clay only, to the water's edge.

"The next rocks seen occur at about six miles above the mouth of the Little Bow River, and are supposed to represent the summit of the lower or yellowish portion of the Belly River series. A rather massive yellowish sandstone here appears on the north bank. It forms a low cliff twenty to thirty feet high, at the edge of the water, and is overlain by greyish and yellowish sandy clays holding some selenite. Similar rocks, and apparently on almost exactly the same horizon, are seen in several places between this point and the Little Bow, the sections being, however, generally near the water's edge, and capped by a heavy covering of drift deposits. Coaly layers now begin to appear in the rocks in some places.[1]

[1] The top of the Foremost beds would thus appear to be somewhat below the top of the yellow beds as here defined by Dawson.

"From the mouth of the Little Bow to the confluence of the Oldman and Bow, rocks similar in general character to those last mentioned, and probably not far from the same horizon, continue to appear in numerous exposures. At seven and a half miles below the Little Bow, a well defined coal-seam, about eighteen inches in thickness, was first observed. It is here at a height of about twenty feet above the river. The sections not being absolutely continuous, and the character of the beds somewhat variable, it was impossible to arrive at certainty as to the equivalency of the beds, but it is probable that the coal-seam just mentioned is that which characterizes the banks nearly to the mouth of the river. It appears at a height above the river-level which varies in accordance with the light dips by which the beds are affected. The rocks associated with the coal are yellowish, brownish and grey, soft sandstones and shales with occasional layers of ironstone. They show numerous alternations of colour, and produce a generally banded appearance in the banks when viewed from a distance. Near the coal seam, and both above and below it, are several carbonaceous shales, which, however, are not very constant. The greatest thickness of beds of the character just described, seen below the coal-seam, was about one hundred feet. Some beds on this part of the river yield fresh and brackish-water molluscs in great abundance, the following being among the most characteristic forms:—*Corbula subtrigonalis*, *Corbula perundata*, *Corbicula Nebrascensis*? *Velatella baptista*? *Cassiopella* n. sp. *Campeloma* like *C. producta;* also species of the genera *Goniobasis*, *Viviparus*, *Physa*, *Unio* and *Sphaerium*, as yet undetermined. From the close resemblance, lithologically and in fauna and accompaniments, of the beds in the vicinity of the coal in these sections on the Lower Belly, with those seen on the Milk River north of the East Butte (p. 44 c.), and again in 1874 nearer to the Butte, I am inclined to suppose the almost absolute identity in horizon of the strata in these localities.

"At a mile and three-quarters below the point above referred to at which the coal was first recognized as a well-defined seam, it is found at a height of fifty feet above the river, still maintaining a thickness of about eighteen inches. Its greater

height above the river is owing to a light northerly dip by which the measures are here affected, and in following the river in its next great bend to the south, at a further distance of about two miles, the coal is about one hundred feet up in the bank. Two miles further on, it is again seen on the opposite or right bank at a similar elevation.

"From this point, the river turns abruptly north, making a great loop which may be called Drift-wood bend. Following this reach of the river to the north, in about a mile and three-quarters, the coal-seam comes down to the water's edge. It is here associated with yellowish sandstone, and has a thickness of three feet three inches. The seam here appears to be of good quality throughout, and this is the most favorable locality observed for working it. The coal contains 9·18 of hygroscopic water only, and it is a very fair fuel.

"The coal, for several miles to the north, undulates at low angles from the water's edge to about twenty feet above it. It varies in thickness from the maximum just given to about eighteen inches, and is again seen with the latter dimensions at the north-western point of Driftwood bend. This coal was not again observed in anything like workable thickness on the Old-man, and, indeed, from this point to near the mouth of the river, the sections of the Cretaceous rocks are comparatively inconsiderable, the banks being more rounded, and the greater part of the depth of the valley being excavated in drift deposits, which here show interesting peculiarities elsewhere described."

The coal horizon described in the above extracts has been further explored and several small mines have been opened on the outcrop of a thicker seam than that observed by Dawson. Where it is mined at Elcan, Taber, and near Woodpecker island, the seam seems to be over 3 feet in thickness and appears to be near the bottom of a series of sandstones containing fresh-water shells; where it is exposed in a road cutting on the highway crossing the river north from Taber it is 3 feet 6 inches in thickness, of which probably 3 feet is good coal. About 90 feet of sombre grey shales containing few fossils, underlie the coal seam in the road cuttings; and near the water's edge carbonaceous layers occur holding a few fragments of unio shells.

Coal for local use is furnished by mines along the river banks and a colliery has been established on the railway line at Taber from which shipment is made to outside points. The seam is about 90 feet below the surface, and has the following section: top coal 7 inches; shale parting 3 inches; bottom coal 41 inches.

The exposure mentioned by Dawson as occurring north of the bend is probably that in sec. 30, tp. 10, range 16, W. 4th mer., where there is a small mine at the top of the bank. Several of these local mines are worked only in the winter, the demand for coal during the summer being very light.

Three miles above the confluence of Oldman and Bow rivers exposures of the underlying Cretaceous are again visible. The following measured section is from Dawson's report.[1]

	Feet	Inches
1. Banded sandy shales, some layers carbonaceous	15	0
2. Nodular, yellowish sandstone (6 to 8 feet)	8	0
3. Soft, laminated sandstone	4	0
4. Greyish, nodular sandstone	4	0
5. Sandy shales, in places slightly carbonaceous. Some ironstone nodules (Reptilian bones and teeth and scales of Ganoids about the middle)	12	0
6. Nodular ironstone	0	6
7. Grey, sandy clay	3	0
8. Carbonaceous shale, or impure lignite	0	10
9. Grey, sandy shale	8	0
10. Blackish carbonaceous layer, or very impure lignite	1	6
11. Alternating greyish, yellowish, and purplish sandy clays, with occasional, soft, or nodularly-hardened sandstones to base of section. Bank presenting a general banded appearance, though beds poorly exposed in detail, about	90	0
	146	10

These beds do not occur in continuous exposures along the valley but it seems probable that they belong to the brackish-water portion of the formation below the Taber coal horizon. They occur in almost continuous exposures along the river from the junction of the Bow and Oldman rivers eastward. The following general section of the Upper Cretaceous is from a well section at Taber. The division of the beds into formations in the section is based largely on their correlation with exposures at other points and may have to be revised.

[1] Geol. Surv., Can., Rept. of Prog., 1882–83–84, pt. C, p. 76.

Record of Well Boring at Taber.

Formation.	Strata.	Thickness Ft.	Thickness In.	Depth. Ft.	Depth. In.
Surface deposits 51 feet.....	Sandy clay and small boulders.....	41			
	Gravel and small boulders...	10			
Pale beds 44 feet..	Shale and sandstone.....	20			
	Shale and bands of limestone	24		95	
Foremost subdivision 301 ft. 10 in.....	Taber coal seam.....				
	Dark shale.....	9			
	Sandstone.....	2			
	Shale.....	3			
	Shaly sandstone.....	2			
	Shale.....	14			
	Sandstone.....	5			
	Mixed limestone and sandstone.....	5			
	Dark shale.....	10			
	Sandstone.....	4			
	Shale.....	11			
	Mixed sandstone and shale .	24			
	Shale.....	6			
	Sandstone.....	5			
	Shale.....	19			
	Sandstone.....	57			
	Shale.....	2			
	Dark shale.....	3			
	Sandy shale.....	32			
	Mixed shale and sandstone .	12			
	Black shale.....	10			
	Mixed shale and sandstone .	7			
	Shale.....	36	6		
	Shaly coal?.....	0	6		
	Shale.....	2	4		
	Coal.....	0	8		
	Dark shale.....	1	0		
	Sandstone and shale.....	17	0		
	Mixed black slate and coal ..	1	10	396	10
Pakowki shales 211 feet.....	Shale.....	8	2		
	Limestone.....	0	6		
	Sandstone.....	5	6		
	Shale.....	180	0		
	Sandy shale.....	11	0		
	Conglomerate.....	2	0		
	Sandy shale.....	4	0	608	

Formation.	Strata.	Thickness Ft.	In.	Depth. Ft.	In.
Milk River sandstones 202 feet..	Sandstone	19	0		
	Coal	0	2		
	Fireclay	0	1		
	Dark shale	7	9		
	Sandstone	7	0		
	Shale	4	0		
	Sandy shale	12	0		
	Sandstone	12	0	water 670	
	Fireclay	3	0		
	Coal	0	3		
	Sandstone	70	0		
	Light shale	0	6		
	Sandstone	65	0	810	
Benton shale 1,390 feet	Mixed sandstone and shale	28			
	Shale	67			
	Shale with sandstone partings	25			
	Probably shale, no record	530			
	Black shale	460			
	Grey sandy beds, some black shales	40			
	Black shales	120			
	White sandstone	10			
	Sandy shales	50			
	Fine-grained white limestone	10			
	Black shale	50		2,200	
	Sandstone	20		2,220	
	Grey conglomerate	20			
Dakota ?	White sandstone with some dark partings	110		2,350	

SECTIONS ON SOUTH SASKATCHEWAN RIVER.

The valley of the Saskatchewan from Bow island (Plates I and IV) to the mouth of Sevenpersons coulée appears to be much newer than the valley of the tributaries above. The scarped banks are cut through soft shales for the most part and under ordinary weathering processes would have broken down in a short time and modified the valley section. That they have not done so is a proof of the recency of the excavation. The rocks exposed

are the sombre clays and sands that are associated with the coal-bearing beds of the Foremost or yellow portion of the Belly River formation, together with shales that probably belong to the top of the Pakowki shales. The top of the series is marked by a coal horizon and a mineable seam has been found underlying the country to the south and east and near Taber to the west.

The upper parts of the escarpments on the river are somewhat yellow in colour and contain several sandy layers with streaks of coal, beneath which is a band of dark clay. About halfway down the bank there is an irregular shelf caused by a second sandy series of beds that are perhaps slightly harder than the shales. The lower shales, that form the escarpments near the river, show both lighter coloured and carbonaceous layers. These beds, excepting certain marine members at the base, probably represent the brackish-water series underlying the freshwater beds and are correlated with those on Milk river east of Pakowki coulée. Dawson describes this part of the river as follows[1]:

"From the confluence of the Bow and Belly to the mouth of Cherry Coulée—eleven miles — the South Saskatchewan flows in a narrow valley between high scarped banks. The rocks exposed are those illustrated in the last section, and continue flat or undulating at very low angles. Vegetation is almost absent from many of the slopes, and the sombre tints of the clays and sandstones give the valley a gloomy and forbidding appearance. Some of the beds yield fossils in abundance embracing *Ostrea glabra*, *Anomia micronema*, *Corbula perundata*, *Velatella baptista*? *Melania insculpta*, *Campeloma multilineata*, *Viviparus*, *Physa Copei* var, *&c.*"

The collections of 1881–84 were identified by J. F. Whiteaves and recorded in Contributions to Canadian Palæontology, vol. I. The forms collected from this vicinity as given in the above publications include *Rhytophorus glaber*, *Planorbis pauci-volvis*, *Physa copei*, *Ostrea subtrigonalis*, *Velatella baptista*, and *Anomia micronema*, collected at the mouth of Bow river and the

[1] Geol. Surv., Can., Rept. of Prog., 1882–83–84, pt. C.

following from a point about a mile below the forks: *Rhytophorus glaber, Ostrea glabra, Anodonta parallela, Unio deweyanus, U. supragibbosus, U. senectus, Corbula subtrigonalis, Campeloma producta, Velatella baptista, Goniobasis subtortuosa*, and *Viviparus conradi.* A similar fauna was collected near Cherry coulée from beds about 35 feet above the river and includes *Corbula subtrigonalis, Planorbis paucivolvis, Physa copei, Thaumastus limnæiformis, Velatella baptista, Melania insculpta, Viviparus conradi*, and *Campeloma multilineata.*

The beds at the top near the coal seams may on closer examination show more freshwater species. The whole series is evidently transitional.

After the discovery of a heavy flow of gas in the well drilled near the South Saskatchewan river on sec. 15, tp. 11, range 11, W. 4th mer., commonly known as "Old Glory," the town of Bow Island obtained a lease of a small area at the top of the bank and had a well bored. This gave a sufficient supply for the town's need and was piped thereto a distance of $3\frac{1}{2}$ miles. The drilling company fortunately kept samples of the strata passed through. From these samples it was possible to determine the thickness of the Pakowki shales and the Milk River sandstones. The well was started in the Foremost beds, passed through the Pakowki shales and the Milk River sandstones, and finished near the base of the Benton shale. The top of the Foremost beds was not shown in the records and the bottom of the Benton shales, although probably reached, is not definitely placed. The section in condensed form is as follows:

Section at Bow Island Well.

Depth from surface	Character of beds	Formation
0 to 55	Surface deposits	Reassorted boulder clay
55 to 270	No samples	Probably pre-Glacial deposits
270 to 275	Gravel	
275 to 300	Grey shale, brown sandstone, ironstone	Foremost beds
300 to 310	Shale with coal seams	
310 to 370	Sandstones and clay shales	
370 to 400	Sandy brown shales	
400 to 630	Brown shale	Pakowki shales
630 to 740	Grey sandy shale, probably sandstones with shale partings	Milk River sandstones
740 to 1,950	Blue-black and brownish-black shales	Benton shale
1,950 to 1,955	Grey shale, gritty	
1,955 to 2,147	No samples	
2,147	Sandstone, gas horizon	Probably Dakota.

Directly north of Bow island in sec. 36, tp. 10, range 11, W. 4th mer., the rocks near prairie level are the yellow portion of the Belly River series or the top of the Foremost beds. A short distance below the surface a light yellow sandstone forms a fair roof for a 3-foot 5-inch coal seam. By barometer elevation the coal is 200 feet lower than Bow Island station or about 2,400 feet above sea-level. Below the coal, sombre clays and dark sandstones are found that are very similar to those in Verdigris coulée. Small streaks of carbonaceous matter occur about 100 feet below the coal seam and above it there is a shell horizon as in Chin coulée. A coal seam is reported to occur at the water's edge but it was not seen. Fossils collected at about 75 feet below the upper coal seam, seem to be *Anomia obliqua*, *Anodonta parallela*, *Lunatia* (?) *obliqua*, *Pteria fibrosa*, and *Ostrea glabra*. Near the water's edge or below the shell bed and the lower lignite, the shales are probably the representatives of the Pa-

kowki shale, though this is not certain. The absence of carbonaceous matter and the presence of marine shells distinguish this division from the Foremost beds.

The coal seam near the top of the bank is mined at several places farther east. In secs. 21 and 22, tp. 12, range 10, two small mines are worked intermittently: one by Jules Lavine, and the other, called the Maple Leaf mine, by R. A. Salisbury (Plate X). The coal is hoisted by outside slope from about 100 feet below prairie level. The valley at this point is at least 300 feet deep and the rock section exposed in the banks probably includes marine shale similar to the Pakowki exposures. The river section measured by barometer down the steeply cut ravine at the mine is as follows, in general terms:

Section in Secs. 21 and 22, Tp. 12, Range 10, on South Saskatchewan River.

Strata.	Thickness Ft.	Thickness In.	Elevation Feet.
Surface level at mine			2,568
Boulder clay	90	10	
Yellow sandstone	10	10	
Coal	4		2,468
Grey sand with yellow layers	95	2	
Yellow sandstone with fossils	5	0	2,368
Grey sand	15	0	
Oyster bed	2	0	2,348
Dark grey clays	58	0	
Streak of lignite			
Dark clay	10	0	
Level of river			2,278
	290	0	

The principal fossils collected from the oyster bed, 70 feet above the level of the river, were *Ostrea glabra* and *O. subtrigonalis*. In the yellow sandstone 20 feet above the oyster bed a greater variety was found including forms resembling *Viviparus leai*, *Lunatia*, *Rhytophorus glaber*, *Mactra alta*, *Corbicula subtrigonalis*, *Thaumastis limnæiformis*, *Anomia micronema*, *Corbula occidentalis*, and *Velatella baptista*.

Directly north of Winnifred in sec. 32, tp. 12, range 9, W. 4th mer., where the valley seems to be narrower and the top of the

bank about 70 feet higher than at the Maple Leaf mine, the section is similar in a general way except that the coal zone is thicker, streaks of lignite appearing throughout 100 feet of beds overlying the sombre shales. The top of the bank is about 400 feet above the river and by barometric readings about 2,640 feet above tide. The top of the coal zone is probably at the same horizon as the coal at the Maple Leaf mine about 8 miles up the river, so that the beds dip east at the same rate that the river channel descends. The top of the section is not well exposed; it probably consists of boulder clay overlying the yellow beds as in the last section. The coal zone contains probably only two seams of economic importance. At the top, at an elevation of 2,440 feet, the lignite is quite black but the seam is divided by a parting of clay. At the bottom, at an elevation of 2,330 feet, a coal seam has been burnt out. This was probably the best seam of the series. Below this 100 feet of sombre coloured clays holding brackish-water fossils extend to the water's edge. The occurrence of a shark's tooth in these beds shows that there were probably occasional incursions of the sea during the period of deposition of the beds. A coal seam at the water's edge seems to mark the base of the brackish-water series, as it does in Verdigris coulée east of Warner. The following forms were collected from the sombre beds: *Ostrea*, *Callista deweyi*?, *Physa copei*, *Corbula perangulata*, and a small shark's tooth.

Continuing Dawson's description[1]:

"The river from this point to the mouth of Swift Current Creek was examined, and a track-survey made of it by McConnell in the autumn of 1882. Only the upper part of this traverse is, however, included in the area of the present report.

"For seventeen miles below Cherry Coulée, beds resembling those last described, and at about the same horizon, continue to appear in numerous sections. At the end of this reach, the beds include very little hard sandstone, and the brownish, greyish and yellowish beds alternate with carbonaceous clays, which become impure lignite coal in some instances. At this place the following section was noted:—

[1] Ibid, pp. 76–78.

	Feet	Inches.
Greyish sands		
Lignite-coal, shaly	3	0
Black shales	5	0
Lignite-coal, shaly	5	0
Yellowish argillaceous sands		

"Below this point, for some miles, the river becomes cañon-like. The brownish earthy-looking beds which above have been exposed in the river banks for many miles, now occupy only one hundred to one hundred and twenty-five feet of the lower part of the scarps, the upper half being composed of light coloured greyish beds, between which and the former the carbonaceous zone intervenes. This arrangement is precisely that described on the Bow and the horizon is undoubtedly the same.

"At a point twenty-two miles below Cherry Coulée, two seams of lignite-coal are exposed, the largest being about four feet in thickness. Three miles further down the following section was measured:—

	Feet	Inches.
Yellowish sandstone		
Shales	10	0
Lignite-coal (fair quality)	4	6
Shales	1	3
Sandstone	1	0
Lignite-coal (fair quality)	4	0
Shales	6	0
	26	9

"The higher coal-seam is one hundred and twenty-five feet above the water-level. Still higher in the section two more coal-seams occur, one of which is over four feet thick. It may be added that the coal-bearing zone above described continues in the river banks, and is that which yields the lignite-coal of the vicinity of Medicine Hat, which, since the date of the examination here referred to, has been opened and is already somewhat extensively worked. A slope has been constructed from the prairie level to the horizon of the seam, and levels run in on the coal. The screens and houses of the mine are situated at the head of the slope, and a branch line has been constructed to connect this point with the Canadian Pacific Railway. The seam worked here varies from four feet six inches to five feet four inches in

thickness. It contains a clay parting, which in some places is as much as three inches thick. Preliminary openings have been made elsewhere along this part of the river, some of which show a seam somewhat thicker than the above. The quantity of fuel here available is practically inexhaustible, and the quality, though inferior to that of Coal Banks, is such as to fit it for all ordinary purposes."

The mines referred to above were situated at Stair and were probably closed after the railway was extended to Lethbridge. The same seams were afterwards mined at Redcliff for domestic use and for the burning of brick.

A section of the coal measures at the old mine measured by J. P. Lawson and published in diagrammatic form in the 1882–84 report is tabulated below.[1]

Section at Coal Mine (Stair).

Strata.	Thickness Ft.	Thickness In.	Depth Ft.	Depth In.
Boulder clay	43	0	43	0
Light sandy shales and clays	49	0	92	0
Dark clay shales	66	0	115	0
Impure coal....0 ft. 8 in.... parting....2 ft. 8 in.... Impure coal....0 ft. 6 in.... parting....2 ft. 8 in.... Impure coal....0 ft. 6 in....	7	0	122	0
Hard sandy clay	17	0	139	0
Coal	0	8		
Hard sandy clay (ironstones)	9	4	149	0
Coal	4	8		
Underclay	3	6		
Sandy clay and clay shale	12	10	170	0
Clay shale with oyster bed at top	16	0	186	0
Coal	0	6		
Shale	3	6	190	0
Coal	5	3		
Clay	3	0		
Coal	2	6	200	9
Sand and clay	24	9		
Coal	0	6	226	0
Sand and clay	17	0	243	0
Dark sandy clay	14	0	257	0
Light sandy clay	5	0	262	0

Height of general prairie level above low water in Saskatchewan. 277 feet
Height of bank at old coal mine 262 feet

[1] Ibid, p. 78.

The section in the river bank at Redcliff about 6 miles west of Medicine Hat shows the gradual disappearance of sandy members from the formation. The coal horizon is near the top of the sombre clays and is overlain by yellowish beds less sandy than in the section to the west. The measurements and description are from a paper by E. H. Sellhorn in "The Canadian Clay Worker" for July, 1914.

Section at Redcliff.

	Thickness in feet.
Sandy loam	2
Clayey sand subsoil	8
Clean sand	15
Grey sand with boulders	10
Blue shale (pressed brick clay)	10
Dark shale	6
Whitish-grey sand	6
Ironstone nodules	2
Yellowish grey sandy clay	20
Dark shale	14
Ironstone nodules	1
Dark shale	6
Buff sandy shale	5
Coal	5
Buff sandy shale	9
Shells (*Ostrea glabra, O. subtrigonalis*)	1
Dark blue shale	11
Coal (worked by Redcliff Brick and Coal Company)	5
Dark clayey shale	2
Coal	3
Bluish grey sand, concealed beds to river probably	45
	186

In the same paper the statement is made that the gas wells bored on the top of the bank are 1,234 feet deep. The gas sands, according to this measurement, are very nearly on the same level as at Medicine Hat. The coal seams in the section may not be persistent or of economic value at Medicine Hat; they have not been exploited, owing to their concealment in the banks by drift material and the cheapness of gas as fuel. The sections obtained in the gas wells show a general thickening of the clay beds at the expense of the sandy formations farther west. It is assumed that the beds underlying the town belong in point of age to the brackish-water formation exposed at Foremost and that beneath are the marine clays that are exposed in Pakowki coulée developed

in much greater thickness and overlying the Milk River sandstone which is represented by brown shales with a thin bed of sandstones at the base. The locations and sections of the wells are given graphically in Figures 2 and 3.

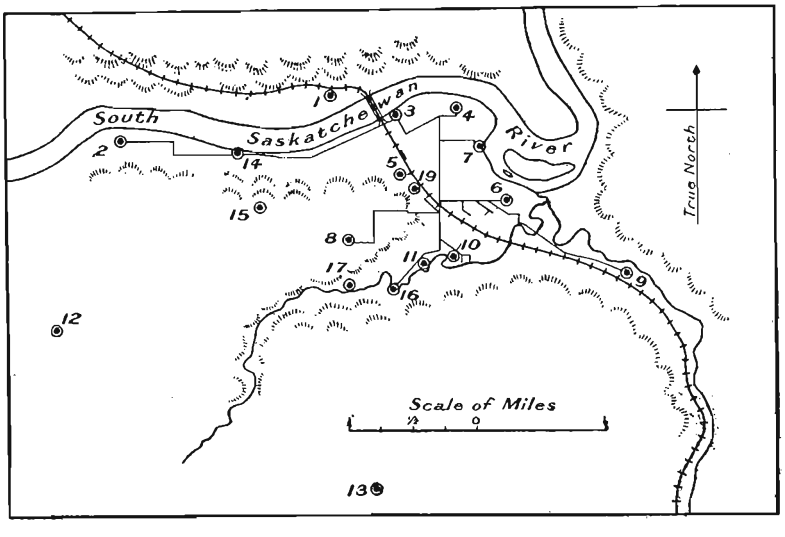

Figure 2. Positions of gas wells at Medicine Hat.

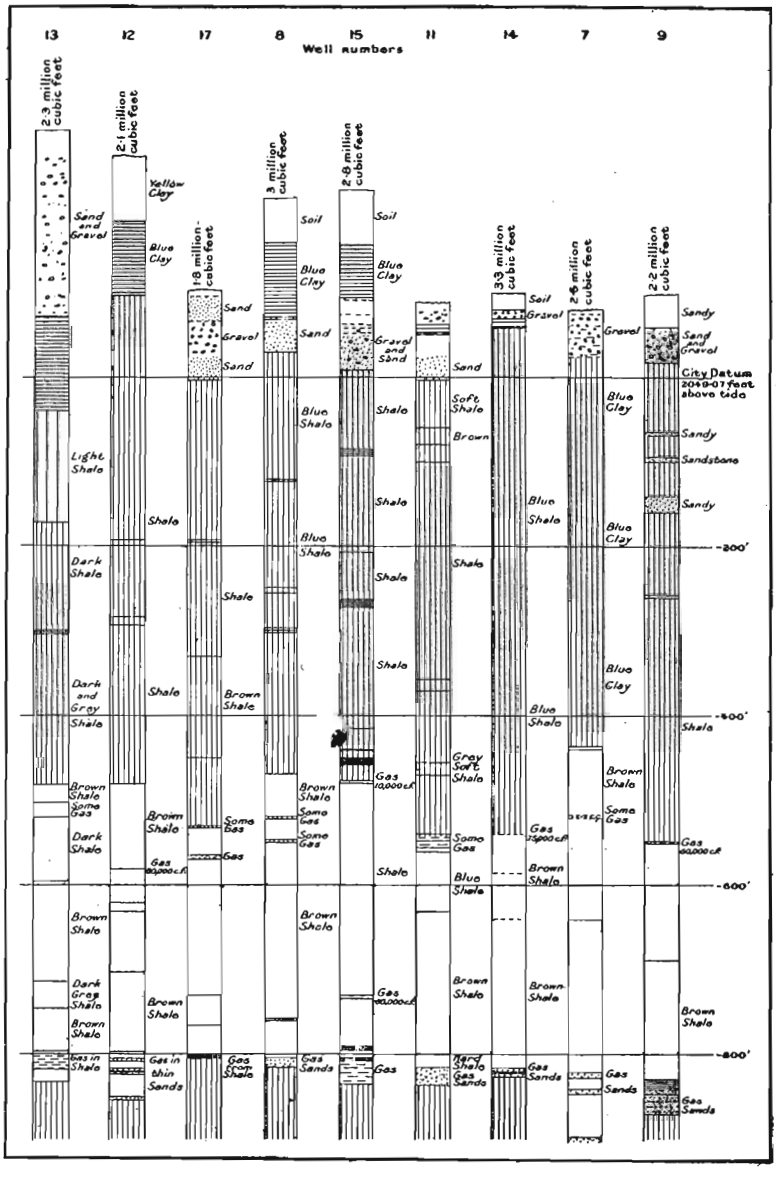

Figure 3. Sections of gas wells at Medicine Hat.

CHAPTER V.

ECONOMIC GEOLOGY.

COAL.

Detailed descriptions of most of the coal occurrences have been given in the descriptive part of the report. The horizons in which the coal deposits occur are, in descending order, as follows:

(1) The summit of the Belly River series.
(2) The upper and lower parts of Foremost beds.
(3) The upper members of Milk River sandstones.

SUMMIT OF BELLY RIVER SERIES OR LETHBRIDGE COAL.

The Lethbridge coal, the principal coal horizon of the western part of these plains, has been fully described in the report of 1884. A few sections are given in the general description in the present report, and some notes on the mines. The following sections at different points along the outcrop are repeated for purposes of comparison.

Middle Coulée.

	Feet	Inches
Coal at headwaters about	1	6

Magrath Mine (St. Mary River).

Shale	5	0
Coal	0	3
Blackish shale	6	0
Coal	0	6
Carbonaceous shale	0	4
Coal	0	8
Carbonaceous shale	0	6
Ironstone shale	0	6
Blackish shale	3	0
Coal	1	0
Carbonaceous shale	1	6
Coal	2	0
Grey shale	4	0
Coal	1	4
Grey shale	4	0

Bakers Mine (St. Mary River).

	Feet	Inches.
Coal	3	4
Shale	10	1
Coal	3	8
Shale		

Mouth of St. Mary River.

Oyster bed	2	6
Coal	0	10
Carbonaceous shale	0	9
Dark shale	9	0
Coal	0	9
Carbonaceous shale	0	9
Dark shale	10	0
Carbonaceous	1	1
Coal	3	6
Shale		

Sherans Mine West End of Bridge, Lethbridge. (Old section.)

Coal	1	6
Grey shale	12	0
Ironstone	0	3
Grey shale	1	9
Coal	0	8
Shale and sandstone	7	0
Coal	1	4
Shale	0	4
Coal	4	0
Carbonaceous shale	2	0
Grey shale	2	0
Ironstone	0	4
Shale	3	0
Carbonaceous shale	3	8
Grey shale	2	0
Coal	0	4

Lethbridge Collieries.

Coal	0	8
Shale	2	2
Coal	0	10
Shale	20	0
Coal	5	6

Oldman River (near Diamond Collieries.)

Coal	1	6
Shale	0	3
Coal	4	6
Shale	1	6
Coal	2	9

Near Chinook Collieries (Boring Record).	*Feet*	*Inches.*
Coal	0	5
Black shale	6	7
Dark shale	10	0
Sandy shale	3	5
Coal	0	7
Black shale	3	2
Coal	1	0
Sandy shale	0	7
Coal	4	4
Brown shale	0	4
Coal	0	10

East Side Oldman River (Coal Banks).		
Coal	1	6
Grey shale	14	0
Coal	0	8
Grey shale	7	0
Coal	1	4
Shaly parting	0	4
Coal	4	0

Galt Mine No. 3.		
Coal	1	6
Parting 2 inches to	0	6
Coal	2	6

At the same horizon on Bow river the seam has the following section:

Coal	1	6
Shaly sandstone	13	0
Carbonaceous shale	2	3
Coal	4	6
Shale and sandy clay	7	0
Coal	1	0
Carbonaceous shale	1	0
Coal	0	8

This coal has been mined in the vicinity of Lethbridge since 1882 and has been in demand as a domestic fuel although the opening of other mines nearer the centres of population has seriously interfered with the output. New mines have been established on the west bank of the river since the official tests of coals were made for this locality, and there is a possibility that higher grade coals than are indicated by these tests may be found, especially in localities where the covering measures are thicker. The coal from the Galt mine was tested at McGill university[1] and the following is a summary of the results.

[1] Pub. No. 83, Mines Branch, Dept. of Mines, Ottawa.

Analysis of Dry Coal from Galt Mine.

Volatile combustible matter	37·5%
Fixed carbon	51·5
Ash	11·0
Calorific value of dry coal	11·710 B. T. U.
Calorific value of coal as fired	10·470 B. T. U.
Evaporation per lb. as fired	5·92 lbs.
Gas producer test, lbs. per B.H.P. per hr.	2·13 lbs.

Moisture; in mine 8·4%, air dried 7·9%.

FOREMOST BEDS.

The coals of this horizon are widely distributed throughout the district and are found practically wherever the rocks are exposed on the side of the old drainage channels, and on the plateau north of Milk river. Coal of good quality occurs in the vicinity of Taber where it is extensively mined. In the newer settlements to the south and east where the seams are near the surface many small mines are operated to supply the local demand for fuel.

In the western part of Milk River ridge the formation passes below the surface and is exposed in the Milk River valley and at the end of the ridge, in the upper part of Verdigris coulée, and on the higher land to the north of Milk river. The coal was first found on Milk river west of the MacLeod-Benton trail and good exposures of the seams may be seen in the cuttings for an old irrigation canal. Other seams occur in the yellowish portion at the top, also near the base of the brackish-water series.

The seam mined near Milk River station is apparently split up by clay bands. The section at Oborns mine is reported to be:

	Feet	*Inches.*
Coal	1	0
Bone	1	3
Coal	1	0
Clay	0	3
Coal	0	5
Clay	0	3
Coal	0	5
	4	7
Coal	2	10

In Verdigris coulée east of Warner a seam near the bottom of the coulée is mined. The seam is probably hard to mine on

account of the poor roof and small coal content. The following approximate section was measured at the entry:

	Feet	*Inches.*
Coal soft lignite	1	0
Shale	2	0
Coal fair lignite	1	0
Dull lignite high in ash	1	0
	5	0

Few exposures of the measures are found for several miles eastward. On the plateau in range 12, there are several outcrops and on the road running between secs. 15 and 16, tp. 3, there has been some mining done by stripping the surface of boulder clay, and quarrying the exposed coal. The seam is reported to be 30 to 34 inches in thickness and there is reported to be a similar seam beneath that is not yet mined. The seam mined at Bembridge (Plate XI) is reported as 27 inches thick and farther east at Hughson's mine in sec. 10, tp. 3, range 11, W. 4th mer., it shows: coal 1 foot 5 inches; clay 1 foot; coal 1 foot 7 inches.

In the valley of Milk river east of Pend-d'Oreille, Royal North West Mounted Police outpost, the coal of the upper part of the series is mined in several places by the settlers. This seam is variable in thickness but is between 3 and 4 feet, and is overlain by an oyster bed.

On Etzikom coulée, coal is reported to occur in range 15, and around Crow Indian lake. In Chin coulée 3 miles east of Foremost, a seam about 3 feet thick occurs in the yellow beds at the top of the exposures. The seam is overlaid by an oyster bed as it is on Milk river. In the valley north of Foremost a coal seam is mined at the foot of the slope. About 2 miles west, at Roberts mine, the seam is from 20 to 24 inches in thickness and is probably 10 feet below the small seam found farther east. The section in the valley is best given by the well section at Foremost. In this, there is given streaks of coal through about 50 feet of beds. The coal that shows in the valley belongs to beds between 179 and 196 feet below the top.

The upper seam is mined on the east bank of Fortymile coulée east of the Bow Island-Foremost highway, where it is reported to consist of two 14 inch seams separated by a clay

parting of 8 inches. It is mined under a cover of 40 feet in secs. 14 and 15, tp. 9, range 11, W. 4th mer., where it is 2 feet 6 inches in thickness including about 4 inches of shale, and is probably the same seam mined farther east, in Sevenpersons coulée (Plate XII).

South of Grassy lake the seam carries about 2 feet 6 inches of coal and is mined at several points at some of which there is possibly a small underlying seam, of little account except where the parting between it and the one above is thin. In a mine on sec. 23, tp. 9, range 13, W. 4th mer., the coal is 2 feet 6 inches thick, and is separated from the lower coal by a varying amount of bone and clay (1 foot thick at the entry, and about 2 feet at the south end of the mine. The underlying seam is 1 foot 6 inches thick). The coal on section 25 in the same township is reported to be about 3 inches thicker.

In the Oldman-Saskatchewan valley the Foremost beds are prominent. A low anticline brings the top of this division to the surface in the valley to the west of Driftwood bend, but, owing to a northward dip, they probably pass below the river valley and emerge again to the east. The coal horizon described by Dawson[1] does not exceed 3 feet 3 inches at the outcrops. Since the earlier report was written, several mines have been opened on the seam, now known as the Taber seam, and in many of them a greater thickness of coal than that indicated above is found. In the Taber mine the coal is said to have a thickness of 48 inches including about 3 inches of clay near the roof. Directly north of Bow Island station the coal of this horizon is 3 feet 5 inches thick and at the Maple Leaf mine in sec. 21, tp. 12, range 10, is 4 feet. Coals of the same horizon occur at Redcliff and in the valley below Medicine Hat. They have not the high fuel value that the coals of the western part of the plains possess and are of lower value than those mined at Lethbridge. The Taber coals, probably the best of this formation, have been tested and the following summary will show their general character:[2]

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[1] Geol. Surv., Can., Rept. of Prog. 1882-83-84, pt. C., p. 75.

[2] Pub. No. 83, Mines Branch, Dept. of Mines.

Analysis of Dry Taber Coal.

Volatile combustible matter	36·0%
Fixed carbon	49·9
Ash	14·1
	100

Calorific value of dry coal	11·040 B. T. U.
Calorific value as used	7·520 B. T. U.
Evaporation per lb. as fired	3·91 lbs.
Gas producer test, lbs. per B.H.P. per hr.	2·42 lbs.

Moisture; in mine 13%, air dried 11·7%.

MILK RIVER SANDSTONES.

At Red creek and to the west of Coutts streaks of lignite are found in the upper part of the Milk River sandstone. The exposures near Coutts show only about 4 inches of coal although there are possibly other seams that may be of value, as there are in the Missouri section at the top of the Eagle sandstone. In the log of well No. 3, United Oils, Etzikom coulée, two seams, one 5 and the other 6 feet thick, are recorded; but, since the well was drilled with a churn drill, the record must be taken to indicate merely the presence of coal in these rocks and not the thickness of the seams.

NATURAL GAS.

The Bow Island area may be taken as the centre of the natural gas region of southern Alberta. It lies on the crown of a very flat anticline, pitching to the north and probably flattening out in that direction and showing a high arch to the south on Milk river. The wells already drilled on the anticline are about sixteen in number and about 2,000 feet in average depth. The gas is obtained at about 800 pounds pressure and comes probably from about the top of the Dakota formation. The possible production of the field is estimated to be about 50,000,000 cubic feet per day. Neighbouring towns are supplied with the gas and a pipe line has been laid to Calgary, 160 miles away.

The higher part of the anticline, that is, the portion toward the south, has been tested by boring in Etzikom coulée and good results have been secured. A flow of 10,000,000 cubic feet has been obtained from about 1,345 feet below the bottom of the

Belly River series, or 2,200 feet below the rocks that form the surface at Bow Island. The gas horizon is the same as that tapped at Bow Island and is shown by the well records to lie about 400 feet above the parti-coloured sands and shales which are believed to represent the top of the Dakota. Gas has also been found in the Grand Trunk Pacific Development Company's well near the International Boundary. The gas obtained from this horizon so far as known is nearly all methane (CH_4), with less than 2 per cent of other gases, mostly nitrogen and oxygen.

In the region in the neighbourhood of Medicine Hat the sandstone member at the base of the Belly River series seems to be filled with gas; while farther west there is evidence in the Bow Island wells that there is water with the gas in this member. In the Taber well, water was encountered and farther south, on Etzikom coulée, and in the well at Foremost, water alone was found. The saturation of these sandstones with water taken in at their outcrop in Milk River valley has helped to retain the gas in the Medicine Hat field.

OIL.

Prospecting for oil in this region has been expensive and difficult. It has so far served to show that oil does not occur in commercial quantities in the rocks above the Dakota. Below that horizon there seems to be no proof of the presence of oil although it has been reported that heavy oil apparently too thick to flow freely had been found in the well at the International Boundary, also that heavy oil was found in the well in Etzikom coulée in Dakota sandstone along with or just beneath a heavy flow of salt water.

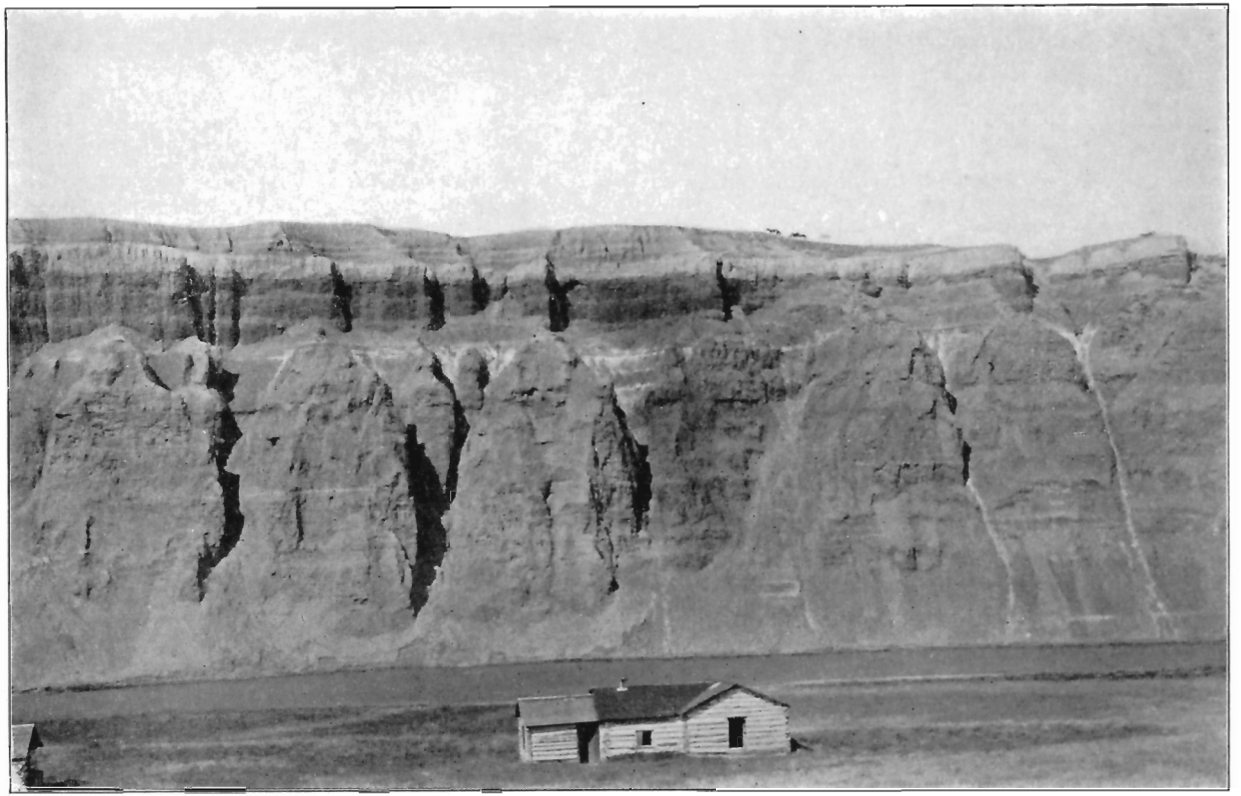
ARTESIAN WATER.

From a general study of the underground geology of the region it has been concluded that an area of large extent is underlain by porous beds carrying water under pressure.

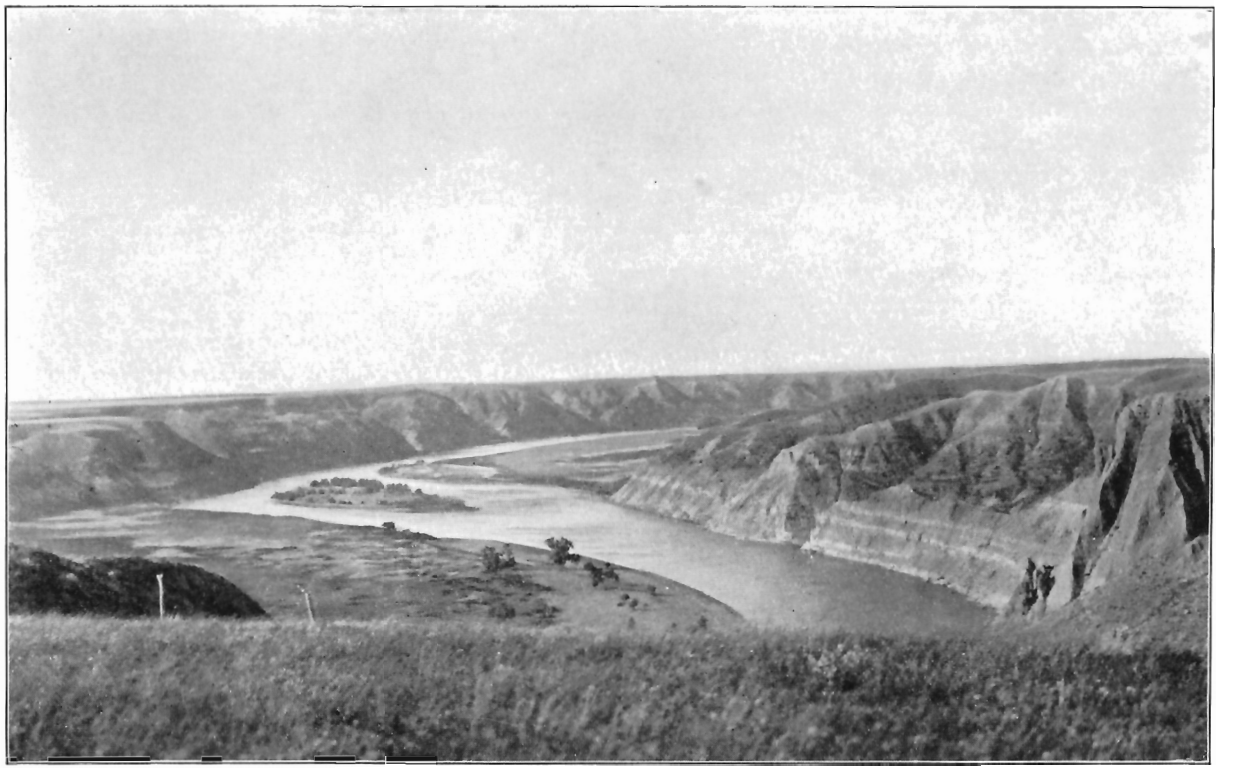
The sandstones along Milk river are porous and receive and retain the water. These beds form an arch or anticline which crosses Milk river and which broadens and flattens to the

north with a general downward inclination in that direction. The saturation of these sandstones is continued down the slopes in a general north and east direction until balanced and held back by natural gas contained in the pores of the rock. As these beds are covered by fine textured shales the contained water is under a pressure dependent on the height of the source of supply and will rise to approximately that elevation. As the country slopes to the north toward the Oldman and South Saskatchewan rivers there is a large area in which the depth from the surface to the underlying water-bearing sands is quite uniformly about 800 feet. The area in which the water may be expected to reach the surface is, however, confined to the part north of Chin coulée and to the lower land reaching the Milk river by way of the Pakowki Lake depression. In the absence of an exact determination of the line between water and gas by experiment, the northern limit of the water has been placed tentatively at the latitude of Purple Springs and Bow Island, but east and west of these points it may trend to the northward. The area that has been mapped as being low enough to warrant the expectation that wells sunk in it deep enough to reach the Milk River sandstones will be flowing wells, comprises about a million acres. This area may be restricted on the north by the presence of gas instead of water and also may be restricted to a still lower level than that marked owing to a possible greater loss of head than that allowed; and pumping may have to be resorted to in the higher ground. The area may be increased to the east and west by sinking deeper wells; the limit of depth assumed for the area marked on the map is 800 feet.[1]

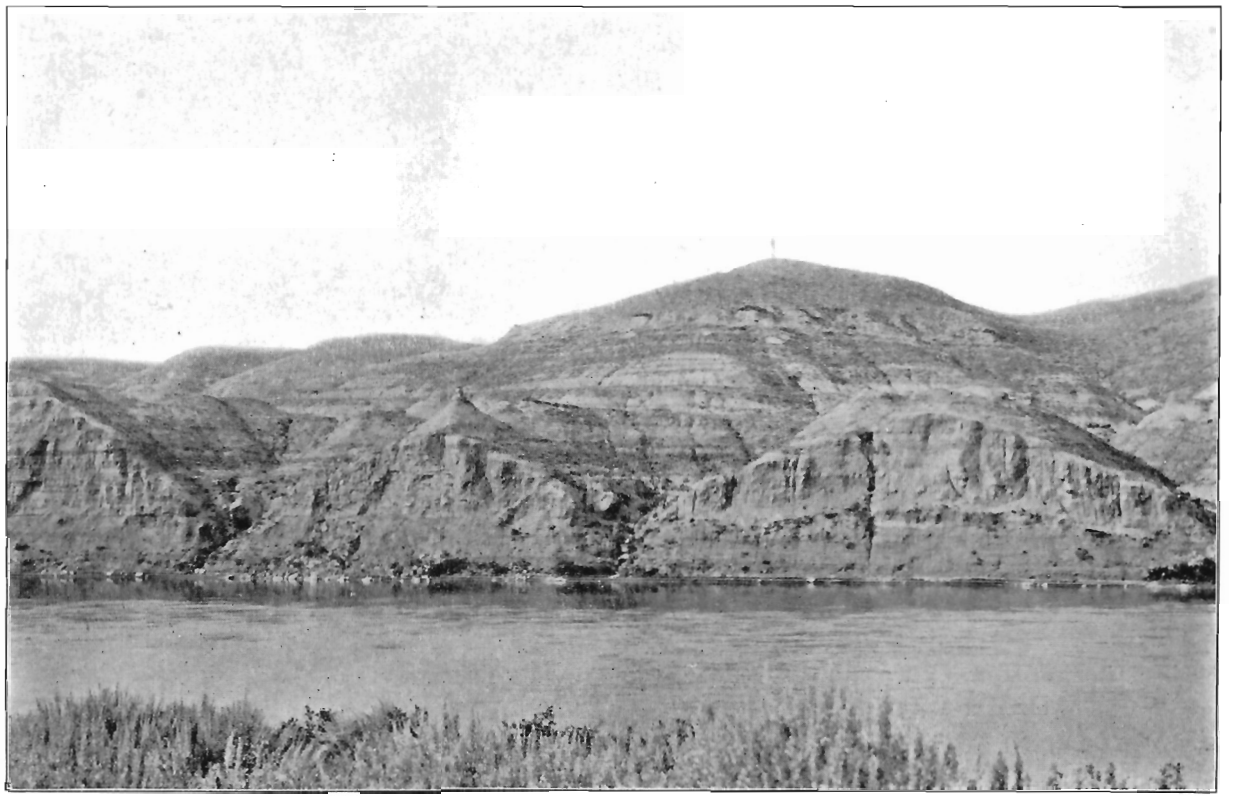
[1] Geol. Surv., Can., Sum. Rept., 1915, p. 104.



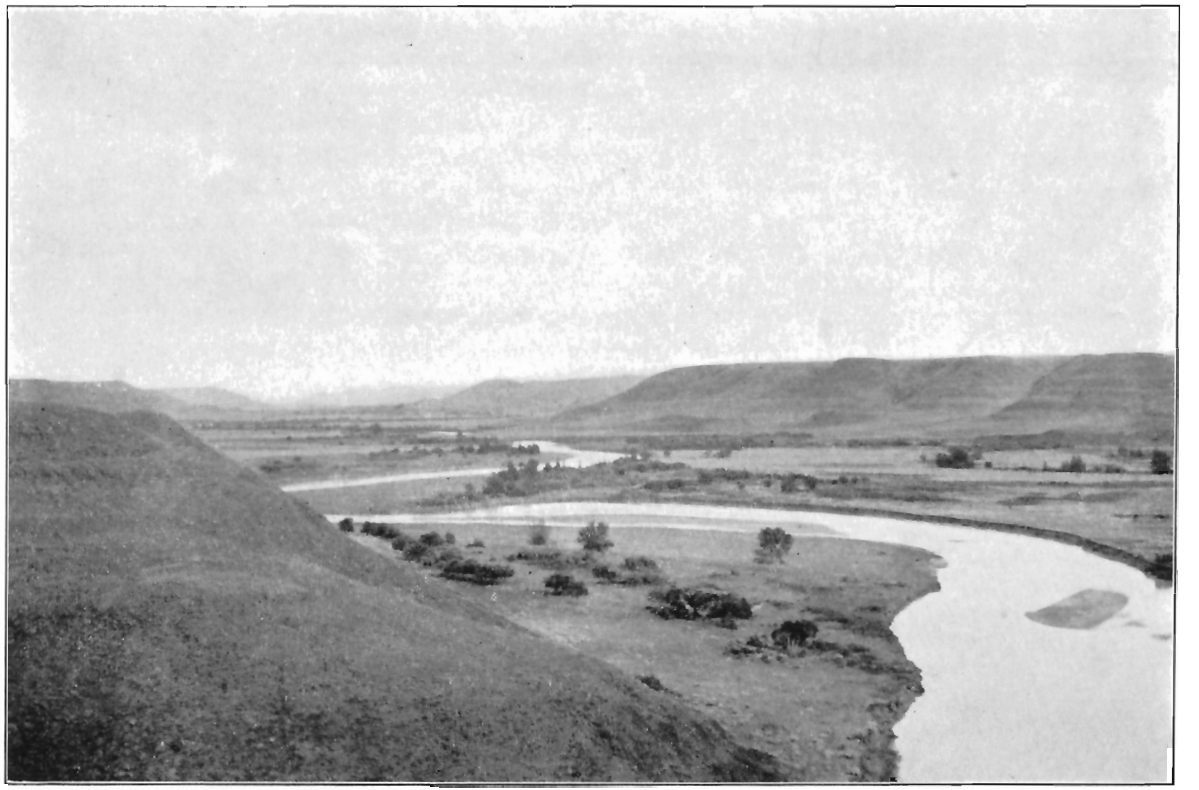
Upper Pierre shale (Bearpaw) exposed on St. Mary river near the old Royal North West Mounted Police outpost west of Magrath mine; Saskatchewan gravels and boulder clay on top. (Page 25.)



The pale beds at Big Island bend, Oldman river. (Pages 33, 98.)

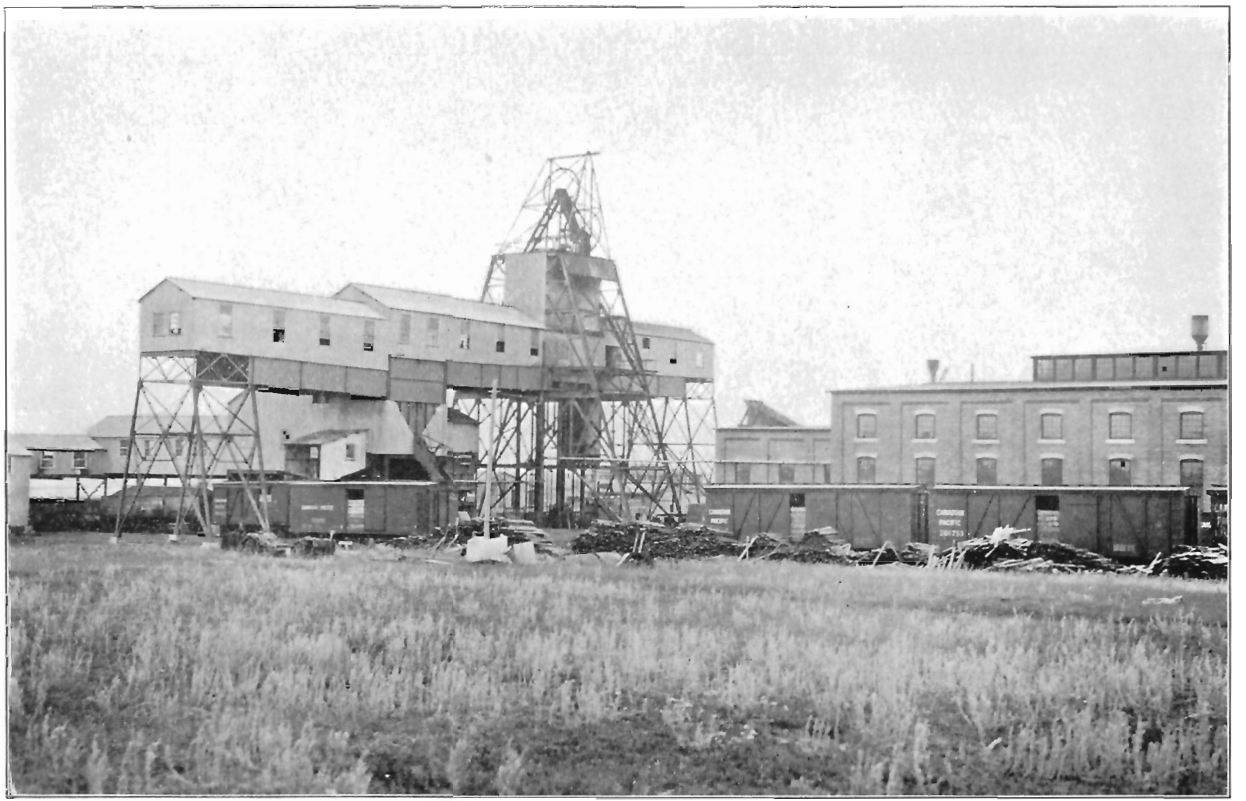


Exposures of Foremost beds on the north bank of the South Saskatchewan just below the junction of Bow and Oldman rivers. (Page 37.)

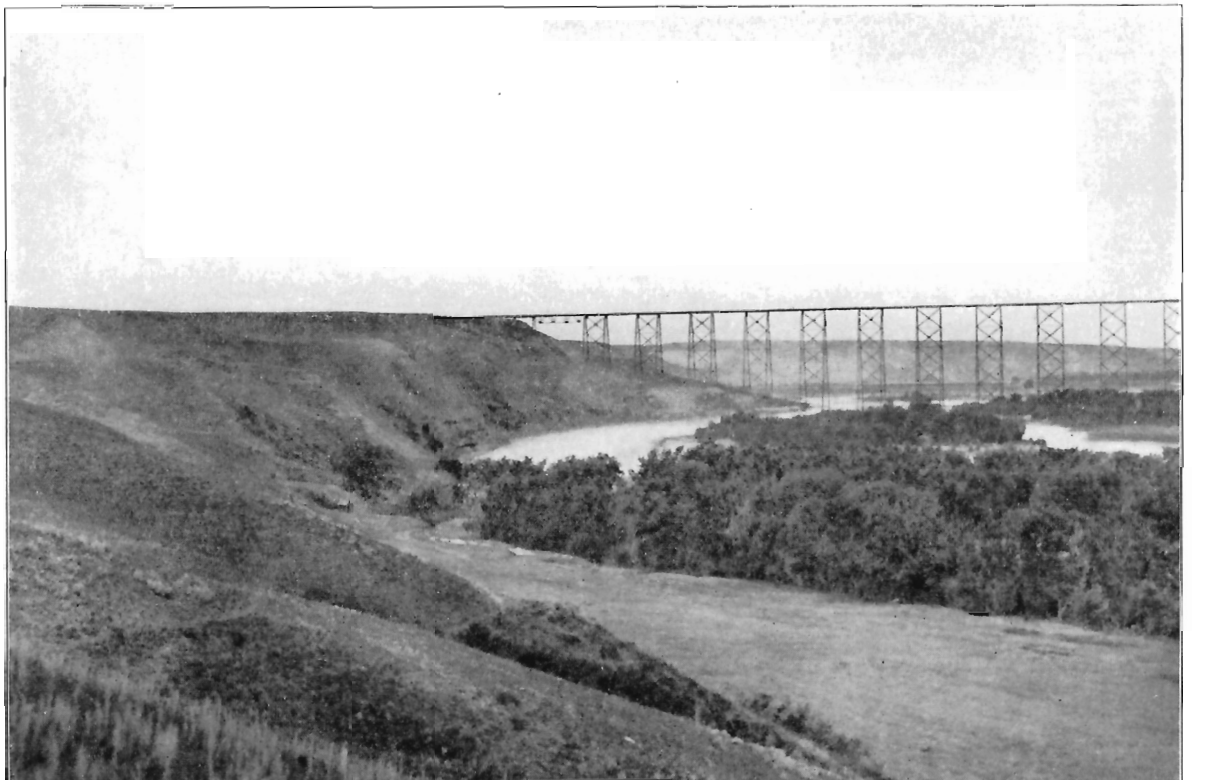


Pakowki shales, in the foreground, Milk River valley east of Pakowki coulée. (Page 60.)

Weathered outcrop of Milk River sandstone north of West butte in Milk River valley. (Page 55.)

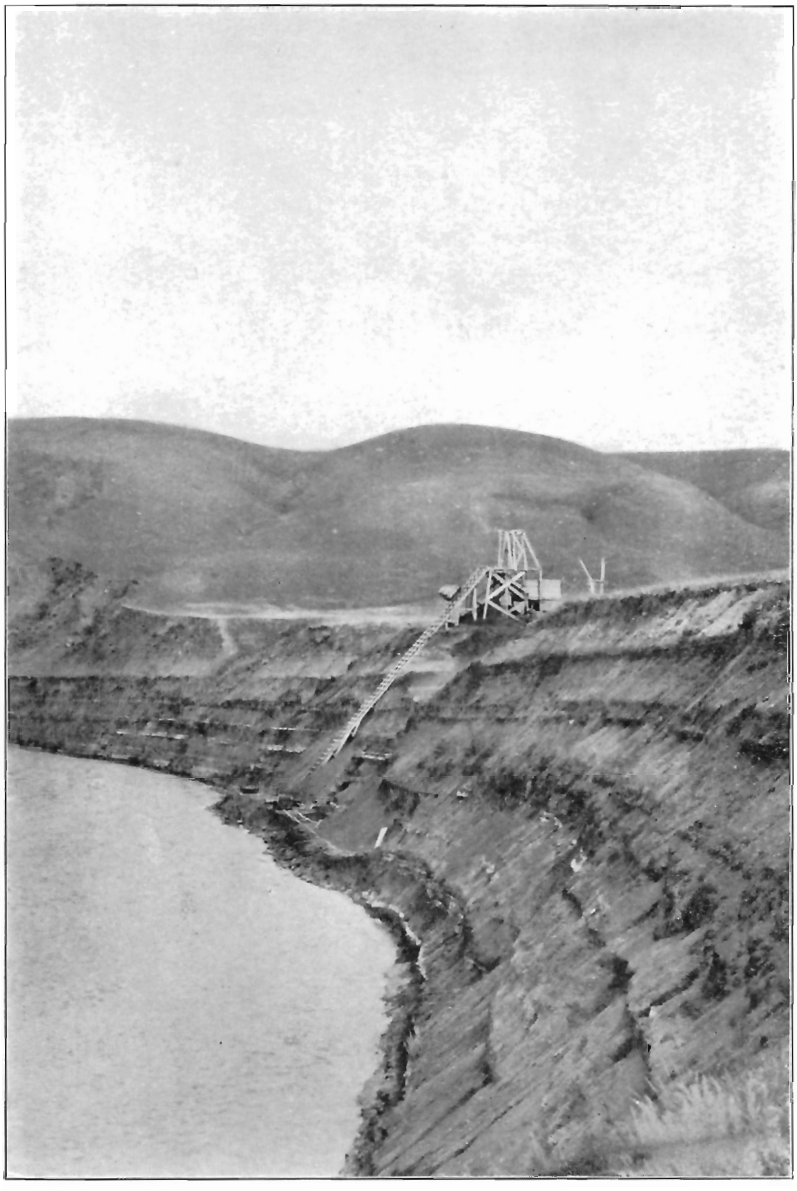


Lethbridge coal mine at Coalhurst, Alberta. (Page 93.)

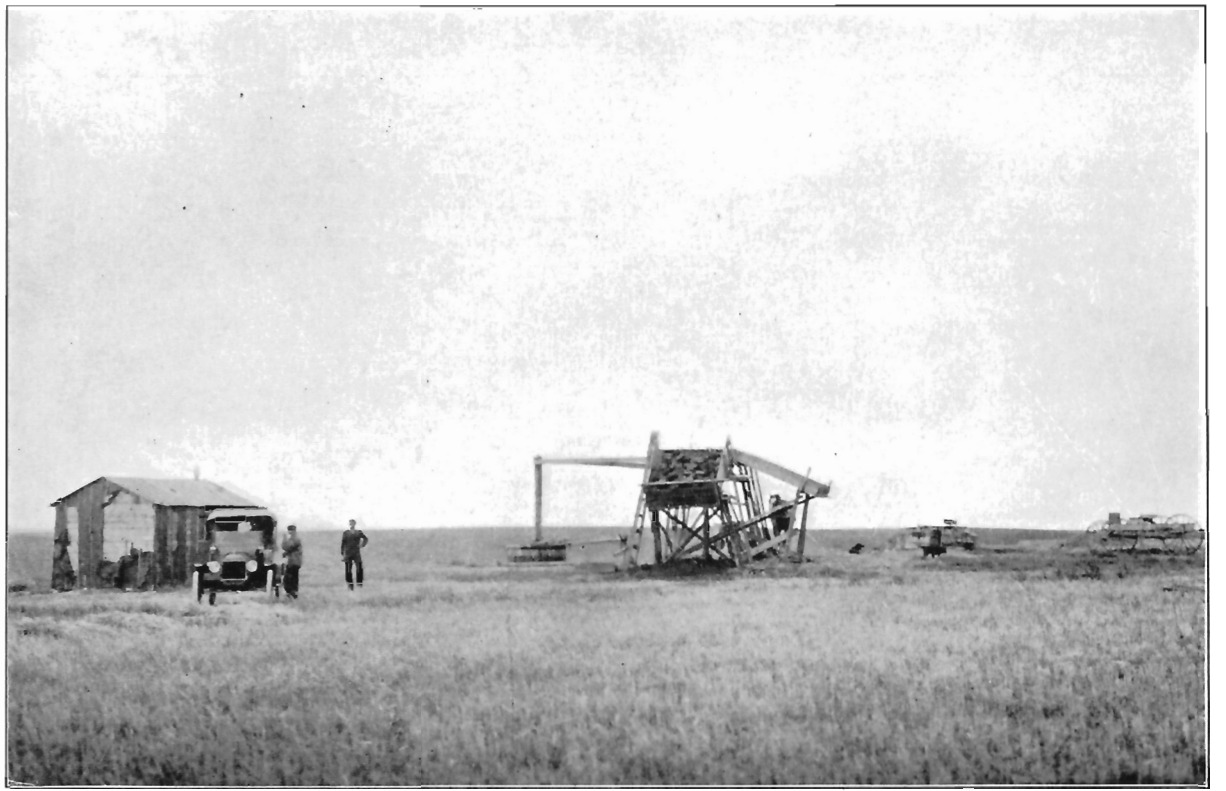


Sheran's mine, the first mine opened in the district, located on left bank of the river above the railway bridge at Lethbridge. (Pages 89, 93.)

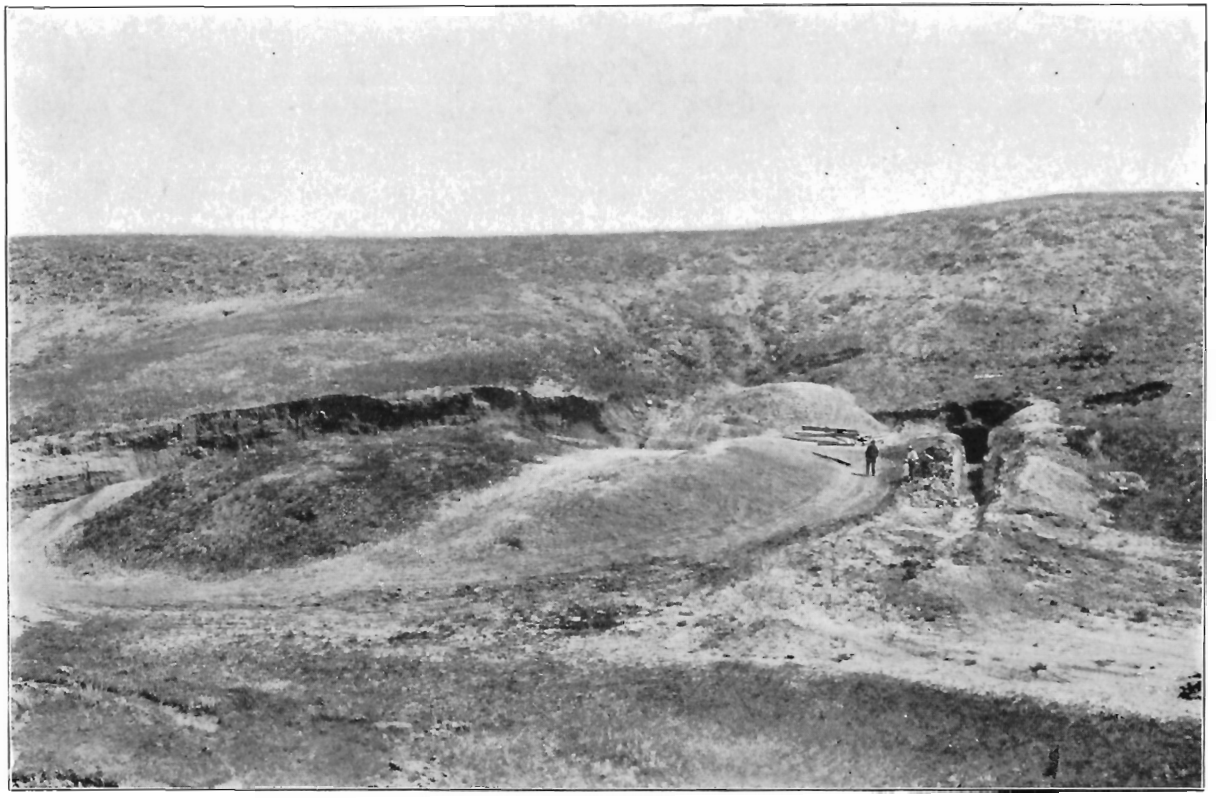
PLATE IX.



Magrath mine, St. Mary river. Base of Bearpaw shales exposed. (Page 85.)

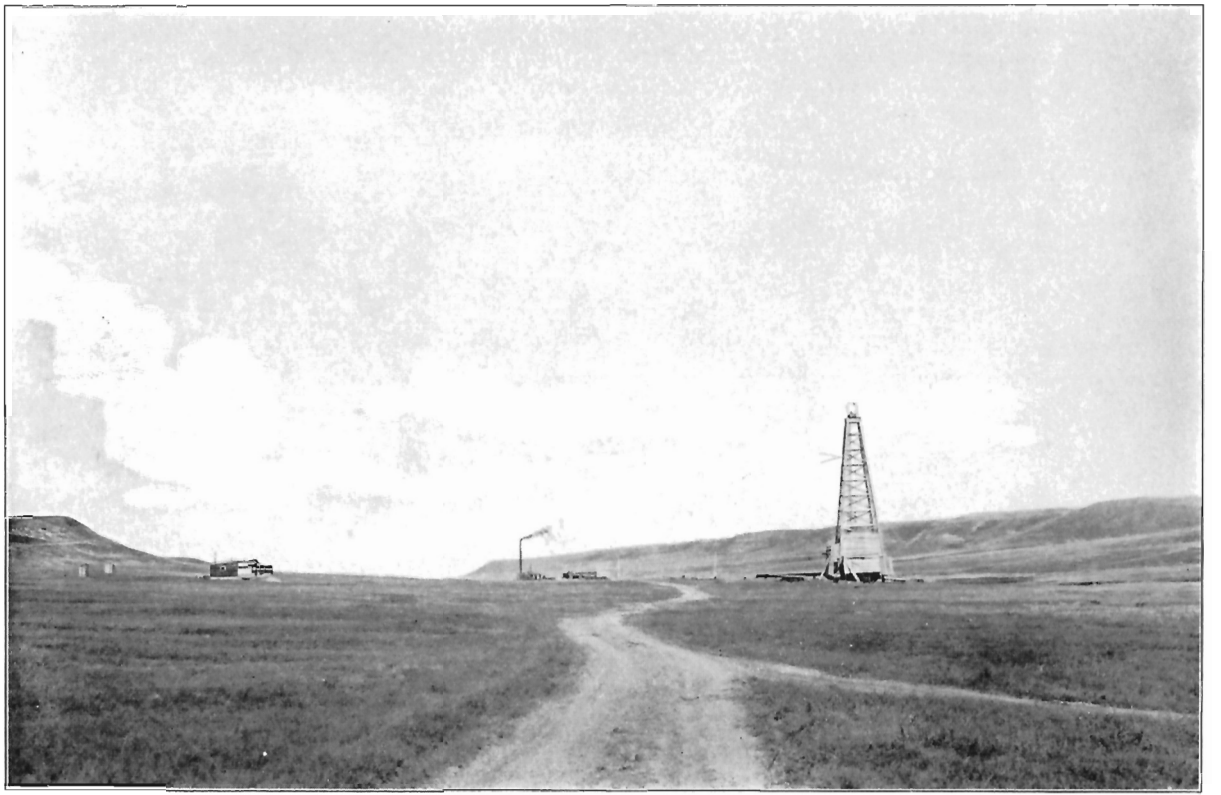


Small mines on the banks of South Saskatchewan north of Winnifred. (Page 107.)

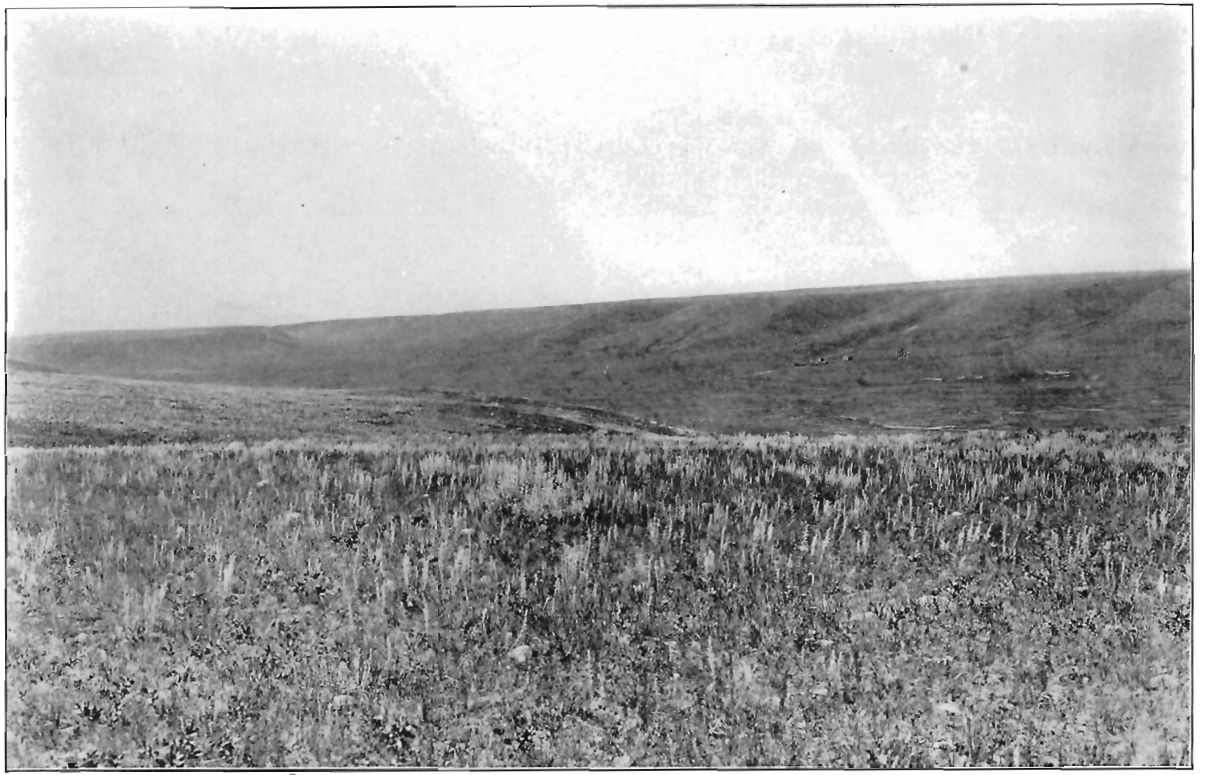


Bembridge mine, Lucky Strike plateau. (Page 77.)

Coal mine opposite mouth of Piegan creek, Sevenpersons coulée. (Page 119.)



Etzikom coulée south of Foremost. (Page 78.)



Verdigris coulée east of Warner. (Page 75.)

EXPLANATION OF PLATE XV.

Reproductions of plates illustrating freshwater forms of fossil invertebrates found in rocks of the Montana group.

Figure 1. *Anodonta propatoris* Whiteaves (pages 26, 36).
From G. S. C. Cont. to Can. Pal., vol. I, pl. IX, fig. 2.

2. *Anodonta parallela* White (page 39).
From Review of non-marine fossil mollusca of North America, U. S. G. S. Ann. Rept. 1882, pl. XIX, fig. 5.

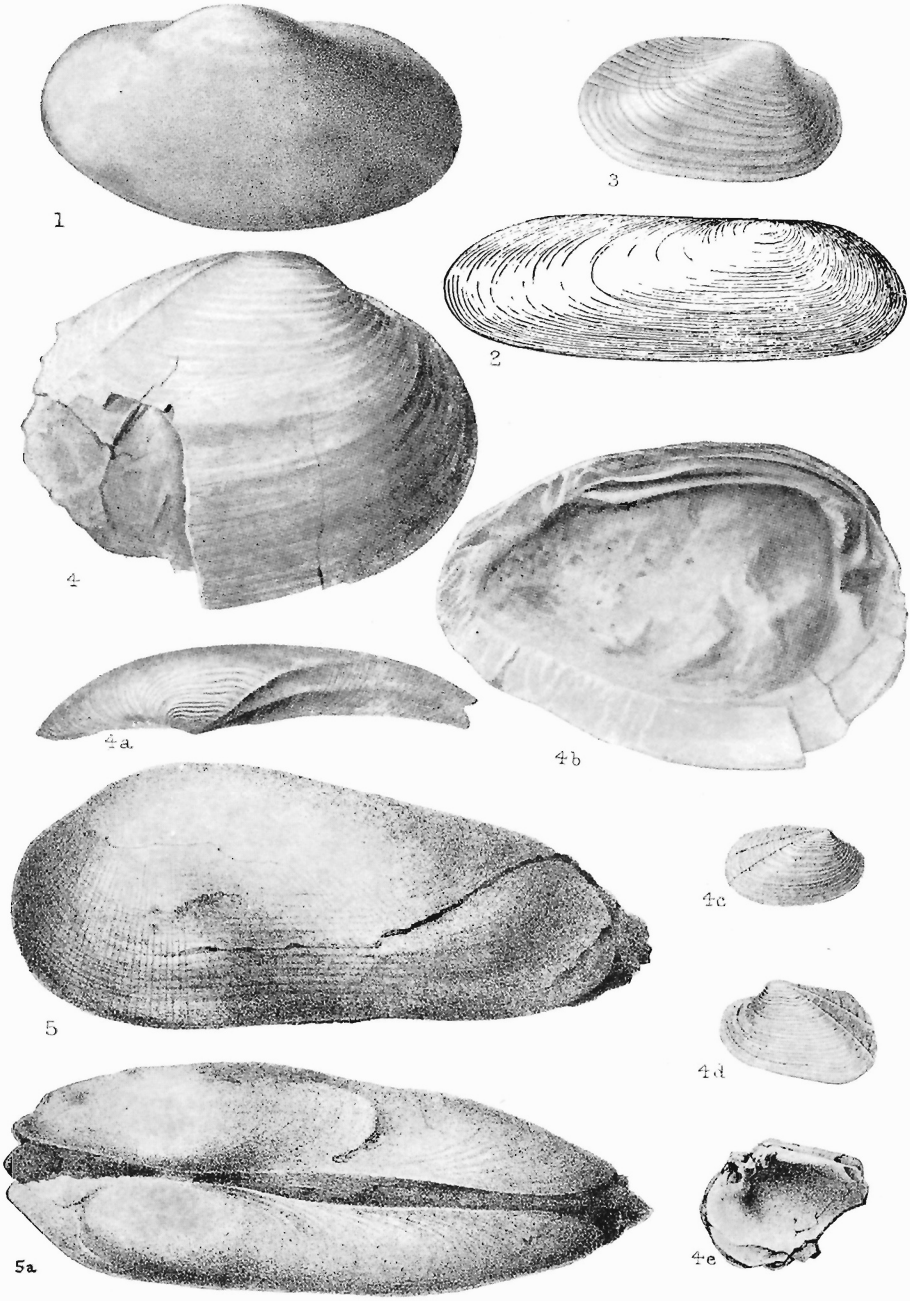
3. *Unio senectus* White (pages 36, 39).
From G. S. C. Cont. to Can. Pal., vol. I, pl. X, fig. 2.

4, 4a, 4b. *Unio priscus* var. *abbreviatus* Stanton (page 75).
From Geol. and Pal. of Duluth River beds, U. S. G. S. Bull. 257, pl. XII, figs. 2, 3, 4.

4c, 4d, 4e. *Unio priscus* Meek and Hayden (page 39).
From U. S. Geol. Survey of Territories, vol. IX, pl. XLI, figs. 8a, 8b, 8c.

5, 5a. *Unio danæ* Meek and Hayden (pages 36, 39).
From U. S. Geol. Survey of Territories, vol. IX, pl. XLI, figs. 3a, 3b.

PLATE XV.



EXPLANATION OF PLATE XVI.

Reproductions of plates illustrating freshwater forms of fossil invertebrates found in rocks of the Montana group.

Figure 1, 1a. *Unio primævus* White (page 36).
From Review of non-marine mollusca of North America, White. U. S. G. S. Ann. Rept. 1882, pl. XIV, figs. 4, 5.

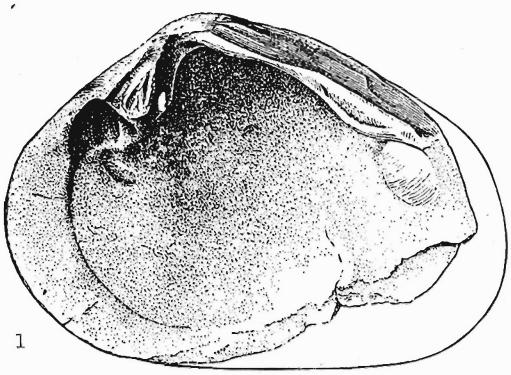
2. *Unio supragibbosus* Whiteaves (page 39).
From G. S. C. Cont. to Can. Pal., vol. I, pl. X, fig. 1.

3, 3a. *Unio deweyanus* Meek and Hayden (page 39).
From U. S. Geol. Survey of Territories, vol. IX, pl. XLI, figs. 2a, 2c.

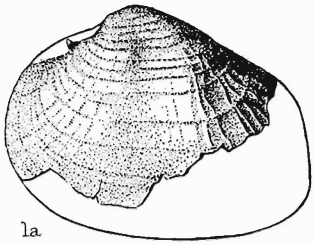
4. *Unio consuetus* Whiteaves (page 36).
From G. S. C. Cont. to Can. Pal., vol. I, pl. IX, fig. 4b.

5, 5a. *Sphærium formosum* Meek and Hayden (pages 36, 39).
From U. S. Geol. Survey of Territories, vol. IX, pl. XLIII, figs. 4b, 4c.

PLATE XVI.



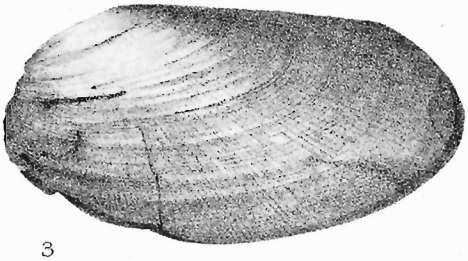
1



1a

5

5a



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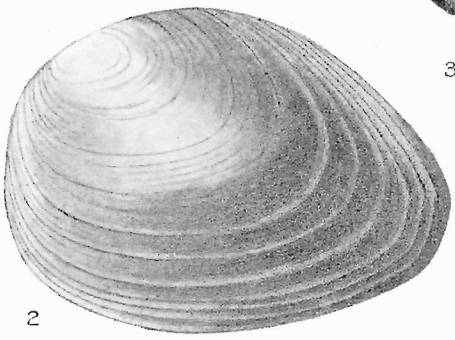

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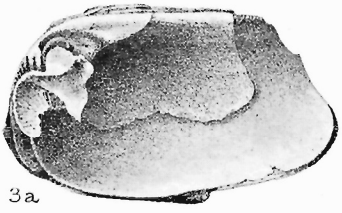


3a

4

EXPLANATION OF PLATE XVII.

Reproductions of plates illustrating freshwater forms of fossil invertebrates found in rocks of the Montana group.

Figure 1. *Campeloma multilineata* Meek and Hayden (page 40).
From U. S. Geol. Survey of Territories, vol. IX, pl. XLIV, figs. 1a, 1b.

2, 2a, 2b, 2c. *Campeloma producta* White (page 40).
From Review of non-marine mollusca of North America, White. U. S. G. S. Ann. Rept. 1882, pl. XXVI, figs. 21, 22, 23, 24.

3. *Goniobasis subtortuosa* Meek and Hayden (page 40).
From G. S. C. Cont to Can. Pal., vol. I, pl. X, fig. 7.

4, 4a, 4b. *Rhytophorus glaber* Whiteaves (pages 40, 46).
From G. S. C. Cont. to Can. Pal., vol. I, pl. X, figs. 4, 4a, 4b.

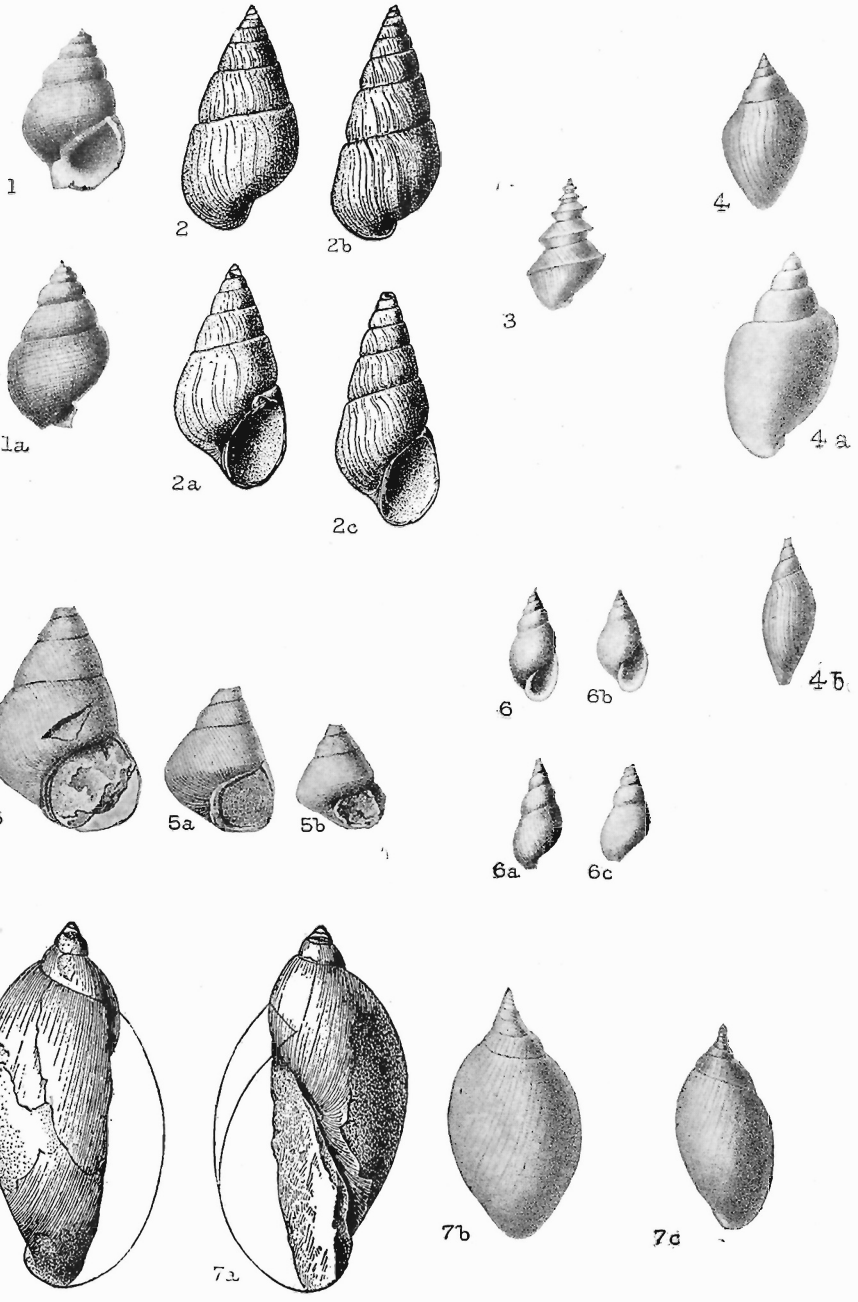
5, 5a, 5b. *Viviparus conradi* Meek and Hayden (page 40).
From U. S. Geol. Survey of Territories, vol. IX, pl. XLII, figs. 15, 15a, 15b.

6, 6a, 6b, 6c. *Thaumastus limnæiformis* Meek and Hayden (page 40).
From U. S. Geol. Survey of Territories, vol. IX, pl. XLIV, figs. 8, 8a, 8b, 8c.

7, 7a. *Physa copei* White (pages 36, 40).
From Review of non-marine fossil mollusca of North America, White. U. S. G. S. Ann. Rept. 1882, pl. XXV, figs. 1, 2.

7b, 7c. *Physa copei* var. *canadensis* Whiteaves (page 40).
From G. S. C. Cont. to Can. Pal., vol. I, pl. II, figs. 5, 5b.

PLATE XVII.



EXPLANATION OF PLATE XVIII.

Reproductions of plates illustrating brackish-water forms of fossil invertebrates found in rocks of the Montana group.

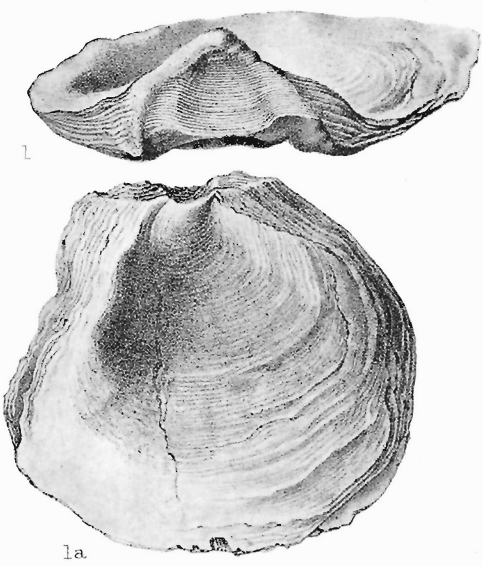
Figure 1, 1a. *Ostrea patina* Meek and Hayden (page 26).
From U. S. Geol. Survey of Territories, vol. IX, pl. X, figs. 2a, 2b.

2. *Ostrea glabra* Meek and Hayden (pages 35, 39, 45).
From U. S. Geol. Survey of Territories, vol. IX, pl. XL, fig. 2b.

3. *Ostrea inornata* Meek and Hayden (pages 27, 35).
From U. S. Geol. Survey of Territories, vol IX, pl. XI, fig. 4a.

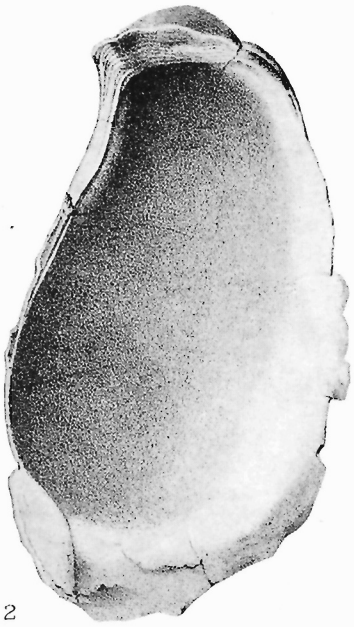
4, 4a, 4b, 4c. *Ostrea subtrigonalis* Evans and Shumard (pages 27,35,36,39).
From Review of non-marine fossil mollusca of North America, White. U. S. G. S. Ann. Rept. 1882, pl. XII, figs. 2, 3, 4, 5.

PLATE XVIII.



1

1a



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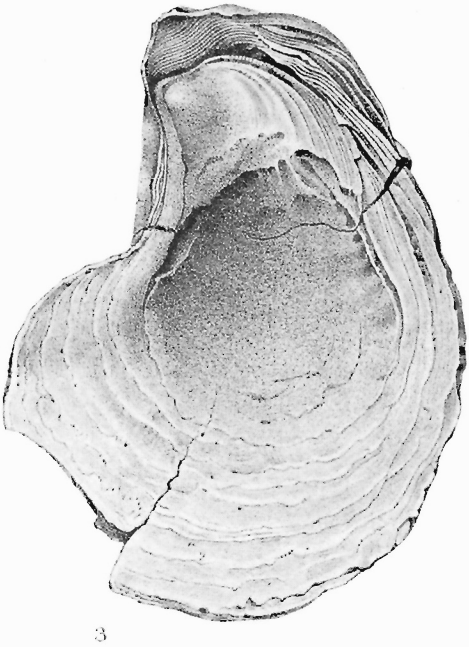
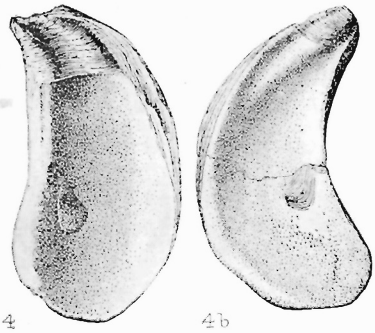
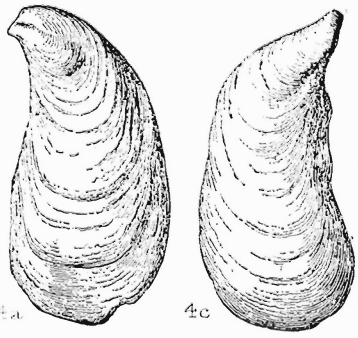


3



4

4b



4a

4c

EXPLANATION OF PLATE XIX.

Reproductions of plates illustrating brackish-water forms of fossil invertebrates found in rocks of the Montana group.

Figure 1, 1a, 1b. *Corbula perundata* Meek and Hayden (pages 36, 40, 46).
From U. S. Geol. Survey of Territories, vol. IX, pl. XL, figs. 4a, 4b, 4d.

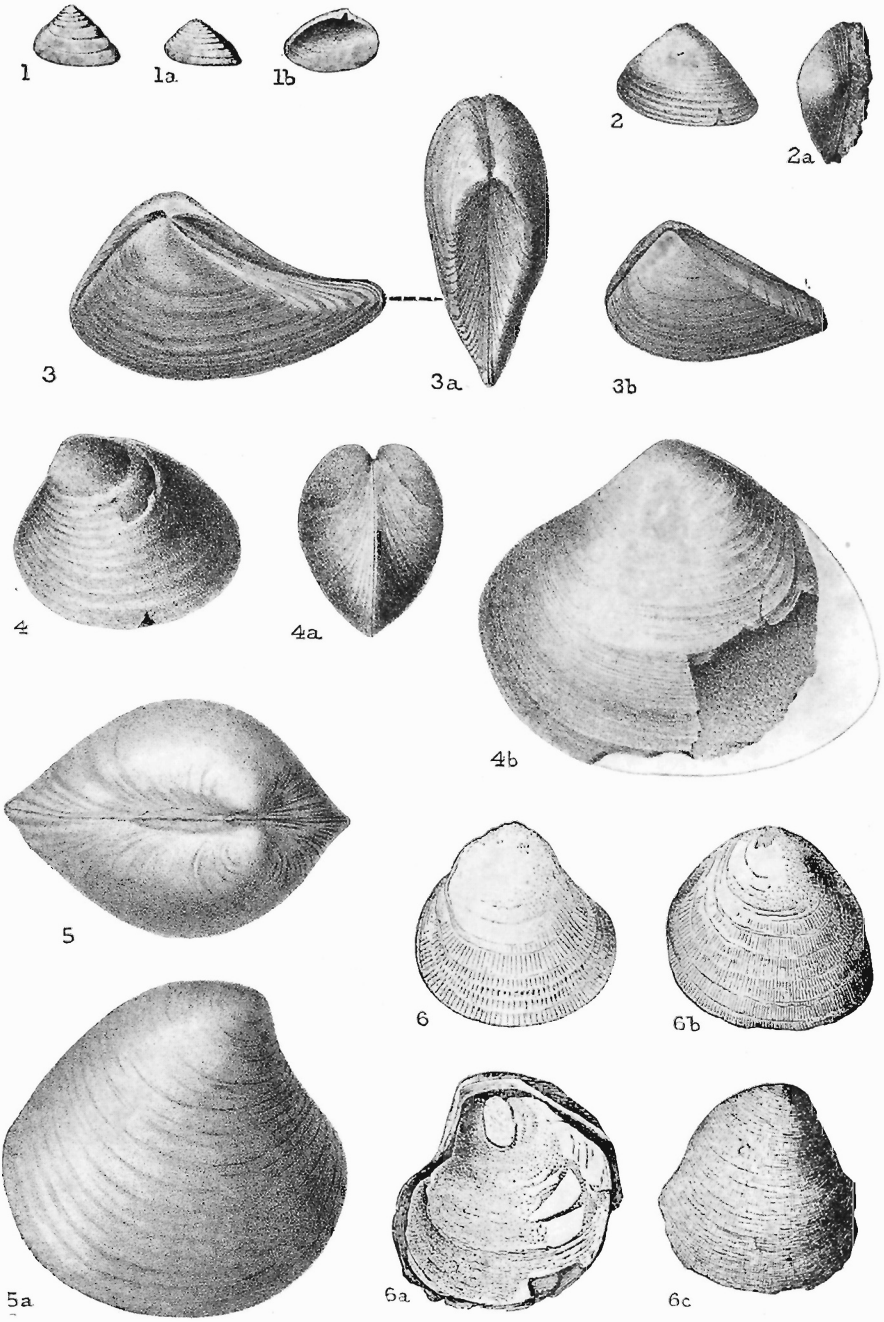
2, 2a. *Corbula subtrigonalis* Meek and Hayden (pages 36, 39, 46).
From U. S. Geol. Survey of Territories, vol. IX, pl. XL, figs. 3a. 3b.

3, 3a, 3b. *Corbula perangulata* Whiteaves (page 39).
From G. S. C. Cont. to Can. Pal., vol. I, pl. I, figs. 5, 5a, 5b.

4, 4a, 4b. *Corbicula cytheriformis* Meek and Hayden (pages 39, 45).
From U. S. Geol. Survey of Territories, vol. IX, pl XL, figs. 5a, 5c, 5e.

5, 5a. *Corbicula occidentalis* Meek and Hayden (pages 29, 35, 36, 39).
From G. S. C. Cont. to Can. Pal., vol. I, pl. I, figs. 3, 3a.

6, 6a, 6b, 6c. *Anomia micronema* Meek (pages 36, 38).
From Review of the non-marine fossil mollusca of North America, White. U. S. G. S. Ann. Rept. 1882, pl. XII, figs. 6, 7, 8, 11.


1
1a
1b
2
2a
3
3a
3b
4
4a
4b
5
5a
6
6b
6a
6c

EXPLANATION OF PLATE XX.

Reproductions of plates illustrating brackish-water forms of fossil invertebrates found in rocks of the Montana group.

Figure 1. *Melania insculpta* Meek (page 40).
From G. S. C. Cont. to Can. Pal., vol. I, pl. X, fig. 6.

1a, 1b. *Melania insculpta* Meek (page 40).
From Review of non-marine fossil mollusca of North America, White. U. S. G. S. Ann. Rept. 1882, pl. XXVI, figs. 4, 5.

2. *Melania whiteavesi* Stanton (page 46).
From Geol. and Pal. of the Judith River beds, U. S. G. S. Bull. 257, pl. XIII, fig. 5.

3, 3a, 3b, 3c, 3d. *Velatella baptista* White (page 40).
From Review of the non-marine fossil mollusca of North America, White. U. S. G. S. Ann. Rept. 1882, pl. XXIII, figs. 16, 17, 18, 19, 20.

4. *Planorbis paucivolvis* Whiteaves (page 40).
From G. S. C. Cont. to Can. Pal., vol. I, pl. X, fig. 5.

5. *Hydrobia subcylindrica* Whiteaves (page 40).
From G. S. C. Cont. to Can. Pal., vol. I, pl. X, fig. 8.

PLATE XX.


1


1a


1b


2


3


3a


3b


3c


3d


4


5

EXPLANATION OF PLATE XXI.

Reproductions of plates illustrating marine forms of fossil invertebrates found in rocks of the Montana group.

Figure 1, 1a. *Lingula nitida* Meek and Hayden (page 26).
From U. S. Geol. Survey of Territories, vol. IX, pl. XXVIII, figs. 18a, 18b.

2, 2a, 2b. *Chlamys nebrascensis* Meek and Hayden (page 27).
From U. S. Geol. Survey of Territories, vol. IX, pl. XVI, figs. 6a, 6b. 6c.

3, 3a. *Pteria (Oxytoma) nebrascana* Evans and Shumard (pages 27, 45).
From U. S. Geol. Survey of Territories, vol. IX, pl. XVI, fig. 3b; pl. XXVIII, fig. 11.

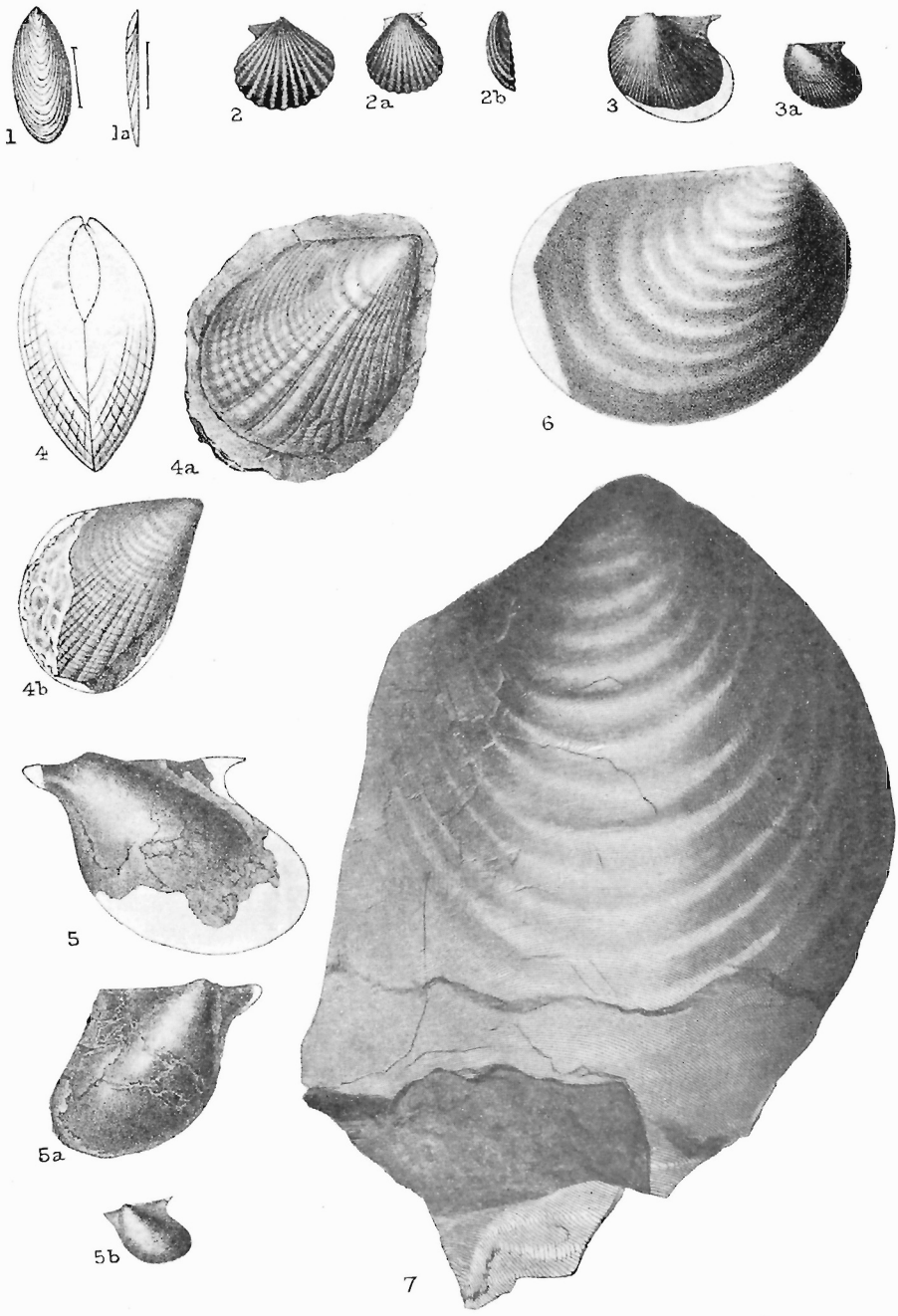
4, 4a, 4b. *Pteria (Pseudopteria) fibrosa* Meek and Hayden (page 27).
From U. S. Geol. Survey of Territories, vol. IX, pl. XVII, figs. 17a, 17b, 17c, 17d.

5, 5a, 5b. *Pteria linguiformis* Evans and Shumard (pages 27, 45).
From U. S. Geol. Survey of Territories, vol. IX, pl. XVI, figs. 1a, 1b, 1c, 1d.

6. *Inoceramus barabini* Morton (page 27).
From U. S. Geol. Survey of Territories, vol. IX, pl. XII, fig. 3.

7. *Inoceramus sagensis* Owen (page 27).
From Owens, Geol. Surv. of Winsconsin, Iowa, and Minnesota, pl. VII, fig. 3.

PLATE XXI.

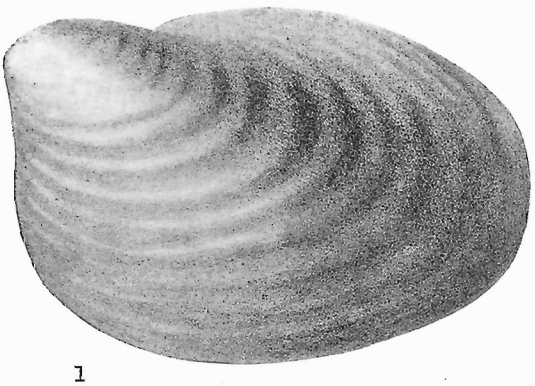


EXPLANATION OF PLATE XXII.

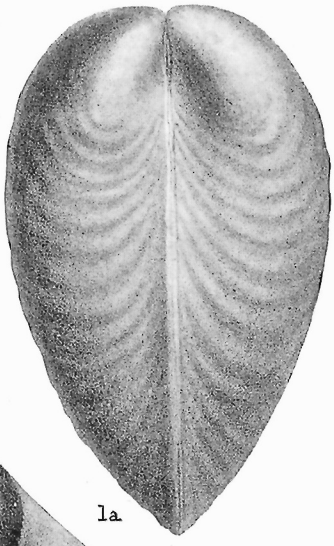
Reproductions of plates illustrating marine forms of fossil invertebrates found in rocks of the Montana group.

Figure 1, 1a. *Inoceramus tenuilineatus* Hall and Meek (page 27).
From G. S. C. Cont. to Can. Pal., vol. I, pl. V, figs. 1, 1a.

2. *Inoceramus vanuxemi* Meek and Hayden (page 27).
From U. S. Geol. Survey of Territories, vol. IX, pl. XIV, fig. 2a.



1



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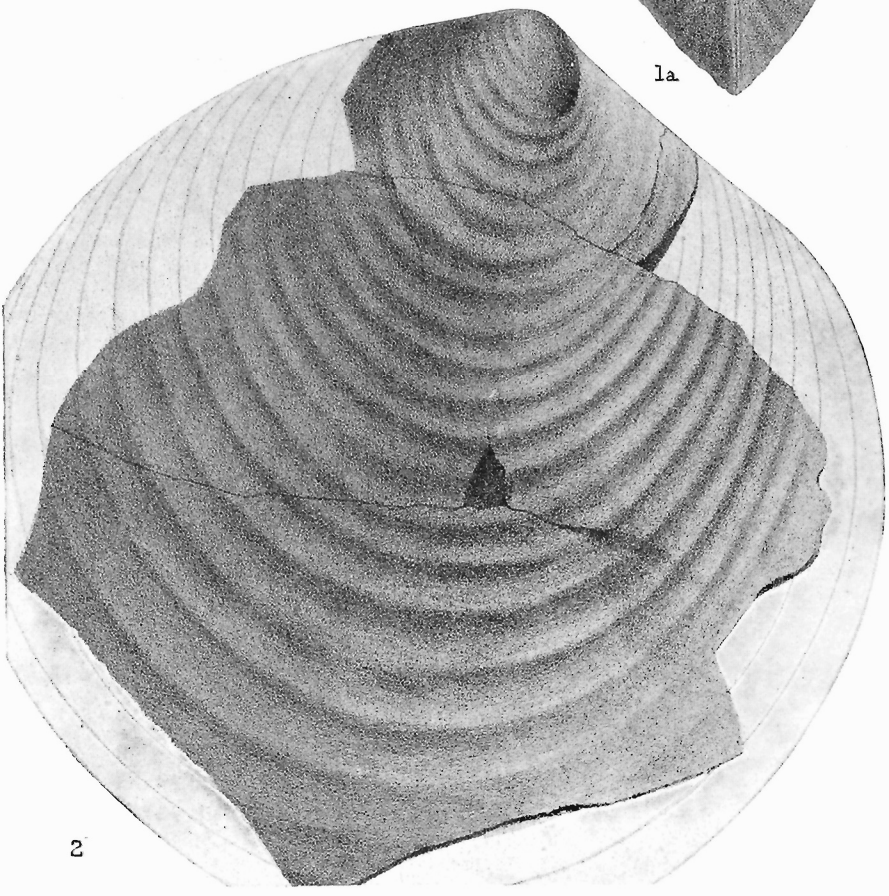


2

EXPLANATION OF PLATE XXIII.

Reproductions of plates illustrating marine forms of fossil invertebrates found in rocks of the Montana group.

Figure 1, 1a. *Gervillia recta* Meek and Hayden (page 28).
From U. S. Geol. Survey of Territories, vol. IX, pl. XXIX, figs. 1a, 1b.

2. *Gervillia recta* var. *borealis* Whiteaves (page 28).
From G. S. C. Cont. to Can. Pal., vol. I, pl. IV, fig. 2.

3, 3a. *Volsella meeki* Evans and Shumard (page 45).
From U. S. Geol. Survey of Territories, vol. IX, pl. XV, figs. 3a, 3b.

4, 4a. *Modiola attenuata* Meek and Hayden (page 28).
From U. S. Geol. Survey of Territories, vol. IX, pl. XXVIII, figs. 8a, 8b.

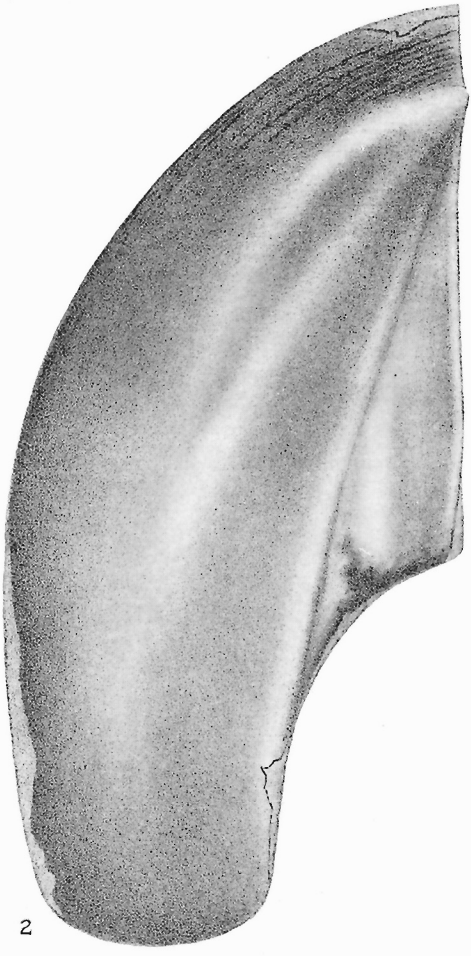
5. *Modiola* (*Brachydontes*) *dichotoma* Whiteaves (pages 28, 35).
From G. S. C. Cont. to Can. Pal., vol. I, pl. IV, fig. 3.

6, 6a. *Modiola tenuisculpta* Whiteaves (page 39).
From G. S. C. Cont. to Can. Pal., vol. I, pl. XXVI, figs. 2, 2a.

PLATE XXIII.

1

1a



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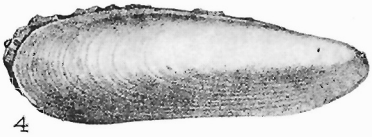
3

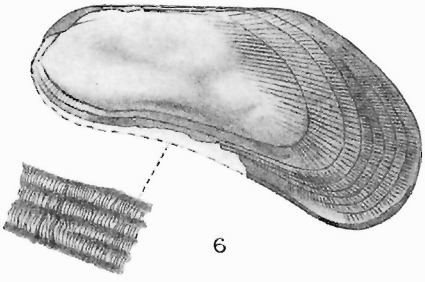
3a



4

4a

5



6

EXPLANATION OF PLATE XXIV.

Reproductions of plates illustrating marine forms of fossil invertebrates found in rocks of the Montana group.

Figure 1, 1a, 1b. *Nucula cancellata* Meek and Hayden (pages 28, 45).
From U. S. Geol. Survey of Territories, vol. IX, pl. XXVIII, figs. 13a, 13b, 13c.

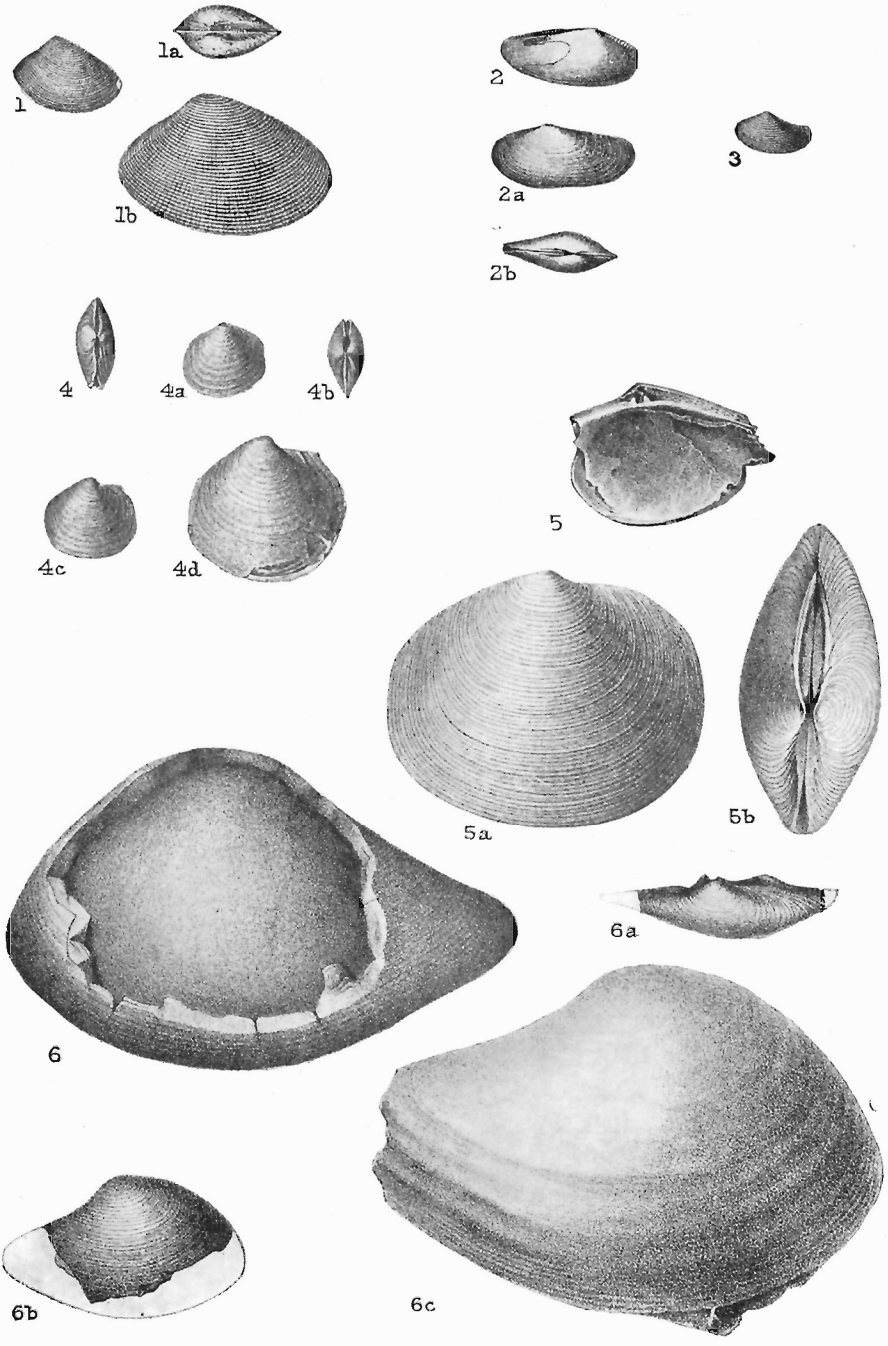
2, 2a, 2b. *Yoldia evansi* Meek and Hayden (page 28).
From U. S. Geol. Survey of Territories, vol. IX, pl. XXVIII, figs. 10a, 10b, 10c.

3. *Yoldia scitula* Meek and Hayden (page 28).
From U. S. Geol. Survey of Territories, vol. IX, pl. XXVIII, fig. 9.

4, 4a, 4b, 4c, 4d. *Lucina subundata* Meek (page 28).
From U. S. Geol. Survey of Territories, vol. IX, pl. XVII, figs. 2a, 2b, 2c, 2d, 2e.

5, 5a, 5b. *Lucina occidentalis* Morton (page 28).
From U. S. Geol. Survey of Territories, vol. IX, pl. XVII, figs. 4a, 4b, 4c.

6, 6a, 6b, 6c. *Tancredia americana* Meek and Hayden (pages 28, 45).
From U. S. Geol. Survey of Territories, vol. IX, pl. XXXVIII, figs. 1a, 1b, 1f, 1g.


1
1a
1b
2
2a
2b
3
4
4a
4b
4c
4d
5
5a
5b
6
6a
6b
6c

EXPLANATION OF PLATE XXV.

Reproductions of plates illustrating marine forms of fossil invertebrates found in rocks of the Montana group.

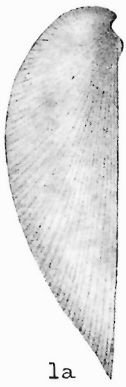
Figure 1, 1a. *Cyprina ovata* Meek and Hayden (page 28).
From U. S. Geol. Survey of Territories, vol. IX, pl. XXIX, figs. 7a, 7b.

2. *Cyprina ovata* var. *alta* Whiteaves (page 28).
From G. S. C. Cont. to Can. Pal., vol. I, pl. V, fig. 3.

3, 3a, 3b. *Cyprina substrapeziformis* Whiteaves (page 29).
From G. S. C. Cont. to Can. Pal., vol. I, pl. XXIV, figs. 2, 2a, 2b.

PLATE XXV.

1



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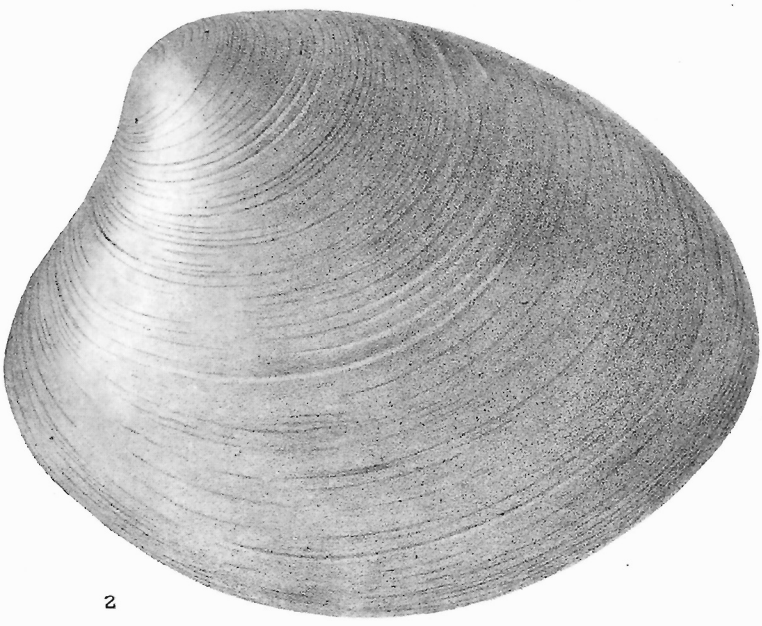


2

3

3a

3b

EXPLANATION OF PLATE XXVI.

Reproductions of plates illustrating marine forms of fossil invertebrates found in rocks of the Montana group.

Figure 1. *Solecurtus* (*Tagelus*) *occidentalis* Whiteaves (page 30).
From G. S. C. Cont. to Can. Pal., vol. I, pl. XXIV, fig. 4.

2, 2a, 2b, 2c, 2d. *Protocardia subquadrata* Evans and Shumard (pages 29, 45).
From U. S. Geol. Survey of Territories, vol. IX, pl. XXIX, figs. 8a, 8b, 8c, 8d, 8e.

3, 3a, 3b, 3c. *Protocardia borealis* Whiteaves (page 29).
From G. S. C. Cont. to Can. Pal., vol. I, pl. VI, figs. 1, 1a, 2, 2a.

4. *Linearia formosa* Meek and Hayden (page 29).
From U. S. Geol. Survey of Territories, vol. IX, pl. XXX, fig. 2.

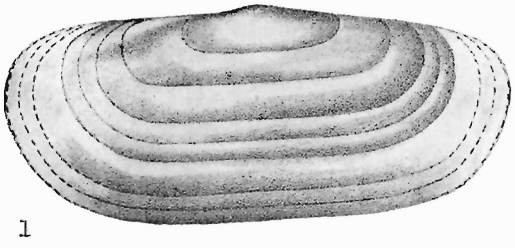
4a. *Linearia formosa* Meek and Hayden (page 29).
From G. S. C. Cont. to Can. Pal., vol. I, pl. XXIV, fig. 3.

5, 5a. *Callista nebrascensis* Meek and Hayden (page 29).
From U. S. Geol. Survey of Territories, vol. IX, p. 184, figs. 15, 17.

5b. *Callista* (*Dosiniopsis*) *deweyi* Meek and Hayden (page 29).
From G. S. C. Cont. to Can. Pal., vol. I, pl. VI, figs. 4, 5, 5a.

6, 6a, 6b, 6c. *Mactra* (*Cymbophora*) *warrenana* Meek and Hayden (page 29).
From U. S. Geol. Survey of Territories, vol. IX, pl. XXX, figs. 7a, 7b, 7c, 7d.

PLATE XXVI.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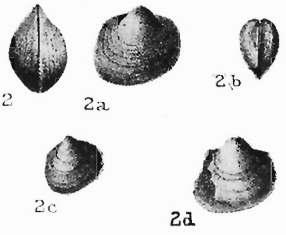
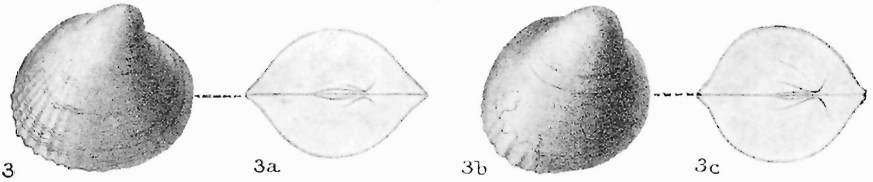
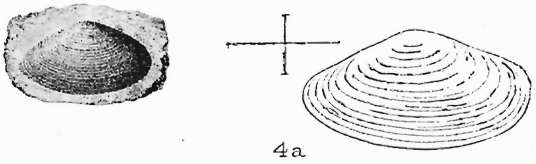
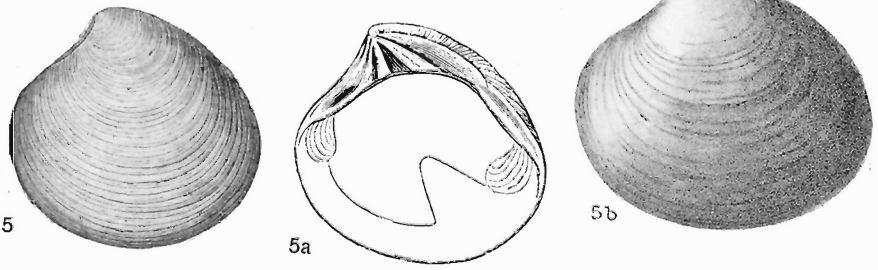
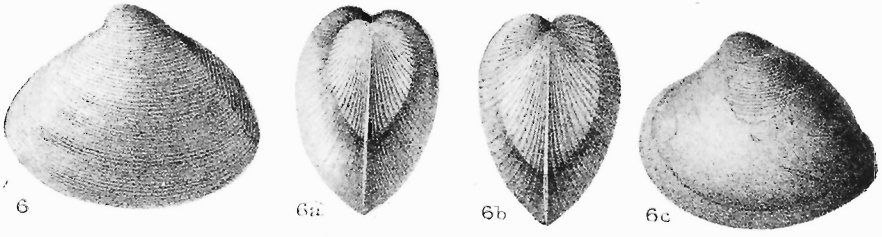

2 2a 2b 2c 2d


3 3a 3b 3c


4 4a


5 5a 5b


6 6a 6b 6c

EXPLANATION OF PLATE XXVII.

Reproductions of plates illustrating marine forms of fossil invertebrates found in rocks of the Montana group.

Figure 1, 1a. *Mactra* (*Cymbophora*) *alta* Meek and Hayden (page 36).
From U. S. Geol. Survey of Territories, vol. IX, pl. XXXVII, figs. 2a, 2b.

2, 2a. *Mactra* (*Cymbophora*) *gracilis* Meek and Hayden (pages 29, 46).
From U. S. Geol. Survey of Territories, vol. IX, pl. XVII, figs. 18a, 18b.

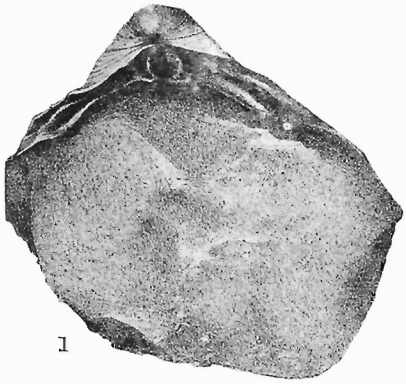
3, 3a. *Pholadomya subventricosa* Meek and Hayden (page 29).
From U. S. Geol. Survey of Territories, vol. IX, pl. XXXIX, figs. 8a, 8b.

4, 4a. *Liopistha* (*Cymella*) *undata* Meek and Hayden (pages 29, 46).
From U. S. Geol. Survey of Territories, vol. IX, pl. XXXIX, figs. 1a, 1b.

5, 5a. *Neæra moreauensis* Meek and Hayden (page 30).
From U. S. Geol. Survey of Territories, vol. IX, pl. XVII, figs. 11b, 11c.

6, 6a. *Martesia tumidifrons* Whiteaves (page 30).
From G. S. C. Cont. to Can. Pal., vol. I, pl. XXV, figs. 1, 2.

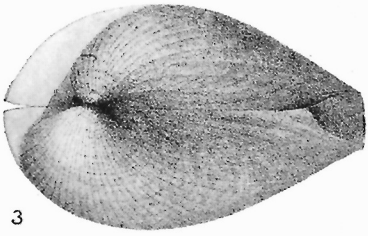
PLATE XXVII.


1


1a


2

2a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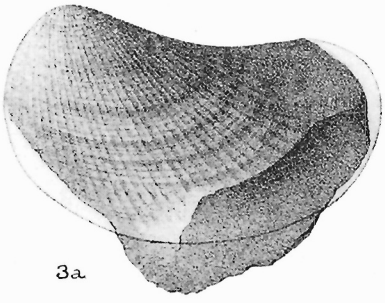
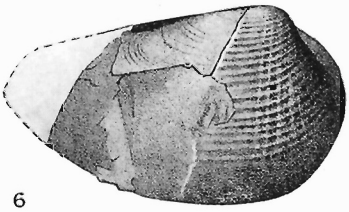

3a


4


4a


5


5a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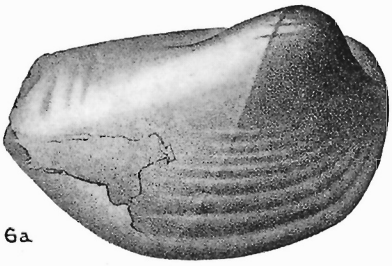

6a

EXPLANATION OF PLATE XXVIII.

Reproductions of plates illustrating marine forms of fossil invertebrates found in rocks of the Montana group.

Figure 1, 1a. *Panopœa subovalis* Whiteaves (page 30).
From G. S. C. Cont. to Can. Pal., vol. I, pl. VI, figs. 6, 6a.

2, 2a, 2b. *Limopsis parvula* Meek and Hayden (page 45).
From U. S. Geol. Survey of Territories, vol. IX, pl. XXVIII, figs. 17a, 17b, 17c.

3. *Goniomya americana* Meek and Hayden (page 45).
From U. S. Geol. Survey of Territories, vol. IX, pl. XXX, fig. 12a.

4, 4a. *Nuculana bisulcata* Meek and Hayden (page 45).
From U. S. Geol. Survey of Territories, vol. IX, pl. XV, figs. 4a, 4b.

5, 5a, 5b. *Cardium speciosum* Meek and Hayden (page 46).
From U. S. Geol. Survey of Territories, vol. IX, pl. XXXVII, figs. 4a, 4b, 4c.

6, 6a. *Hydatina parvula* Whiteaves (page 30).
From G. S. C. Cont. to Can. Pal., vol. I, pl. XXIV, figs. 5, 5a.

7, 7a, 7b. *Haminea occidentalis* Meek and Hayden (page 30).
From U. S. Geol. Survey of Territories, vol. IX, pl. XVIII, figs. 11a, 12a, 12b.

8, 8a, 8b. *Cinulia concinna* Meek and Hayden (page 30).
From U. S. Geol. Survey of Territories, vol. IX, pl. XXXI, figs. 6a bis, 6b bis, 6c bis.

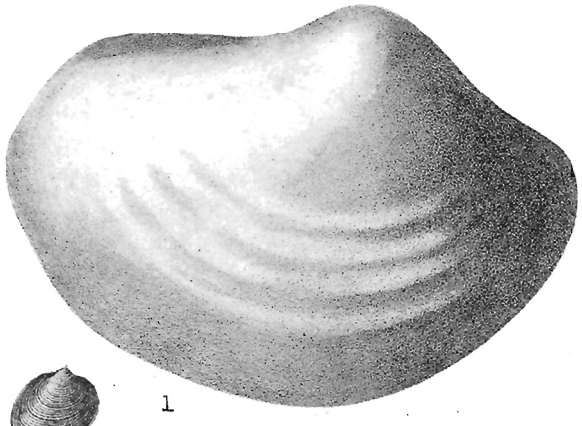
9. *Actæon attenuatus* Meek and Hayden (page 30).
From U. S. Geol. Survey of Territories, vol. IX, pl. XIX, figs. 17a, 17b.

10. *Entalis paupercula* Meek and Hayden (page 46).
From U. S. Geol. Survey of Territories, vol. IX, pl. XVIII, fig. 14.

11, 11a. *Anisomyon alveolus* Meek and Hayden (page 30).
From U. S. Geol. Survey of Territories, vol. IX, pl. XVIII, figs. 4a, 4b.

12, 12a, 12b. *Anisomyon centrale* Meek (page 30).
From G. S. C. Cont. to Can. Pal., vol. I, pl. VII, figs. 1, 2, 2a.

PLATE XXVIII.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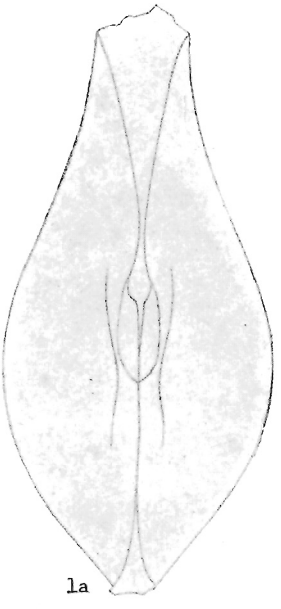

1a

2


2a


2b


3


4


4a


5


5a


5b


6

6a


7


7a


7b


8a


8

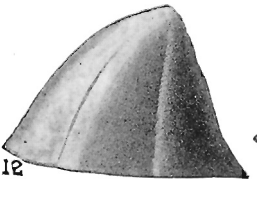

8b


9


10


11


11a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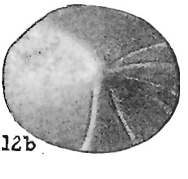
12a


12b

EXPLANATION OF PLATE XXIX.

Reproductions of plates illustrating marine forms of fossil invertebrates found in rocks of the Montana group.

Figure 1, 1a, 1b, 1c. *Anisomyon patelliformis* Meek and Hayden (pages 30, 46). From U. S. Geol. Survey of Territories, vol. IX, pl. XVIII, figs. 5a, 5c, 5d, 5e.

2, 2a. *Vanikoropsis tuomeyana* Meek and Hayden (pages 31, 46). From U. S. Geol. Survey of Territories, vol. IX, pl. XXXIX, figs. 2a, 2b.

3, 3a, 3b. *Lunatia subcrassa* Meek and Hayden (page 46). From U. S. Geol. Survey of Territories, vol. IX, pl. XXXIX, figs. 3a, 3b, 3c.

4, 4a, 4b. *Lunatia concinna* Hall and Meek (pages 30, 46). From U. S. Geol. Survey of Territories, vol. IX, pl. XXXII, figs. 11a, 11b, 11c.

5, 5a. *Anchura americana* Evans and Shumard (page 31). From U. S. Geol. Survey of Territories, vol. IX, pl. XXXII, figs. 8a, 8b.

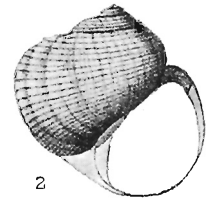
6, 6a. *Aporrhais biangulata* Meek and Hayden (page 46). From U. S. Geol. Survey of Territories, vol. IX, pl. XIX, figs. 6a, 6b.


1

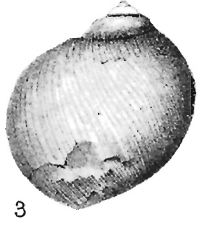

1a.


1b


1c


2


2a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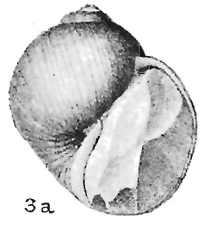
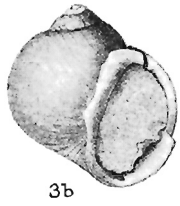
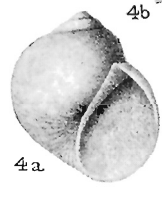

3a

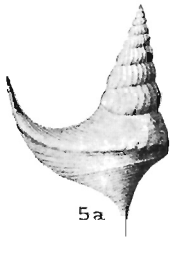

3b


4


4b


4a


5


5a


6


6a

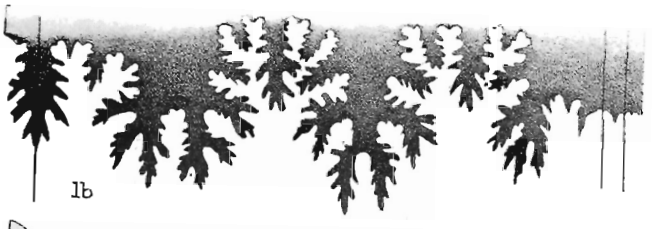
EXPLANATION OF PLATE XXX.

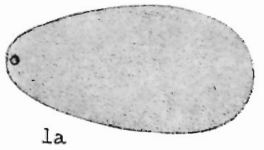
Reproductions of plates illustrating marine forms of fossil invertebrates found in rocks of the Montana group.

Figure 1, 1a, 1b. *Baculites compressus* Say (pages 31, 47).
From U. S. Geol. Survey of Territories, vol. IX, pl. XX, figs. 3a, 3b, 3c.

2, 2a. *Baculites ovatus* Say (page 31).
From U. S. Geol. Survey of Territories, vol. IX, pl. XX, figs. 2a, 2b.

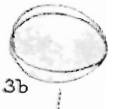
3, 3a, 3b, 3c. *Baculites asper* Morton (page 46).
From U. S. Geol. Survey of Territories, vol. IX, pl. XXXIX, figs. 10a, 10b, 10c, 10d.


1b

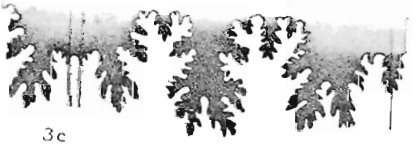

1a


1

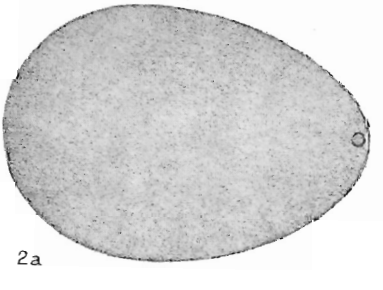

3


3b


3a


3c


2

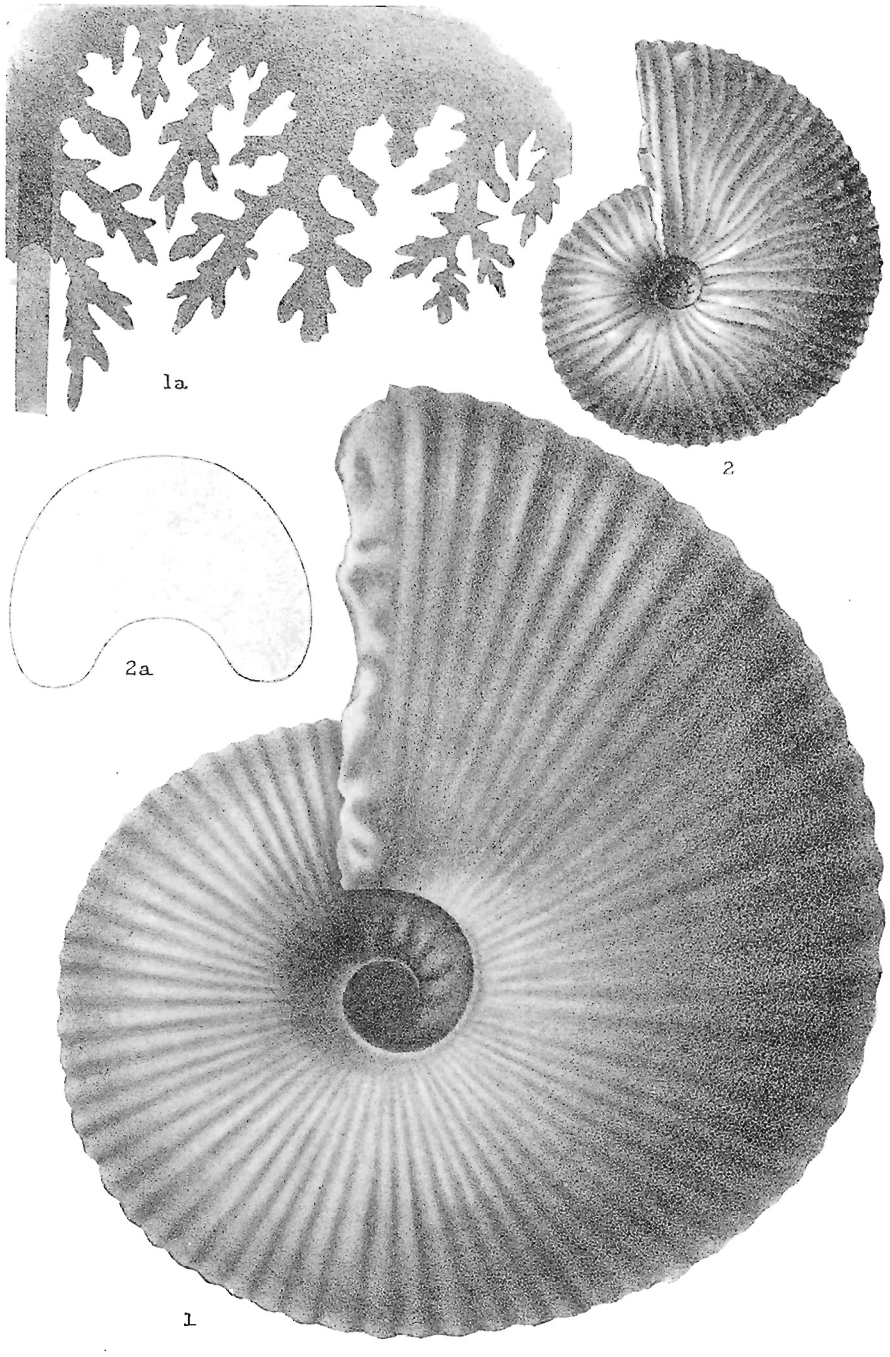

2a

EXPLANATION OF PLATE XXXI.

Reproductions of plates illustrating marine forms of fossil invertebrates found in rocks of the Montana group.

Figure 1, 1a. *Scaphites subglobosus* Whiteaves (page 32).
From G. S. C. Cont. to Can. Pal., vol. I, pl. VII, fig. 3; pl. VIII, fig. 1a.

2, 2a. *Scaphites subglobusos* Whiteaves (page 32).
From G. S. C. Cont. to Can. Pal., vol. I, pl. VIII, figs. 2, 2a.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EXPLANATION OF PLATE XXXII.

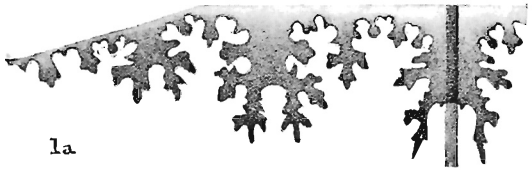
Reproductions of plates illustrating marine forms of fossil invertebrates found in rocks of the Montana group.

Figure 1, 1a. *Scaphites abyssinus* Morton (page 31).
From U. S. Geol. Survey of Territories, vol. IX, pl. XXXV, figs. 2a, 2b.

2, 2a. *Scaphites Nicolleti* Morton (page 31).
From U. S. Geol. Survey of Territories, vol. IX, pl. XXXIV, figs. 2a, 2b.

3. *Scaphites nodosus* Owen (page 32).
From Owens, Geol. Surv. of Wisconsin, Iowa, and Minnesota, pl. VIII, fig. 4.

PLATE XXXII.



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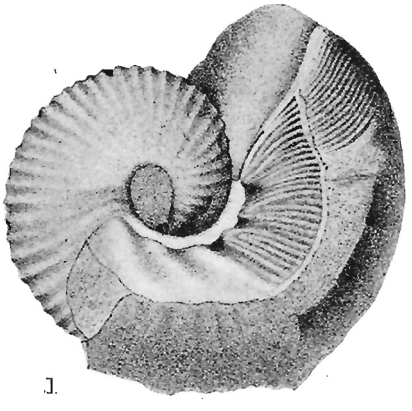

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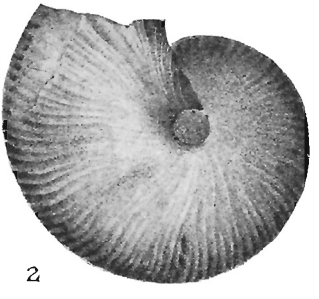

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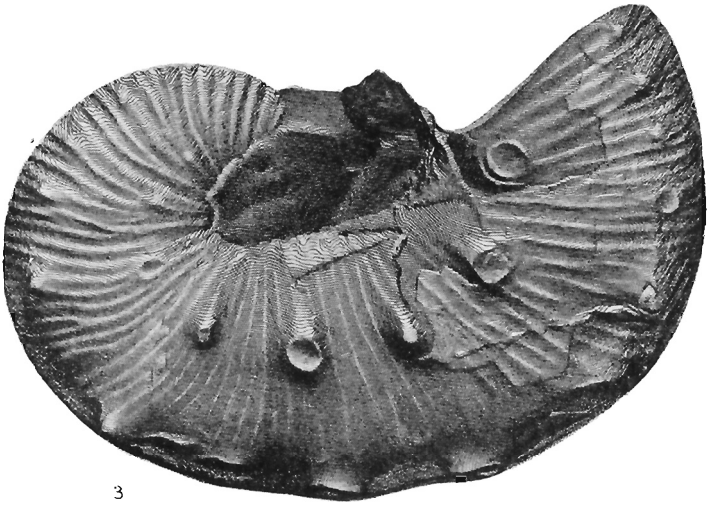

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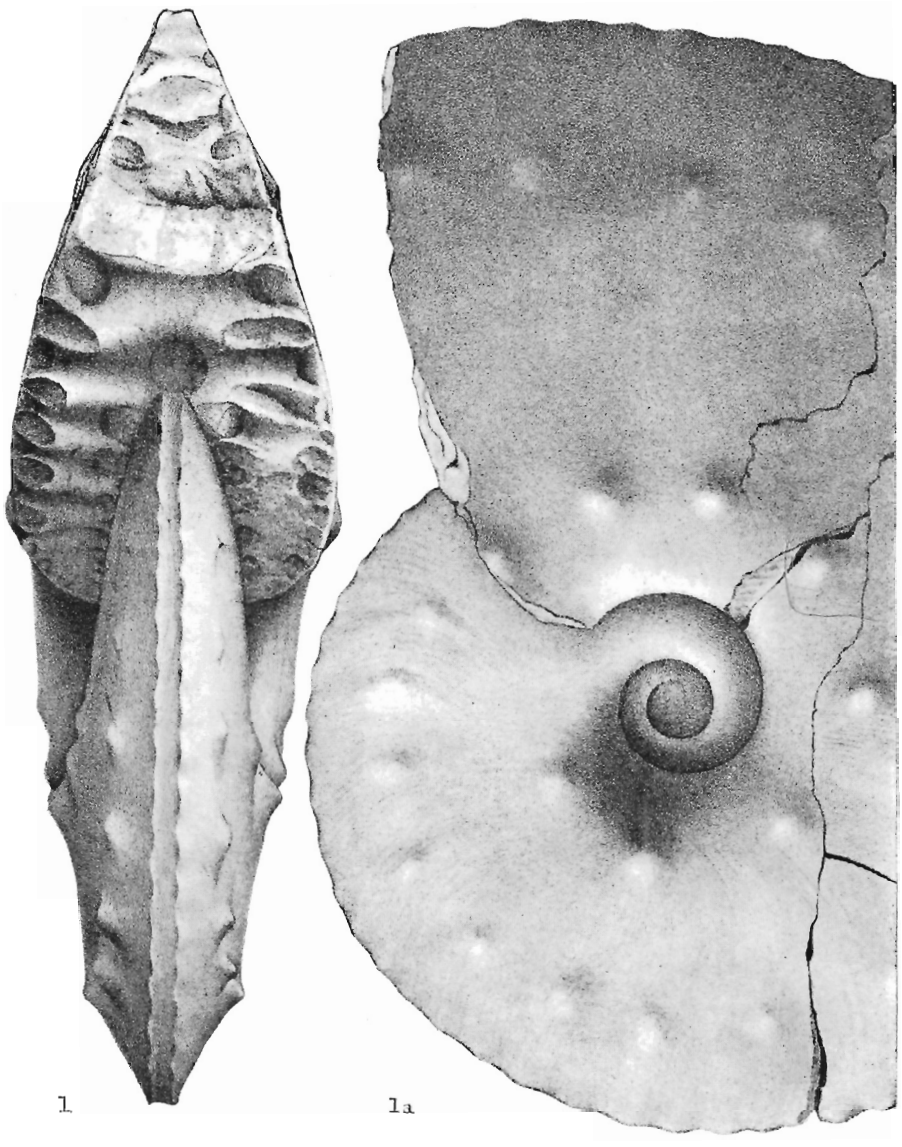
EXPLANATION OF PLATE XXXIII.

Reproductions of plates illustrating marine forms of fossil invertebrates found in rocks of the Montana group.

Figure 1, 1a. *Placenticeras placenta* var. *intercalare* Meek (page 32).
From U. S. Geol. Survey of Territories, vol. IX, pl. XXIII, figs. 1a, 1b.

PLATE XXXIII.



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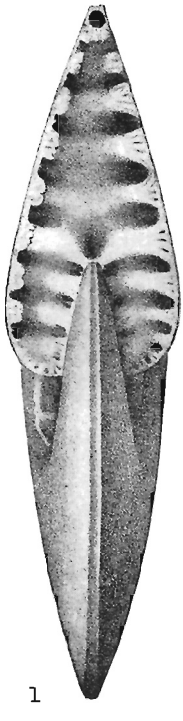
EXPLANATION OF PLATE XXXIV.

Reproductions of plates illustrating marine forms of fossil invertebrates found in rocks of the Montana group.

Figure 1, 1a. *Placenticeras placenta* DeKay (page 32).
From U. S. Geol. Survey of Territories, vol. IX, pl. XXIV, figs. 2a, 2b.

2, 2a. *Nautilus dekayi* Morton (page 32).
From U. S. Geol. Survey of Territories, vol. IX, pl. XXVII, figs. 1a, 1b.

PLATE XXXIV.



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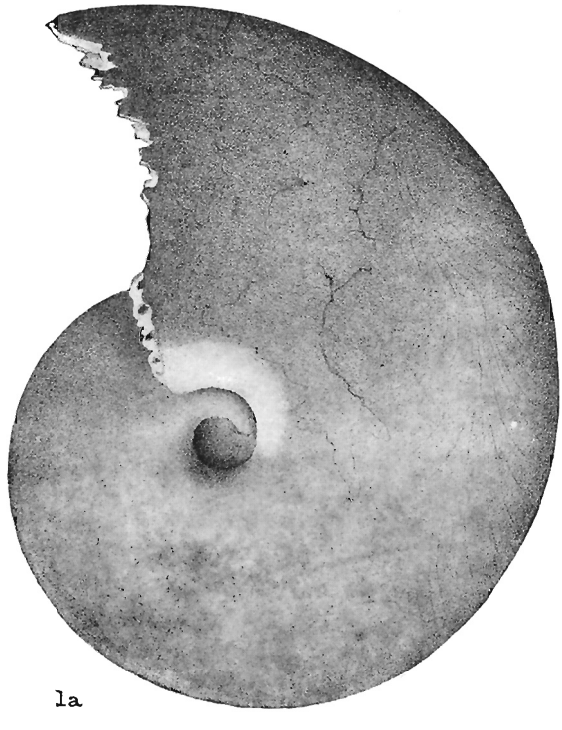

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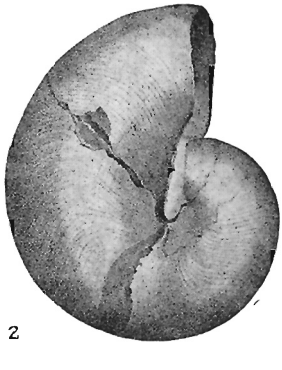

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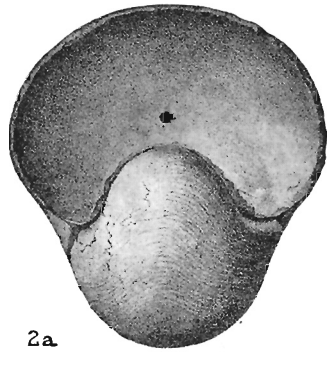

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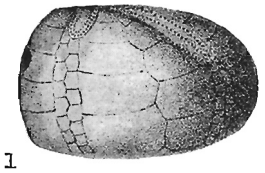
EXPLANATION OF PLATE XXXV.

Reproductions of plates illustrating marine forms of fossil invertebrates found in rocks of the Montana group.

Figure 1, 1a, 1b, 1c. *Hemiaster humphreysianus* Meek and Hayden (page 47).
From U. S. Geol. Survey of Territories, vol. IX, pl. X, figs. 1a, 1b, 1c, 1d.

2. *Palæastacus* (?) *ornatus* Whiteaves (page 32).
From G. S. C. Cont. to Can. Pal., vol. I, pl. XXV, fig. 3.

PLATE XXXV.



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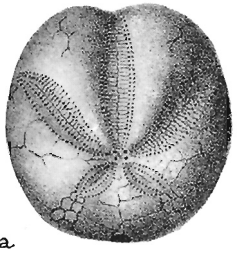

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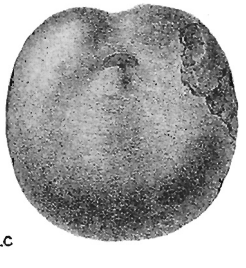

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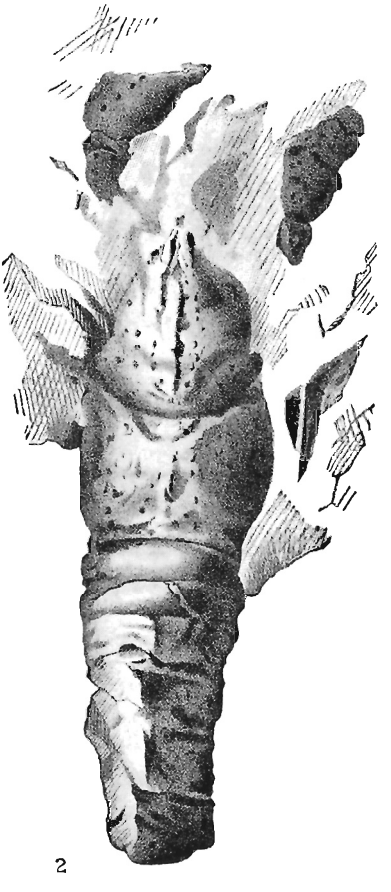

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PUBLICATIONS OF THE GEOLOGICAL SURVEY.

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

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

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

Publications Issued Since 1909.

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

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

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

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

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

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

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

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

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

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

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

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

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MEMOIR 93. *Geological Series 78.* The southern plains of Alberta—by D. B. Dowling. (In press.)

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The Museum Bulletins, published by the Geological Survey, are numbered consecutively and are given a series number in addition, thus: Geological Series No. 1, 2, 3, etc.; Biological Series No. 1, 2, 3, etc.; Anthropological Series No. 1, 2, 3, etc.

In the case of Bulletins 1 and 2, which contain articles on various subjects each article has been assigned a separate series number.

The first Bulletin was entitled *Victoria Memorial Museum Bulletin*; subsequent issues have been called *Museum Bulletins*.

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Geological Series 3. The occurrence of Helodont teeth at Roche Miette and vicinity, Alberta—by L. M. Lambe.

Geological Series 4. Notes on Cyclocystoides—by P. E. Raymond.

Geological Series 5. Notes on some new and old Trilobites in the Victoria Memorial Museum—by P. E. Raymond.

Geological Series 6. Description of some new Asaphidae—by P. E. Raymond.

Geological Series 7. Two new species of Tetradium—by P. E. Raymond.

Geological Series 8. Revision of the species which have been referred to the genus Bathyurus (preliminary report)—by P. E. Raymond.

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Geological Series 10. A new genus of dicotyledonous plant from the Tertiary of Kettle river, British Columbia—by W. J. Wilson.

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MUS. BULL. 20. *Geological Series 29.* An Eurypterid horizon in the Niagara formation of Ontario, 1915—by M. Y. Williams.

MUS. BULL. 21. *Geological Series 30.* Notes on the geology and palæontology of the lower Saskatchewan River valley, 1915—by E. M. Kindle.

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