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OIL & GAS,
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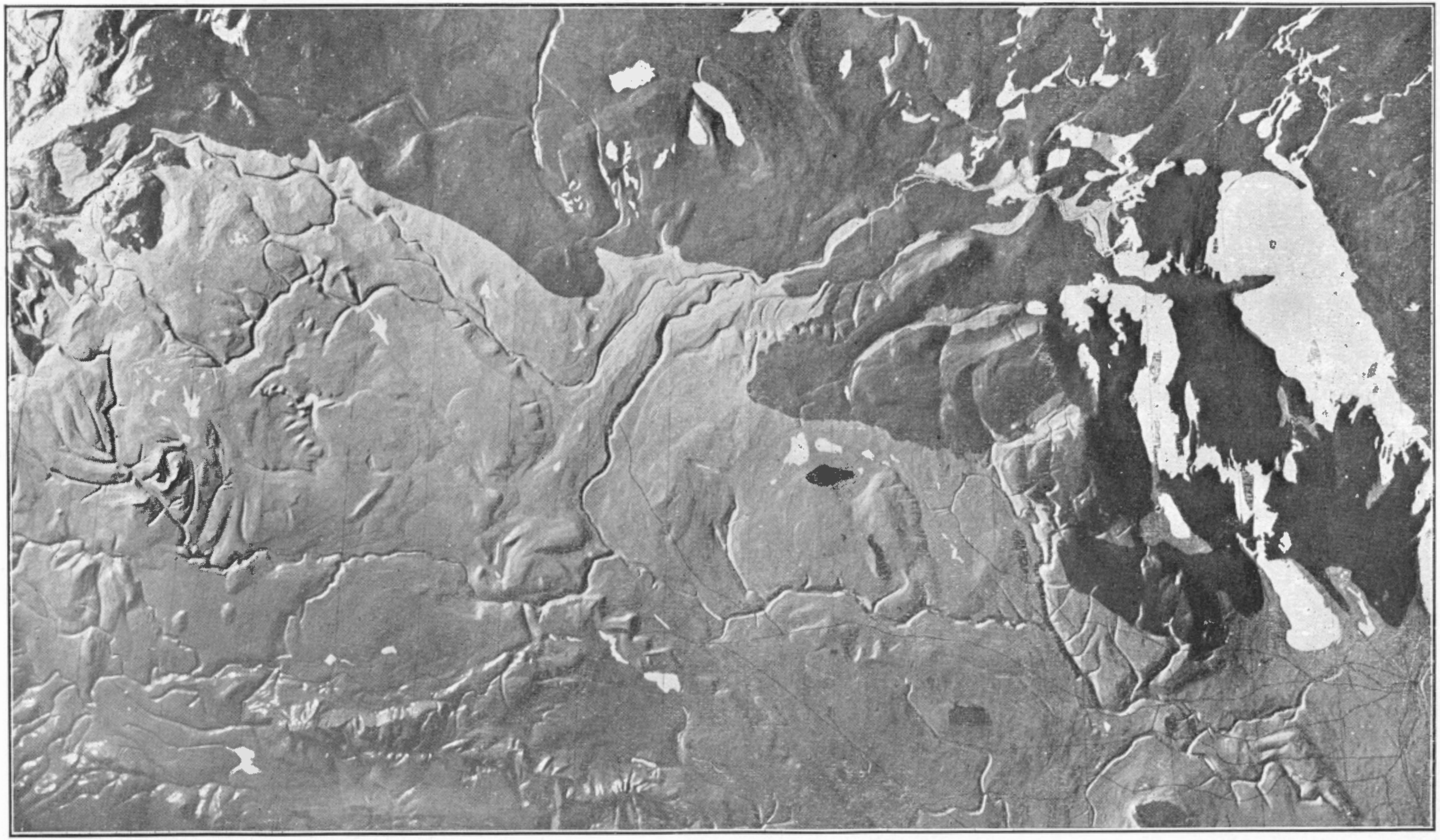

From a model by D. B. Dowling.

Relief map of the country between the Foothills and Lake Winnipeg. Wooded country shaded.

CANADA
DEPARTMENT OF MINES
GEOLOGICAL SURVEY

Hon. Robert Rogers, Minister; A. P. Low, Deputy Minister;
R. W. Brock, Director.

MEMOIR No. 29—E

OIL AND GAS PROSPECTS

OF THE

NORTHWEST PROVINCES

OF

CANADA

BY

WYATT MALCOLM

OTTAWA
GOVERNMENT PRINTING BUREAU
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No. 1220

To R. W. Brock, Esq.,

Director Geological Survey,

Department of Mines.

Sir,—I beg to submit the following memoir on the Oil and Gas Prospects of the Northwest Provinces of Canada.

I have the honour to be, sir,

Your obedient servant,

Wyatt Malcolm.

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OIL AND GAS PROSPECTS OF THE NORTHWEST PROVINCES OF CANADA.

BY

Wyatt Malcolm.

INTRODUCTION.

General Statement.

This memoir is a compilation of information obtained in great part from the reports of Canadian geologists. The object is to lay before the public what is known regarding the oil and gas possibilities of the northwestern provinces of Canada. To this end it was thought advisable to present in a concise form the geological conditions to be met, and for the benefit of those who are interested in boring operations stress is laid on the lithology and thickness of the different geological formations. Logs of wells of different localities are also given, and evidence bearing on gas and oil production and possibilities is presented.

The author is indebted to D. B. Dowling for reading the manuscript and for helpful criticism.

Location and Area.

The area to be described embraces nearly the whole of the Provinces of Manitoba, Saskatchewan, and Alberta. It is that part of the northwest bounded by the 49th parallel on the south, the Rocky mountains on the west, Peace river on the north, Lake Winnipeg on the east, and a line joining Lakes Winnipeg and Athabaska on the northeast.

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SUMMARY AND CONCLUSIONS.

The plains of western Canada are underlain by a great body of sediments, nearly horizontal in attitude, and resting on a Pre-Cambrian base. The eastern contact between the Pre-Cambrian rocks and the later formations runs in a generally northwest direction from Lake Manitoba past Athabaska, Great Slave, and Great Bear lakes. In the eastern part of the plains a great unconformity exists between the Palæozoic systems, consisting of limestones, dolomites, and shales, and the Cretaceous system, consisting of shales and sandstones, so that we find the Dakota sandstones of the Cretaceous system resting directly upon limestones of the Devonian system. The Palæozoic strata are exposed by faulting in the Rocky mountains and much of the later sediments has been eroded, only traces of the lower members being left. In the west, deposition during Carboniferous, Triassic, and Jurassic times has to a great extent bridged over the unconformity seen in the east, and the geological column includes formations found in nearly all the great systems from the Cambrian to the Recent. In western Alberta and in some parts of south Saskatchewan the Cretaceous sediments are overlain by Tertiary deposits. Overlying all is a mantle of unconsolidated Pleistocene and Recent deposits.

Little has been done yet to test the gas and oil possibilities of the district. A few wells have been sunk, and in a number of these gas in commercial quantities has been struck. Prospecting for oil has been less successful.

Prospecting for oil has been carried on in two different areas in the Pincher Creek district, southwestern Alberta, one on the south branch of the south fork of Oldman river, and the other on Oil creek, which flows into Waterton lake. This has apparently resulted in no great measure of success. In northern Alberta the Dakota sandstone, where exposed along the Athabaska and its tributaries, is impregnated with a bituminous substance believed to be a petroleum product, and it is thought that liquid petroleum exists in this porous rock at some distance from the outcrop. To test the validity of this belief, wells were drilled during the nineties by the Dominion Government at Victoria on the Saskatchewan, at Athabaska Landing, and at the mouth of Pelican river. In the first two wells the Dakota sandstone was not reached, while in the last it was reached at a depth of

750 feet, penetrated about 87 feet, and found to carry maltha or heavy, tarry petroleum.

Prospecting for gas has been much more encouraging. The boring at the mouth of Pelican river, although disappointing so far as oil is concerned, proved the presence of a great reservoir of gas in the Dakota sandstones, and heavy flows were struck at 820 and 837 feet. In southern Alberta, also, gas is found in paying quantities. A good field exists at Medicine Hat, and flows have been obtained at several different points west of that city. At Bow island a flow of several million feet is obtained.

Thus, while the presence of oil in commercial quantities remains to be proved, boring operations have demonstrated beyond a doubt the existence of large reservoirs of natural gas, and it seems probable that further exploratory work throughout the wide area underlain by the Cretaceous rocks should lead to the discovery of other reservoirs.

It is believed that the Devonian limestone is the source of the gas and petroleum products of northern Alberta, while the porous Dakota sandstone forms the reservoir into which they have risen and in which they have been retained by the overlying shales. The Dakota sandstone is the productive formation at the mouth of Pelican river, and it is also believed to be the gas-bearing formation at Bow island in southern Alberta. As the Devonian limestone and Dakota sandstone are of wide distribution and probably underlie the western part of Manitoba and a great part of Saskatchewan and Alberta, the prospects for the discovery of other gas fields seem favourable. On account of the great thickness of sediments overlying these formations, the driller, however, must be prepared to go to a considerable depth.

[1] GENERAL CHARACTER OF THE DISTRICT.

Topography.

"The topography of the district included within the provinces discussed in the following report, consists of many diverse types, due both to structure and erosion. The most prominent feature is the Rocky mountains. This series of ranges, as will be seen from maps of such areas as the Crowsnest or Cascade coal fields, is merely a

[1] Dowling, Coal Fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia, p. 16.

series of inclined blocks of the harder rocks upon which the softer Cretaceous beds have been laid.

"They present a rugged outline and steep faces from weathering and glacial erosion; but their topographic features do not indicate great age, as is shown by the close connexion between their structure and present form.

"The three provinces to the east of the mountains, although generally called plains, are in reality undulating table lands, which may be divided roughly into four topographic divisions:—

"The first consists of a plain lying upon the Archæan floor, from which all but the Palæozoic rocks have been removed; and in Manitoba this is smoothed over by deposits of glacial drift and by the sediments laid down by the glacial lake Agassiz.

"The second is a plateau which has for its eastern edge the northeastern escarpment of the Cretaceous shaly deposits.

"The third division is more diverse in character; but is roughly outlined on its eastern edge by the elevation known as the Coteau. The rocks which are exposed throughout this division have a larger proportion of sandstones among them than in the second. To this, no doubt, is due the greater relief in the topography.

"The fourth division may be called the foothills area, and the character of its topography is due more to structure than to drainage denudation. The foothills consist generally of ridges of inclined strata running parallel to the Rocky mountains, cut through at intervals by stream valleys.

"First division.—This is the lowest in elevation and is essentially a region of lakes, with the exception of the southern end, which is covered by silts and clays of lacustrine deposition—now forming the fine farming lands of southern Manitoba. The drainage is northward to the Nelson river, which flows to Hudson bay. The surface features east and north of Lake Winnipeg differ from those to the west in that this eastern part is mostly of the mammillated character usually found in a country underlain by Archæan rocks, with but a thin mantle of surface drift.

"Second division.—The second topographic division consists of a plateau formed of shales and other soft rocks. The surface has suffered great denudation, so that its general elevation is hard to estimate; but a large portion of the area is nearly 1,000 feet above the level of the Manitoba lakes. Several valleys have been eroded through the escarpment. The wider openings are those through which flow the Assiniboine and Saskatchewan rivers, whose valleys, back from the face of the escarpment, show as deep narrow cuts with frequent scarped banks. The eastern edge of this plateau between the indentations formed by drainage channels forms the elevations known as the Pembina, Riding, Duck, Porcupine, and Pas mountains.

"In this division the drainage is divided between the general eastern drainage of the Qu'Appelle, Assiniboine, and Souris waters, and the northeastern drainage of the Saskatchewan.

"Third division.—This, extending from the Coteau to the foothills, may be considered as consisting of three sloping planes from which its recent topography has been derived. The dividing lines between these three planes are: the watershed between the two branches of the Saskatchewan, and the valley of the Belly river. North of the watershed mentioned, the country slopes generally from the mountains northeasterly, and is drained radially by streams that run to Hudson bay and the Mackenzie valley. South from this the slope is southeastward to the depression occupied by the Belly river. Southward again the slope changes to nearly east; but following the valley of the south Saskatchewan we find north of the Cypress hills and Wood mountains a slope to the north.

"On these plains the relief is very much accentuated by the fact, that much of the country is bare of timber; but elevations such as the Cypress hills, standing 2,500 feet above the level of the railway at Irvine, or the Hand hills, which are 800 feet above the surrounding plain, become pronounced topographic features.

"Fourth division.—The topography of the foothills is much more diverse than that of the other three previously discussed. From the south the foothill area gradually widens to the north, and in the valley of the Crowsnest river, as it emerges from the mountains, the erosion has narrowed the foothill belt to a few miles. . . . . .

Communication.

"The natural means of communication by waterways is restricted to the navigation of some of the lakes in Manitoba, and the streams crossing the plains. The streams are navigable only at high water; and they all have strong currents; hence the difficulties of navigation from shallow water and current combined are so great that over-land transport is necessary. This is being supplied by the railway lines which traverse the area, generally in an east and west direction. The main line of the Canadian Pacific railway was the first through line connecting the eastern and western adjacent portions of Canada. It crosses the Rocky mountains by the Bow River valley through the Kicking Horse pass. Subsequently, branches from St. Paul to Moose-jaw, and from Medicine Hat to Kootenay Landing passed through the coal mining districts of Souris river and the Crowsnest pass. Two transcontinental lines now building—the Canadian Northern and the Grand Trunk Pacific—reach from Winnipeg to Edmonton. A third line—a branch of the Canadian Pacific—will shortly be completed to the same point. Transverse roads are also included in the present general scheme: such as the railway from Edmonton to Calgary; that from Calgary to McLeod; and McLeod to a connexion in Montana. Another transverse route is provided by the Canadian Pacific and Canadian Northern branches from Prince Albert to Portal, on the Dakota boundary. The third set of transverse roads includes a number in Manitoba. An outlet to Hudson bay is also being located from the lower part of the Saskatchewan." It is probable also that not many years will elapse before one or more railways are run north to open up the Athabaska and Peace River district.

Commercial Possibilities.

The world is waking to the possibilities of the great western plains of Canada as an agricultural country. There is every year a great influx of settlers from Europe, the United States, and the older Canadian provinces, and this will continue until the Northwest becomes the home of millions of agriculturists. Towns are rapidly springing up as distributing centres, and villages are growing into cities. With the increase of population will come an increased demand for material for light and fuel, so that the finding of a market for oil and gas will be an easy problem, and the demand will be sufficient to greatly stimulate the efforts of drillers.

GENERAL GEOLOGY.

General Statement.

In the area under study nearly all of the great geological systems are represented, from the Pre-Cambrian to the Recent or Post-Pleistocene. The Palæozoic sediments consist chiefly of limestones and shales, while those of later age consist of shales and sandstones. Throughout the great plain these sediments lie nearly horizontal, although they are affected more or less by slight local undulations. Towards the Rocky mountains a downward warping of the strata forms a broad trough occupying a large part of Alberta and extending from the 112th meridian to the foot-hills. East of this trough is a broad anticline. In the foot-hills and in the Rocky mountains there is a great deal of folding and faulting, and the mountains consist of a series of great thrust fault blocks. The Palæozoic and Mesozoic sediments are widely distributed, while those of later age are more restricted in their distribution and lie in the great Alberta trough or form scattered elevations that have resisted erosion. To the west the Palæozoic and Mesozoic rocks are exposed through the agency of faulting, and to the east and north through absence of overlapping deposition and to some extent by subsequent erosion of the overlying beds. Good sections are also obtained in the erosion valleys of such rivers as the Athabaska and Peace.

A much greater volume of sediments is exposed in the west than in Manitoba or northern Alberta. In the west also the geological column is nearly complete, while in the east and north unconformities exist representing great intervals of time. In the Rocky mountains great bodies of argillites followed above by limestones were deposited during Cambrian times to a thickness of many thousand feet, but in Manitoba no rocks of this age are to be found. Ordovician limestones and shales, while of great thickness in the mountains, are only about 500 feet thick in Manitoba. The Silurian dolomites and quartzites of the Rockies are 1,300 feet thick, while Silurian limestones of Manitoba are only 200 feet, and the Devonian dolomites of the Rockies are 1,500 feet, while those of Manitoba are only 500 feet. In the Rocky mountains and foot-hills there is a thickness of more than 7,000 feet of Carboniferous shales, limestones, and quartzites, of more than 1,200 feet of Permo-Triassic shales, of 1,600 feet of Jurassic shales, and of 375 feet of Kootanie shales and sandstones;

while in Manitoba and Saskatchewan no traces of these are seen, and strata of the Dakota group of the Cretaceous system rest directly upon Devonian limestones. Rocks of the Dakota, Colorado, and Montana groups of the Cretaceous system are widely distributed, and sections of these are seen on Athabaska and Peace rivers, in Manitoba and in the foot-hills, while exposures of the upper beds are seen in a great many places over the great plain. These do not vary so much in aggregate thickness, but, like the other systems, the Cretaceous is also thicker towards the west. The Laramie is represented by a great thickness of sandstones and shales lying in the broad Alberta trough and by a much diminished thickness in the scattered elevations of southern Saskatchewan. Some of these elevations are capped by coarse deposits of Tertiary age, and overlying the whole plain is a mantle of glacial drift and lacustrine deposits.

Description of Formations.

Owing to the impossibility of correlating many of the formations found in one part of the district with those of the same system in another part, no single table of formations can be given. Nearly all of the great geological systems are represented, and, along with the descriptions of these, will be given partial tables of the formations found in different localities. Under the heading "Economic Geology" will also be given various sections, which it is hoped will be of use to those engaged in boring operations.

CAMBRIAN.

While some sediments of Palæozoic age underlie the whole of the area under consideration, outcropping along its eastern and western edges and extending northwest into the basin of the Mackenzie river and south a great distance into the United States, the different Palæozoic systems have by no means equal distribution. The Cambrian rocks attain a great thickness in the Rocky mountains where they are brought to the surface by folding and extensive faulting. They have a great extent north and south, and outcrops, more or less elongated in the direction of the mountain ranges, extend from the 49th parallel northwestward into the northeastern part of British Columbia. They are also found in the Mackenzie mountains, the continuation of the Rocky Mountain system into that portion of country lying immediately east of the Yukon territory.[1] The east and west extension of the Cambrian system, however, is not so great, and nowhere in Manitoba or Saskatchewan have outcrops of this system been found, nor in Alberta beyond the Rocky Mountain system. It probably undergoes a rapid thinning from the Rocky mountains eastward, for in the northern part of the Black hills of South Dakota it has a thickness of only a little over 300 feet and thins down gradually to the southeast.[2] As exposed in the Black hills it is known as the Deadwood formation, and is equivalent to the middle Cambrian of the Rocky mountains. It consists of conglomerate, quartzite, ferruginous sandstone and many alternations of green shale, limestone breccias, and fucoidal limestone flags, while at the top are found Scolithus sandstone or quartzite and thick green shales.[3]

Regarding the rocks of Cambrian age lying in the Rocky mountains between latitudes 49° and 51° 30′, Dawson says[4]: "Of the rocks referred to throughout this report as Cambrian no complete general section can be offered. So far as this district is concerned, they form the basal formation, and it will probably be necessary to seek their actually lowest beds in the Purcell or Selkirk ranges, in which it is probable that they occur in conjunction with still older crystalline rocks. The component beds of the great Cambrian series are, in the main, quartzites and quartzitic shales, passing into argillites, and occasionally including limestone or more or less calcareous or dolomitic materials, and conglomerates. Sheets of contemporaneous trap also occur, probably at several horizons. The colours of these beds are extremely varied, and though, as a rule, considerably indurated, they seldom show traces of metamorphism resulting in the production of crystalline minerals.

"The most instructive section obtained of a portion of the Cambrian formation is that found near Waterton lake, and in the eastern part of the South Kootanie pass. This embraces a thickness of about 3,000 feet. . . . . .

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1 Joseph Keele. A Reconnaissance across the Mackenzie Mountains on the Pelly, Ross, and Gravel Rivers, p. 36.

2 N. H. Darton. Twenty-first Annual Report U. S. Geol. Survey, Part IV, p. 505.

3 T. A. Jaggar, Jr. Economic Resources of the Northern Black Hills. U. S. Geol. Survey. Professional Paper No. 26, p. 21.

4 G. M. Dawson. Preliminary Report on the Physical and Geological Features of that Portion of the Rocky Mountains between Latitudes 49° and 51° 30′. Geol. Survey, Canada, I, 157 B.

"Between the eastern summit of the South Kootanie pass and the Flathead river, the minimum estimated thickness of the outcropping Cambrian beds is 11,000 feet, but the section includes neither the summit nor the base of the series. Other sections show a probable thickness of over 5,000 feet for a part of the series, but none were found in which its whole volume could be ascertained."

Some difference of opinion is held regarding the age of the series. While R. A. Daly agrees with Dawson[1] in placing these sediments in the Cambrian system, C. D. Walcott, of the Smithsonian Institution, believes them to be Pre-Cambrian.

The Cambrian exposed in the Rocky mountains along the main line of the Canadian Pacific railway is represented by two series, the Bow River group and the lower part of the Castle Mountain group. [1] Walcott gives a detailed classification of these, and regards as Pre-Cambrian the shales of the Bow River group on which he finds the conglomerates resting unconformably.

Bow River Series.—According to McConnell,[2] "the Bow River group forms the basal member of the section in this part of the mountains, and, as developed along the line of railway, consists mainly of a great series of dark-coloured argillites, associated with some sandstones, quartzites, and conglomerates. The base is not seen, but the part exposed has an estimated thickness of 10,000 feet.

"The argillites are usually dark-greyish in colour, but become greenish and purplish in places, are very impure, and frequently grade into flaggy sandstones, which are often slightly calcareous. The small quantity of lime present is due, doubtless, in most cases to a decomposition of the feldspathic constituents of the rock. They are hardened and occasionally cleaved, and scales of mica are often developed along divisional planes, but on the whole show comparatively little alteration for beds of this age."

The conglomerates characterize more especially the top of the series, and occur in thick beds alternating with quartzites and shales. They are hard and unyielding, carry pebbles of milky or semi-transparent quartz and fresh-looking, whitish feldspar. The matrix contains an abundance of pale mica.

The quartzites are found chiefly in the upper part of the series.

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[1] Smithsonian Miscellaneous Collections Vol. 53, No. 5 (1908) and No. 7 (1910).
[2] R. G. McConnell, The Geological Structure of a portion of the Rock Mountains. Geol. Survey, Canada, II, 29 D.

They are largely developed in the watershed range between Eldon and Laggan.

"The Bow River series occupies the wide longitudinal valley east of the watershed range, and is met with all along the line of railway between Silver City and Stephen . . . . It is possible that some of the schistose rocks of the Ottertail and Beaverfoot valleys, which have been referred to the Castle Mountain group, may belong to this series."

In the Yellowhead[1] pass the Bow River series consists of about equal thicknesses of black argillite and pinkish and greenish quartz-conglomerate. The latter is usually squeezed into a schistose-conglomerate with more or less development of sericite, and in some places the alteration is so complete as to produce a mica-schist.

Farther north, on the Omineca and Finlay rivers the Shuswap series[2] is overlain by a band of slates, quartzites, and conglomerates similar in lithological character and in geological position to the Bow River series farther south, and like it probably referable to the lower and middle Cambrian. The conglomerates consist principally of small rounded quartz and feldspar pebbles embedded in a hard siliceous matrix. A characteristic of the conglomerates of the Bow River series is the purplish colour of many of the quartz grains. In places they are greatly crushed and become quite schistose. On the Omineca the series attains a thickness of about 4,000 feet.

Castle Mountain Group.—The Castle Mountain group has been described by McConnell as occurring along the main line of the Canadian Pacific railway and on the Omineca river, and has been recognized by McEvoy in the Yellowhead pass. It ranges in age from the middle Cambrian up into the Ordovician.

Along the Canadian Pacific railway this group has a minimum thickness of 7,700 feet, but as the whole series was never seen in one section, it is highly probable that the total volume approaches 10,000 feet.[3] It overlies the Bow River series, and in the eastern ranges it is overlain by the intermediate limestone of Devonian age, and in the west, along the Columbia river, by graptolitic shales of Ordovician age.

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[1] J. McEvoy. Geol. Survey, Canada. Notes on map showing Yellowhead Pass Route from Edmonton to Tête Jaune Cache.

[2] R. G. McConnell. An Exploration on the Finlay and Omineca Rivers. Geol. Survey, Canada, VII, 34 C.

[3] R. G. McConnell. Geol. Survey, Canada, II, 24 D.

"The Castle Mountain group is essentially a limestone formation, and consists of ordinary and magnesian limestones, together with every gradation between them and calcareous shales and schists. Its mode of stratification, like its composition, and dependent upon it, is very variable, and massive beds of hard limestone are often replaced in the course of a few miles, by cleavable calc-schists and soft shales. The beds are more persistent along the strike than in a transverse direction, and the harder bands project as longitudinal ridges, often of great length, separated by valleys, which mark the position of the softer varieties." As a rule the strata are more dolomitic and more heavily bedded near the base of the column, and become more shaly and calcareous above, although the sequence and relative importance of the various members of the group differ widely in different sections. The dolomites of the Castle Mountain range occur in heavy beds, often several feet thick, and on fresh fracture have a greyish or banded appearance. A large portion of the rocks of this group consists of mixtures of dolomites and limestones in various proportions, while a great series of greenish calc-schists, and greenish and reddish shales and slates associated with the limestones and dolomite, is found in the Wapta valley.

In the Yellowhead pass[1] the rocks of this group consist of "grey quartzites with slaty layers between the beds, some black slates, banded grey and yellowish sericite schist holding crystals of iron-pyrites, lead-grey wrinkled sericite-schist, dark-blue limestone and cream-coloured crystalline limestone."

A grey limestone formation passing in places into a calc-schist is found in the Peace River pass and on the Omineca and Finlay rivers.[2] It overlies the Bow River conglomerates, although in many places the latter are absent, either from non-deposition or in consequence of faulting, and the limestone comes in direct contact with the Shuswap series. No fossils were found in the limestones, but they probably range from the middle Cambrian to the Ordovician.

The Athabaska sandstone, which is probably of Cambrian or Pre-Cambrian age, lies to the south and east of Lake Athabaska. It is coarsely granular in texture, passing in places into a conglomerate, and is white to dull red in colour. A vertical section of 400 feet was obtained near the east end of Lake Athabaska.

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[1] J. McEvoy. Geol. Survey, Canada. Map of the Yellowhead Pass Route.
[2] R. G. McConnell. Geol. Survey, Canada, VII, 34 C.

ORDOVICIAN.

The upper part of the Castle Mountain group, which has already been described, belongs to the Ordovician system. In addition to this there have been recognized, in the Kicking Horse pass and in the Mackenzie mountains east of Yukon, series of rocks that have been referred to this system. Little, however, seems to be known of their distribution between these two widely separated points. In the eastern part of the area under study outcroppings show the existence of an elongated zone of Ordovician strata running through Manitoba, along the west shore of Lake Winnipeg, and including the islands of that lake. It bears a little west of north, extending some distance north of the lake where it turns more towards the west, narrows down, and is finally concealed by the Devonian system beyond Lake Ile a la Crosse. The strata dip slightly to the southwest and pass below the strata of later age, but the extent of the system in that direction is not known.

The Graptolitic Shales.—The Ordovician system is represented in the Kicking Horse pass by the Graptolitic shales.[1] "They occupy an intermediate position between the Halysites beds and the Castle Mountain group, into both of which they appear to graduate. They have a thickness of about 1,500 feet in the Beaverfoot range, south of Palliser, but thin out considerably going north towards the Wapta canyon. They consist, as a rule, of hard black or nearly black shales, are very fissile and separate easily into regular slate-like laminæ, but sections are also found showing much disturbance . . . . In some sections the shales alternate with small beds of limestone, and near the top are occasionally associated with quartzites and dolomites." The Graptolitic shales, like the Halysites beds, which they accompany, were not detected in the eastern part of the mountains. The graptolites from this formation may, according to Professor Lapworth,[2] be referred to the age of the Utica slate, or at any rate to the Trenton-Utica fauna of the United States and Canada.

Ordovician of Manitoba and Saskatchewan.—The Ordovician system rests directly on the Archæan at the east and, dipping to the southwest at a very low angle, is overlain conformably by the Silurian system. The lowest member is a sandstone. This is overlain by shales and limestones, bearing fossils of Trenton age, and followed

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[1] R. G. McConnell. Geol. Survey, Canada, II, 22 D.
[2] Geol. Survey, Canada, II, 23 D.

above by red shales and reddish and white limestones referred to the Hudson River or Cincinnati formation. The following table[1] of formations for Minnesota and Manitoba shows the relative position assigned to each:—

Formations in Minnesota.				Formations in Manitoba.	
Hudson River or Cincinnati Period.	Richmond group Utica group.			Stony Mountain Utica?	Limestones and shales.
Trenton Period.	Trenton group.	Maclurea beds.	Trenton Period.	Trenton.	Upper mottled limestone.
		Fusispira and Nematopora beds.			Cat Head limestone.
		Clitambonites beds.			Lower mottled limestone.
	Black River group.	Fucoid and Phylloporina beds.		Black River?	Winnipeg sandstone and shales.
		Ctenodonta beds.			
		Rhinidictya bed.			
	Stones River group.	Strictoporella bed.			
		Vanuxemia bed.			
		"Lower Banff."			
	Chazy formation.	St. Peter Sandstone.			

The Winnipeg sandstone and shales are of varying thickness owing to the unevenness of the floor on which they were deposited. The thickness of the pure sandstone in the Lake Winnipeg basin is apparently much less than to the south. At Grindstone point a section of 40 feet is exposed, while a channel on the lake in front of the exposure cuts 50 feet deeper into these beds. At Black island exposures of similar beds form a continuous section of about 100 feet.[2] This basal series thins out towards the north, and in the area north of Lake Winnipeg it attains a thickness of only 10 to 20 feet of soft and rather coarse sandstone.

1 D. B. Dowling. Geol. Survey, Canada, XI, 35 F.
D. B. Dowling. Geol. Survey, Canada, XI, 39 F.

The formation consists of soft friable sandstones, generally shaly in the upper part. They are generally light coloured, but in places are darkly stained with iron. The upper part seems to consist mainly of shales in the southern part of Manitoba. The fossils found in Manitoba suggest a passage from the Black River to the Trenton. In Minnesota the Black River[1] is composed mainly of greenish shales, and the shales below the limestone in the borings at Rosenfeld and Selkirk may be taken as the passage beds from the Black River. On the other hand the basal sandstone found on Reed lake in the area north of Lake Winnipeg is evidently of later age than farther south, and is immediately below beds that on Lake Winnipeg are called the Upper Mottled. Fossils collected by J. B. Tyrrell from these sandstones belong to the middle and upper part of the Trenton.[2]

The Trenton of Manitoba is subdivided into three parts, the Lower Mottled limestone, the Cat Head limestone, and the Upper Mottled limestone. Division is made on broad distinctions in the general appearance of the rocks as well as on evidence furnished by the fauna. The thickness of the series near Winnipeg is about 295 feet, and in a well at Rosenfeld the measured thickness of this limestone band is 305 feet. There is a thinning out towards the north, and on Reed lake the Upper Mottled limestone rests directly on the basal sandstone formation.

The Lower Mottled limestone is the lowest member of the series. This limestone forms the principal part of the sections at Grindstone point, Bull head, and Dog head, and on the islands north to Berens island. The section given by these several exposures amounts to a thickness of about 70 feet. The formation consists of a dark-yellowish to greyish-white mottled limestone,[3] some beds of which are quite fossiliferous.

The Cat Head limestone, of which good exposures are seen at Cat head, is the middle member of the series, and has a thickness of about 70 feet. It consists of fine-grained, evenly coloured, yellow, dolomitic limestone, with numerous concretions of dark coloured chert. The lower beds resemble lithographic limestone and are very rich in fossils.

The Upper Mottled limestone is obtained from the quarries at East Selkirk, and used as a building stone in Winnipeg. Exposures

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[1] D. B. Dowling. Geol. Survey, Canada, XI, 39 F.
[2] D. B. Dowling. Geol. Survey, Canada, XIII, 11 F.
[3] D. B. Dowling. Geol. Survey, Canada, XI, 38 F.

are found in the valley of the Red river, at a few points on the west shore of Lake Winnipeg, and in the area north of this lake. It has a thickness of about 130 feet. In Manitoba it rests on the Cat Head limestone, but in the escarpment running northwest from Lake Winnipeg and forming the edge of the Trenton the Lower Mottled and Cat Head limestones thin out and disappear, so that on Reed lake the Upper Mottled limestone rests directly on the basal sandstones.[1] The formation consists of light-yellowish, mottled, dolomitic limestone. It is more or less fossiliferous. Some beds exposed near the northern end of Lake Winnipeg are quite porous and contain impressions of salt crystals.[2] On Namew lake the limestone is for the most part thick-bedded and of a yellowish-grey colour, but some of the lower beds south of Wekusko lake have a reddish colour, which is sometimes rather blotchy.[3]

The Stony Mountain formation has not so wide a distribution apparently as the underlying limestone. The only natural exposures are at Stony mountain and Little Stony mountain. It is shown by bore-holes to extend from Stonewall southeastward to the vicinity of Winnipeg.[4] In the Rosenfeld well-section the 190 feet of shaly beds and limestone overlying the 305 feet of limestones representing the Trenton of Lake Winnipeg may be referred to the Stony Mountain formation.[5] Towards the north the formation evidently thins out very much. It was not recognized in the basin of Lake St. Martin, and if it occurs at the north of Lake Winnipeg the thickness cannot be great, for at the Grand rapids of the Saskatchewan the Silurian beds are found near the mouth of the river, and only a short distance eastward the upper beds of the Trenton appear. At Stony mountain a complete section is not obtained, but of the known 110 feet lying below the Silurian the lower part consists of shales and the upper part of thick-bedded limestones. The limestones are greys of various tints, are more or less argillaceous, and some of the beds are quite porous. It is possible that, if the section were complete, the upper beds with part of the shales beneath could be correlated with the Richmond group and the lower shales with the Utica of Minnesota.

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[1] D. B. Dowling. Geol. Survey, Canada, XIII, 11 FF.
[2] D. B. Dowling. Geol. Survey, Canada, XI, 87 F.
[3] J. B. Tyrrell. Geol. Survey, Canada, XIII, 15 F.
[4] D. B. Dowling. Geol. Survey, Canada, XI, 47 F.
[5] D. B. Dowling. Geol. Survey, Canada, XI, 92 F.

SILURIAN.

The distribution of the Silurian system is somewhat similar to that of the Ordovician. Outcroppings have been recognized in the Rocky mountains, in the Beaverfoot range, on the Gravel river, and possibly in the Peace River pass. In the east a zone extends northward through Manitoba to the east of Lakes Manitoba and Winnipegosis, and then turning westward probably underlies the great plain of the lower Saskatchewan and Carrot rivers,[1] passing below the Cretaceous beds to the west. In Manitoba the Silurian passes below Devonian rocks to the west, but its extension in that direction is not known.

The Halysites Beds.—The Silurian in the Beaverfoot range is represented by the Halysites beds overlying the Graptolitic shales. [2] These beds appear to have a very limited distribution, and are found in disconnected strips along the central and more elevated parts of Beaverfoot range. They consist of about 1,300 feet of dolomites and quartzites. The quartzites occupy the lower part of the series, are usually light coloured and occur in even, massive beds. They are dolomitic in places and often pass gradually into the overlying dolomites. The dolomites are very evenly bedded, are light grey to bluish in colour and compact to moderately crystalline in texture. Beds holding Halysites were found in one place in the Peace River pass.

Niagara.—Outcrops of this formation have been traced from Grand rapids westward through Cross lake and Cedar lake, and down the east shore of Lake Winnipegosis from the northeast angle to latitude 52° 32′, and are seen on the Fairford river and at several points on Lake St. Martin.[3] Silurian limestone is also seen on the shores of Cumberland lake, near Cumberland House.[4] Little is known of the system south of the region of the lakes, but some fragments of rock collected from the top beds at Stonewall look as if they might belong to this system. The strata rest on the Ordovician and have a slight dip to the southwest. Some light anticlines have been detected on the east shore of Lake Winnipegosis. Tyrrell says that [5] "though there is considerable local variation in the character of the rock, it

[1] W. McInnes. Geol. Survey, Canada, Summary 1907, p. 47.
[2] R. G. McConnell. Geol. Survey, Canada, II, 22 D.
[3] J. B. Tyrrell. Geol. Survey, Canada, V, 202 E.
[4] J. B. Tyrrell. Geol. Survey, Canada, XIII, 36 F.
[5] Geol. Survey, Canada, V, 202 E.

is doubtful whether the variations are sufficiently persistent to enable the geologist to determine with any degree of accuracy the total thickness of the terrane." He places the thickness at 200 feet, and gives the following description of the strata:—

"Compact, thin-bedded dolomites, found chiefly on the west side of Lake Winnipegosis.

"Compact and porous dolomites containing a considerable number of fossils, seen on Cross lake and vicinity.

"Hard, tough, light-yellowish, dolomitic limestone, seen on the Saskatchewan river at Grand rapids.

"Soft white or light-yellow, chalky or argillaceous limestone, with a number of fossils. Near the bottom is a hard band containing large numbers of *Pentamerus decussatus*." Some of the beds carry numerous impressions of salt crystals, and in the vicinity of Lake St. Martin are some hills composed for the most part of gypsum, while a few consist of anhydrite. The Silurian in the vicinity of Cumberland House consists of thick-bedded white limestone. In some places it is cherty and in other places weathers into a rather soft sponge-like or vesicular mass.

DEVONIAN.

The Devonian system is of wide distribution throughout the western plains, and probably underlies nearly the whole area under study. Outcrops are found along the Rocky mountains. A band runs northward through Manitoba, along and a little west of Lakes Manitoba and Winnipegosis. For some distance northwestward through Saskatchewan it is concealed by the Cretaceous, but in the vicinity of Lac LaRonge a band is again exposed and probably runs northwest to a point a little west of Lake Athabaska, where it widens out and extends in a broad zone down the valley of the Mackenzie. Rocks of this system probably extend from this exposed eastern zone westward to the Rocky mountains, and Schuchert[1] has represented the middle (late Hamilton) and upper Devonic seas as occupying this portion of the earth's surface.

The Intermediate Series.—The representative of the Devonian system in the Rocky mountains has been designated the Intermediate series. In the section in the vicinity of the main line of

[1] Palæogeography of North America. Bull. Geol. Soc. America, Vol. 20, Plates 76 and 77.

the Canadian Pacific railway there is a thickness of about 1,500 feet. It consists chiefly of dolomitic limestone. [1]"The typical dolomites of this formation are dark-brownish in colour, are finely crystalline, and are often irregularly hardened by concretionary action. They have, in many places, a blotched appearance, due to small cavities becoming filled with calcspar, are cherty, and are characterized throughout by an abundance of corals. In some sections a light-greyish variety is not infrequent. It is more coarsely crystalline than the dark variety and is unfossiliferous. In addition to the dolomites, beds and bands of sandstone, quartzite, and calcareous limestone are found all through the series. A light-yellowish siliceous band, varying in thickness from 100 to 400 feet, occurs near its base, on the south fork of Ghost river and along the eastern part of Devils Lake valley, and is also found at the entrance to the White Mans pass." McEvoy,[2] in describing the Devono-Carboniferous system of the Yellowhead pass says, "the lower part is composed of alternating beds of fine-grained bluish and grey limestone and brown, rather crystalline, dolomite. These limestones are more or less siliceous throughout and have numerous cherty bands. Below these the lowest beds seen in the group are chiefly quartzites and dolomitic quartzites." In the Bighorn coal basin the total thickness of the Devonian, comprising the Intermediate beds and Lower Banff limestones, is about 3,250 feet.

Devonian in Manitoba.—Outcrops of this system are found along the eastern shore of the south half of Lake Winnipegosis, along the western shore of the same lake, and on the shores of the north half of Lake Manitoba. The following table of formations is given by Tyrrell[3]:—

"*Upper Devonian or Manitoban*—

Light-grey hard brittle limestone containing *Athyris vittata*, etc., underlaid by red argillites, outcropping at Rose island and vicinity in Swan lake, and at Point Wilkins..	100 feet.
Light-grey hard limestone seen at Onion point, Snake island, Beardy island, etc....	40 "

[1] R. G. McConnell. Geol. Survey, Canada, II, 19 D.
[2] Notes on the map showing the Yellowhead Pass Route from Edmonton to Tête Jaune Cache.
[3] Geol. Survey, Canada, V, 199 E.

Red and grey shale seen near the mouth of Bell river, south of Weston point, etc...	70 feet.
"*Middle Devonian or Winnipegosan—*	
Whitish or light yellow, hard, tough, generally compact, dolomite containing *Stringocephalus Burtini* and numerous other fossils. It outcrops chiefly on the islands and shores of Dawson bay, and southward to Point Richard on Lake Manitoba..	100 "
Porous, spongy, yellow dolomites of Pemmican island, Devils point, Macoun point, etc.... ..	100 "
"*Lower Devonian—*	
These beds have not been clearly defined, but they appear to be composed of red and other shales.	100 "

That the lower Devonian beds are softer than the overlying and underlying rock is shown by the absence of cliffs and by the extended depression along the strike of the beds now largely occupied by Lakes Winnipegosis and Manitoba. The white, tough dolomites of the Winnipegosan formation contain some porous bands with impressions of salt crystals, and the red shales at the bottom of the Manitoban formation are marked almost everywhere along their eastern outcrop by brine springs. At Monkmans salt springs the salt industry was once conducted on a small scale.[1] The boring on Vermilion river gives the following section of a portion of the Devonian system[2]:—

Compact white limestone..	120 feet.
Blue-grey clay shale..	10 "
White gypsum...	15 "
Red shale..	110 "
Shale and limestone..	68 "

[3]As it is probable that these beds represent an upward continuation of the Point Wilkins limestones, and, therefore, in the main, overlie the highest Devonian beds seen on the shores of Swan lake or Lake Winnipegosis, the section adds considerably to the thickness of the Devonian as given above.

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[1] J. B. Tyrrell. Geol. Survey, Canada, V, 165 E.
[2] J. B. Tyrrell. Geol. Survey, Canada, V, 87 E.
[3] J. B. Tyrrell. Geol. Survey, Canada, V, 89 E.

At different points on the shores of Lake Winnipegosis the series is found to be undulating and folded into low local anticlines, or lightly faulted.

On the shore of Lac LaRonge large angular blocks of a buff-coloured dolomite are so numerous as to lead to the belief that strata of the same kind are in place immediately below. Fossils contained in the blocks are of Devonian age, at about the horizon of the "Stringocephalus zone" (middle Devonian).[1]

Devonian in Alberta.—Limestones of Devonian age outcrop on the Firebag, Clearwater, Athabaska, and Peace rivers. On the first three they are overlain by tar sands. On Peace river fossiliferous greyish limestones interbedded with gypsum outcrop from Little rapid down to Peace point, and in the vicinity of Vermilion falls horizontal, evenly bedded, light-greyish or cream-coloured limestone alternates with softer and more argillaceous bands. They are fossiliferous, but do not appear to be bituminous. In the vicinity of the falls they have an exposed thickness of 60 feet.[2]

On Clearwater river thick-bedded, hard, yellowish-grey limestone, with a bituminous odour on fresh fracture, outcrops at the Cascade rapid, while at the Pas rapid a porous, grey, bituminous limestone outcrops, and one bed was stained with free petroleum. Two miles below the Terre Blanche rapid a porous thick-bedded, grey limestone outcrops. No fossils were observed, and the beds appear to be lower than those farther west.[3]

In the valley of the Athabaska the Devonian system underlying the tar sands is exposed for a considerable distance at the water's edge. Exposures are first met at Crooked rapids, and the last one is seen about 10 miles below Calumet river, or 63 miles below the confluence of the Clearwater and Athabaska rivers. From Crooked rapids to the Forks the general dip is to the north, but it is very slight and is about equal to the fall of the river. Only a few feet of Devonian strata are exposed, and owing to a number of small folds they sink in a few places below the surface of the valley. Below the Forks for some miles the strata are horizontal, or nearly so, but farther down they undulate in gentle folds. Seldom is there exposed a greater thickness than 50 feet.[4] The limestone is greyish, evenly

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[1] Wm. McInnes. Geol. Survey, Canada, Summary Report 1909, p. 154.
[2] R. G. McConnell. Geol. Survey, Canada, V, 45 D.
[3] Robt. Bell. Geol. Survey, Canada, 1882–84, 26 CC.
[4] R. G. McConnell. Geol. Survey, Canada, V, 33 D.

bedded, more or less argillaceous, and in places passes into calcareous shale. It is terminated upward for some distance below Crooked rapid by a thin bed of conglomerate, consisting principally of subangular limestone pebbles, siliceous grains, and a calcareous cement. In places the cement is ferruginous.[1] Fossils are numerous, and indicate a horizon in the upper Devonian.

[2] "The walls of transverse joints and other spaces in the limestone were frequently observed to be blackened with petroleum, and at a place nearly opposite to the mouth of the Little Red river some irregular cavities contained inspissated pitch. These limestones were not found to yield petroleum on fresh fracture, although they had occasionally a bituminous smell."

Saline springs are found along the river. At La Saline, 28 miles below the Forks, are several saline springs depositing calcareous tufa and small amounts of common salt, gypsum, and native sulphur.[3] Sulphuretted hydrogen is also emitted from the bank. Two miles above the mouth of Red Earth creek there is a copious saline spring emitting large quantities of sulphuretted hydrogen.

CARBONIFEROUS, PERMIAN, AND TRIASSIC.

Carboniferous rocks of great thickness are found in the Rocky mountains, but no outcrops have been recognized on the Canadian plain. It would be interesting, and perhaps of economic importance, to know to what extent and to what depth the Devonian system is overlain in Alberta and Saskatchewan by the Carboniferous, but any opinion expressed by the writer would be pure conjecture. We know: (1) That the system attains a great thickness in the Rocky mountains; (2) that no outcrops have been recognized overlying the Devonian along the eastern edge of the Cretaceous in Manitoba, Saskatchewan, or Alberta; (3) that to the north of Alberta there is a wide distribution of the Devonian unconcealed by the Carboniferous; (4) that the Carboniferous is exposed in the Black hills and has a wide distribution in the valley of the Mississippi, in the states of Nebraska and Iowa, and southward, and (5) that the thickness of the system in the Black hills is very much less than that in the Canadian Rockies. The occurrences of the Carboniferous in the

[1] R. G. McConnell. Geol. Survey, Canada, V, 33 D.
[2] Robt. Bell. Geol. Survey, Canada, 1882–84, 24 CC.
[3] R. G. McConnell. Geol. Survey, Canada V, 35 D

United States and of the Devonian in the Mackenzie basin are so distant that it would be unwise to base on them any judgment as to the distribution of the system in Alberta and Saskatchewan. The difference in thickness of the system in the Black hills and the Canadian Rockies might, however, suggest a rapid thinning eastward, but leaves the question of extent unanswered.

The system consists of a series of shales, limestones, and quartzites. [1]McConnell, from his study of the geology along the main line of the Canadian Pacific railway, gives the following classification:—

Age.	Formation.	Principal characters.	Thickness.
			Feet.
Carboniferous passing downward into Devonian.	Upper Banff shales	Reddish-weathering and usually calcareous shales, and quartzites. The quartzites, where present, occupy the lower part of the division.	500–1,500. Usually about 700.
	Upper Banff limestone.	Moderately crystalline, greyish limestone, often cherty and crinoidal.	3,000.
	Lower Banff shales	Calcareous shales and shaly limestone. Shales are dark coloured, but usually weather red.	500–700.
	Lower Banff limestone.	Heavily-bedded bluish and fairly compact limestone.	600–800

[1] Geol. Survey, Canada, II, 15 D.

[1] Dowling's study of the Cascade coal basin led to the following classification:—

Age.	Formation.	Principal characters	Thickness.
			Feet.
Permo-Triassic....	Upper Banff shale.	Reddish-weathering, dark, sandy shale, capped by yellow dolomitic limestone possibly 100 feet thick. Permian age not well proven.	1,200–1,300
	Rocky Mountain quartzite.	Fine-grained sandstones, generally of a light yellow tint, lower part greyish white.	1,600.
	Upper Banff limestone.	Light-bluish and grey limestones, with grey and dark shales towards the middle. Passes gradually into the shales below.	2,500–3,000.
Carboniferous.....	Lower Banff shale.	Dark-grey shale, often weathering brownish.	1,000–1,500.
	Lower Banff limestone.	Heavily-bedded limestones without shaly partings.	2,000.

Malloch on his map of the Bighorn[2] coal basin gives the following legend:—

Triassic...............	Upper Banff shale (with a thin bed of limestone).	
Devonian to Permian....	Rocky Mountain quartzite (Permian ?).	
	Upper Banff limestone (Carboniferous).	
	Lower Banff shale (Carboniferous ?).	
	Lower Banff limestone	Probably Devonian.
	Intermediate beds (dolomites).	

The combined thickness of the Lower Banff shale, Upper Banff limestone, and Rocky Mountain quartzite in the Bighorn basin is about 1,300 feet, and that of the Upper Banff shale is 293 feet.

Referring to the Devono-Carboniferous of the Yellowhead pass, McEvoy[3] states that "the upper part of this group consists of fine-grained bluish-weathering grey limestone, bluish rather crystalline

[1] Geol. Survey, Canada, Cascade Coal Basin, Alberta, 1907, p. 9.
[2] Geol. Survey, Canada, 1910.
[3] Notes on map of the Yellowhead Pass Route from Edmonton to Tête Jaune Cache.

limestone, siliceous shales and quartzites, with at least one band of black carbonaceous shale." The Banff limestones have also been recognized in the Peace River pass still farther north.[1] These are overlain by dark calcareous shales and impure limestones of Triassic age.

For comparison the following portion of a generalized section in the Black Hills[2] region is given:—

Age.	Formation.	Principal characters.	Thickness.
			Feet.
Triassic (?)	Spearfish.........	Red sandy shales and gypsum beds.	350–600
Carboniferous. (Permian).....	Minnekahta limestone.	Thin-bedded grey limestone...	30-50
	Opeche...........	Red slabby sandstone and sandy shale.	90–130
Carboniferous (Pennsylvanian ?)	Minnelusa........	Sandstones, mainly buff and red, in greater part calcareous; some thin limestone included.	450–750
Carboniferous. (Mississippian)..	Pahasapa limestone	Massive grey limestone	250-700
	Englewood limestone.	Pink slabby limestone..........	25–50

JURASSIC.

Fernie Shale.—This series is found in the Rocky mountains and the foot-hills, but no outcrops have been seen farther east. The following description shows that these shales thin out very rapidly towards the east, and it is probable that they do not extend to any considerable distance beyond the foot-hills.

[3]"In the locality where this formation received its name—near Fernie, B.C.—it consists of a series of black and brownish shales, 1,060 feet in thickness, overlying 500 feet of sandy argillites. Eastward, through the Crowsnest pass, the series decreases in thickness, and at Blairmore, near the edge of the mountains, there is only 700 feet. On the Cascade river the section is 1,600 feet, and consists of black shales and grey sandstones, with an occasional limestone bed

[1] McConnell. Geol. Survey, Canada, VII, 32 C.
[2] N. H. Darton. U. S. Geol. Sur. Professional Paper 32, p. 25.
[3] Dowling. Geol. Survey, Canada, The Coal Fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia, p. 23.

towards the base. In the Moose Mountain area—an outlier of the Rockies—the thickness is only 225 feet. The formation has been traced northward to the Athabaska river, and preserves its general black, shaly appearance. Few fossils have been obtained in these measures, but these are characteristic." The thickness in the Bighorn coal basin is 723 feet.

CRETACEOUS.

The Cretaceous system is exposed in the Rocky mountains and extends eastward, overlying nearly the whole of Alberta and Saskatchewan and the western part of Manitoba. The escarpment of the Pembina, Riding, Duck, and Porcupine mountains is the approximate eastern outcrop in Manitoba, and from this escarpment the boundary runs northwest through Saskatchewan and Alberta to the lower courses of the Athabaska and Peace rivers. Southward the system extends a long distance into the United States.

[1] Following is a table of the formations represented:—

[1] Dowling, Coal Fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia, p. 20.

—	Groups.	Alberta.	Saskatchewan.	Manitoba.	Montana.	Dakota.	Kind of rocks.	Character of fossils.
Tertiary.	Oligocene.	Oligocene.	Oligocene.				Conglomerates and sandy clays.	Land and fresh-water.
	Eocene.	Paskapoo.	Laramie.	Laramie.	Laramie.	Laramie.		
		Edmonton.					Sandstones and clays.	Freshwater.
Cretaceous.	Montana.	Bearpaw.	Pierre-Foxhill	Odanah.	Foxhill.	Foxhill.	Sandstones and clays.	Land plants, brackish water.
					Bearpaw.	Pierre.	Shales.	Marine.
		Belly R.	Belly R.		Judith R.		Sandstones.	Brackish and fresh.
		Claggett.		Millwood.	Claggett.	Pierre.	Shales.	Marine.
		Eagle.			Eagle.		Sandstones.	Marine.
	Colorado.	Niobrara.		Niobrara.	Niobrara.	Niobrara.	Calcareous shales.	Marine.
		Cardium.				Greenhorn.		
						Benton.	Shales.	Marine.
		Benton.		Benton.	Benton.	Graneros.		
	Dakota.	Dakota.		Dakota.	Dakota.	Dakota.	Sandstones.	Freshwater.
	Kootanie.					Fuson. Minnewaste. Dakota.	Sandstones and shales.	Land plants.
		Kootanie.			Cascade. Kootanie.	Morrison.		

To further show the distribution of the different formations and their thickness in different localities, other tables representing the results of the observations of Canadian geologists are given.

Section from the Forgetmenot and Moose Mountain ridges of the foot-hills[1]:—

			Feet.
Cretaceous	Montana	Edmonton	
		Bearpaw (Pierre Foxhill)	650
		Judith River (Belly River)	850
		Claggett (Lower Dark Shales)	250
	Colorado	Niobrara — Cardium Sandstone	50
		Benton — Benton	725
	Dakota		950
	Coal Measures, Kootanie		375

Lithologically a similar succession of formations occurs in the Bighorn coal basin, but the fossil evidence goes to show that they are not exactly the same. Local names have been given to several of the formations as follows[2]:—

Upper Cretaceous	Brazeau sandstones, shales, and conglomerates.
	Wapiabi shales.
	Bighorn sandstones, conglomerates, and intercalated shales.
	Blackstone shales.
	Dakota sandstones and shales.
Lower Cretaceous	Kootanie formation (coal-bearing).

Table of formations of southern Alberta, with approximate maximum thickness[3]:—

		Feet.
Laramie	Porcupine Hill beds. Sandstoness, frequently thick-bedded and generally comparatively soft, with intercalated greyish and blackish shales and shaly clays. Freshwater	2,500
	Willow Creek beds. Soft sandstones, shales, clays, and sandy clays, generally with a pronounced reddish or purplish tint. Freshwater	450
	St. Mary River beds. Sandstones, shales, and shaly clays in frequent alternations, and generally well bedded. Freshwater except near base	2,800
Cretaceous	Fox Hill Sandstones. In some parts of the district well defined as a massive yellowish sandstone, but inconstant, and apparently often represented by a series of brackish-water, transition beds between the Laramie and Pierre	80
	Pierre Shales. Natural grey or brownish to nearly black shales, include a zone of pale, soft sandstone in the north-eastern part of the district and frequent intercalations of harder sandstones near the mountains. Marine	750
	Belly River series. Composed of an upper or "pale" and lower or "yellowish" portions, and consisting of alternations of sandstones, sandy clays, shales, and clays	910
	Lower dark shales. Grey to nearly black shales, frequently with arenaceous shales	800

[1] Cairnes, D. D. Geol. Survey, Canada, Moose Mountain District, p. 35.
[2] Malloch, G. S. Bighorn Coal Basin, Geol. Survey, Can., 1911.
[3] Dawson, G. M. Geol. Survey, Canada, 1882-84, 112 C.

Table of formations of central Alberta and the adjacent portion of Saskatchewan[1]:—

Post-Tertiary	Recent deposits. Sands, clays, and silts....	
	Upper Boulder clay. Light-grey sand, and generally, indistinctly stratified clay, containing numerous pebbles of gneiss, quartzite, etc....	
	Lower Boulder clay. Dark-grey, thick-bedded, or massive, sandy clays containing pebbles of quartzite, etc., and numerous fragments of lignite....	
	Pebble bed. Quartzite shingle lying in a loose matrix....	
Miocene	Gravels, fine sands, and argillaceous marls, the gravels consisting of quartzite shingle, being sometimes cemented into a hard conglomerate by calcareous cement	270
Laramie	Paskapoo Series. Grey and brownish-weathering, lamellar or massive sandstones, and olive, sandy shales. Exclusively freshwater....	5,700
	Edmonton Series. Soft whitish sandstones and white or grey, often arenaceous clays, with bands and nodules of clay ironstone and numerous seams of lignite. Brackish water. Correspond to the lowest portion of Dawson's St. Mary River series....	700
Fox Hill and Pierre	Brownish-weathering sandstones and dark-grey clay shales....	600
Belly River Series	Soft, whitish sandstones and arenaceous clays, changing towards the east to light-brownish and yellowish sandstones and sandy shales, bottom not seen....	

Table of formations in the Athabaska and Peace River district, northern Alberta[2]:—

ATHABASKA RIVER SECTION.

Laramie—		
Foxhill sandstone.	Montana	
LaBiche shales (upper part) 700 feet.[3]	Montana	
Unrepresented—		
LaBiche shales (lower part)	Colorado	225 "
Pelican sandstone	Colorado	40 "
Pelican shale	Colorado	90 "
Grand Rapids sandstone	Colorado	300 "
Clearwater shale	Colorado	275 "
Tar sands		140–220 "

PEACE RIVER SECTION.

Laramie—Wapiti River sandstones.		
Montana	Foxhill sandstone.	
Montana	Smoky River shales.	
	Dunvegan sandstone	600 + feet.
Colorado	Fort St. John shales	700 "
Colorado	Peace River sandstones	400 "
Colorado	Loon River shales	400 "
Dakoka, unrepresented.		

Table of formations of the Cretaceous system of northwestern Manitoba[4]:—

		Feet.
Pierre	Odanah Series. Light grey, hard, fissile shales very poor in fossils....	400
	Millwood Series. Dark grey, soft shale	664
Niobrara	Light grey, mottled, calcareous, clay shale with bands of chalky limestone, everywhere containing a large number of foraminifera	130–540

1 Tyrrell, J. B. Geol. Survey, Canada, II, 127 E.
2 McConnell, R. G. Geol. Survey, Canada, V, 53–59 D.
3 See also log of well drilled at Athabaska Landing.
4 Tyrrell, J. B. Geol. Survey, Canada, V, 199 E.

		Feet
Benton.......	Dark grey, very soft, non-calcareous shale, poor in fossils, and weathering into gentle slopes....	160
Dakota......	A rather soft, white or light-grey sandstone, often calcareous.......	13–200

The Kootanie Formation.—This formation outcrops in the Rocky mountains and in the foot-hills, and it has been recognized at least as far north as the Bighorn coal basin. On the Athabaska river it is absent, for there the Dakota formation rests directly on the Devonian, and it has not been seen in Manitoba. It is recognized, however, in the southern part of Dakota and in Montana. [1] "The maximum deposition during this period was west of the axis of the Rocky mountains. In the Elk River escarpment the formation measures 5,300 feet. East of this, at Blairmore, it is reduced to 740 feet. North, near Banff, it has a thickness of 3,900 feet; and in Moose mountain, east of the main range, there are 375 feet. Northward, on the Bighorn, the thickness is about 2,000 feet. It would seem that east of the mountains the formation was not of great importance, owing to thinning of the beds." It rests on the Jurassic and in the Moose Mountain district there is no evidence of an unconformity between the two. It is an important coal-bearing formation. [2] "At the top is usually a coarse, dark sandstone bed, 10 to 30 feet thick. Below this are chiefly dark shales and sandstones, presenting a general brownish appearance. Interbedded with these are the coal seams. Below these is a very prominent and persistent hard sandstone bed, 30 to 75 feet in thickness. This weathers to a peculiar yellow colour, similar to that often seen on limestone. The faces of its bedding planes are also pitted in a peculiar manner; but it is not at all calcareous. A fractured surface always presents a brown to an almost black, fine-grained appearance." In the Bighorn coal basin the formation consists of black shales, shaly and siliceous sandstones, coal seams, and conglomerates. The beds vary greatly in thickness and texture within short distances. The thickness in this basin is over 3,600 feet.[3]

The Dakota Formation.—This is probably the most important formation of the Northwest so far as the oil and gas industry is concerned. It is the bitumen-bearing formation of the Athabaska

[1] Dowling, Coal Fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia, p. 24.
[2] Cairnes. Geol. Survey, Canada, Moose Mountain District, p. 32.
[3] Malloch, Bighorn Coal Basin, Geol. Sur., Can., 1911, p. 33.

river, and probably the chief reservoir of gas of southern Alberta. It is of wide distribution, probably extending from the Rocky mountains eastward into Manitoba and from Athabaska river southward far into the United States, overlain to a great extent by more recent formations.

In the Moose Mountain district [1]the upper beds consist of light-coloured sandstones, shales, and clays of green, blue, and grey tints, with a few persistent red beds near the top. These are succeeded below by darker and harder beds, overlying some coarser, lighter coloured sandstones, which in their turn overlie 300 or 400 feet of thinner, harder, darker strata of sandstone and shales. Below these are a few thicker beds of quartzitic grey sandstone followed by 10 to 30 feet of conglomerate at the base of the Dakota formation. The total thickness is 900 to 1,700 feet. [2]The Moose Mountain district seems to be beyond the limits of the volcanic ash bed lying at the top of the formation on the north branch of the Oldman river and near the Crowsnest pass.

In the Bighorn coal basin it is represented by shales and sandstones, with a bed of white quartzose sandstone at the base. The thickness of the formation is 1,800 feet.

In Manitoba the formation is exposed at several points along the foot of the northern portion of the Manitoba escarpment. On account of the irregularity of the Palæozoic floor on which it rests unconformably the thickness varies greatly, and is given as 13 to 200 feet. A thickness of about 90 feet has been recognized in the [3]Morden well. In this Province the formation is [4]"composed of white or reddish sandstones, either cemented by a calcareous matrix or often quite incoherent, being then an even-grained white quartzose sand. It grades up into a light green and rather hard sandstone, commonly interstratified with thin bands of shale.

"Very few fossils have been found in this sandstone, and those that have been found are confined to the greenish upper beds. They consist chiefly of carbonized fragments of wood and coniferous leaves, but the following animal remains have been collected, viz.:—

Lingula subspatulata, Hall and Meek.
Ostrea congesta, Conrad.

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[1] Cairnes. Moose Mountain District, p. 31.
[2] Dowling, Bull. Geol. Soc. Am. Vol. 17, p. 300.
[3] Tyrrell, J. B. Royal Soc. Can. Vol. IX (1891), Sec. IV, p. 97.
[4] Tyrrell. Geol. Survey, Canada, V, 209 E.

Modiola tenuisculpata, Whiteaves, N. Sp.
Cycloid scales of fishes."

A few outcrops have been seen in Saskatchewan. On Carrot river, 4 miles above the west line of the Indian reserve, is a soft sandstone [1] containing some carbonaceous material. It is probably overlain by a hard, purplish sandstone. No fossils were found, but it probably is the Dakota formation. Along the south shore of Wapawekka lake, to the east of Lac LaRonge, are [2] scarped banks of white quartz sands, in places coherent enough to form a sandstone. In this cliff is a bed of lignite. The formation probably is of Dakota age. On Beaver river, just above the mouth of Dore river, are some banks 90 feet high of soft white or light-yellow sandstone, and on the south shore of Ile a la Crosse lake is a light-yellow sandstone with thin beds and nodules of calcareous ironstone. It contains carbonized plant remains, and though no recognizable fossils were found the beds probably belong to the Dakota formation.[3]

In descending Athabaska river from Athabaska Landing one meets in succession exposures of the following formations:—

LaBiche shales (upper and lower).
Pelican sandstone.
Pelican shales.
Grand Rapids sandstone.
Clearwater shales.
Tar sands.

The strata are nearly horizontal, but dip slightly to the south, and thus underlie one another in the order named. The lowest of these formations has attracted considerable attention on account of its being bituminous.

At Boiler rapid, 40 miles below Grand rapids and 193 miles below Athabaska Landing, the Tar sands first appear, and are overlain by 275 feet of Clearwater shales, above which lies the Grand Rapids sandstone. At Middle rapid, 3 miles below Boiler rapid, 40 feet of Tar sands is exposed; 2 miles below Long rapid 100 feet is exposed, and at the head of Crooked rapid, 140 feet. Here the sands rest on the Devonian limestone, and there is very little unconformity to indicate the great lapse of time between the deposition of the two

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[1] McInnes, W. Geol. Survey, Canada, Summary Report 1907, p. 42.
[2] McInnes, W. Geol. Survey, Canada, Summary Report 1909, p. 155.
[3] Tyrrell. Geol. Survey, Canada, VIII, 19 D.

formations. The Tar sands increase in thickness from 140 feet at Crooked rapid to 200 feet at the Forks, where Fort McMurray is situated. The Clearwater shale continues to overlie them as far as the Forks, but below this point it almost disappears on account of a decrease in the height of the valley. Heavy sections of the Tar sands are exposed for miles below the Forks. About 10 miles below the mouth of Calumet river the last exposure is seen, although 2½ miles below the same river the limestone is overlain by 50 feet of light-coloured shale. Above Crooked rapid the beds dip southwesterly at from 5 to 10 feet to the mile, while below, the general dip is to the north, but it is very slight, averages less than 2 feet to the mile, and is about equal to the fall of the river.[1]

The formation is exposed at intervals for several miles up many tributaries of the Athabaska. On Firebag river, at a point 18 miles from its mouth a small exposure was seen.[2] Sections are seen several miles up Moose and Red rivers. On Muskeg river outcrops occur up to 14 or 15 miles above the portage from the Athabaska. An exposure was observed on Clearwater river 3 miles above its confluence with the Pembina, while on the latter river exposures were seen for 12 miles above the mouth.

The Tar sands must have consisted originally of almost unconsolidated sands and soft sandstone ranging in texture from a fine silt to a coarse grit. They have been cemented into a coherent tarry mass by inspissated petroleum. They vary in colour from a grey to a dark brown or jet black, according to the quantity of contained tar. Where they are heavily saturated they are much softened by the heat of summer, and the tar issues from the sands and forms pools at the base of the escarpment.[3] The formattion contains occasional lenticular beds of ironstone and quartzite, lignite seams 2 or 3 feet thick, and fragments of fossil wood. On Pembina river, 5 miles above its mouth, there is a seam of lignite 4 feet thick.

On lithological and stratigraphical evidence McConnell assigned the Tar sands to the Dakota period. Tyrrell,[4] on palæontological evidence, would include in the Dakota the Grand Rapids sandstone, the Clearwater shales, and the Tar sands. The fauna shows that marine conditions prevailed in part at this time in northern Alberta,

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[1] McConnell, R. G. Geol. Survey, Canada, V, 32–36 D.
[2] Dowling. Geol. Survey, Canada, VIII, 67D.
[3] McConnell. Geol. Survey, Canada, V, 34 D.
[4] The Ottawa Naturalist, Vol. XII, p. 37.

while freshwater conditions prevailed in Dakota and Montana and probably along the western margin.

Benton.—This formation is probably of very general distribution throughout the southern part of the Canadian plain, as it outcrops in Manitoba and in the foot-hills as well as in Montana and Dakota, and is recognized in wells at various points.

In the Moose Mountain district[1] this formation consists of dark marine shales lithologically similar to the Bearpaw and Claggett. They are soft and pliable and weather easily. They are 500 to 800 feet thick. The Blackstone shales of the Bighorn coal basin are homogeneous, dark grey, calcareous shales, and probably correspond with the lower part of the Benton.[2]

Concerning the formation in Manitoba, Tyrrell says:—

[3] "Overlying the Dakota sandstones, the Benton formation occurs as a band of dark grey, almost black shale, holding a considerable quantity of carbonaceous material. This shale is evenly bedded, and breaks down readily into thin flakes, on which account it generally forms sloping banks. With the dark shales are associated thin beds of white, soft, sweet-tasting magnesian clay.

"In the bore on Vermilion river, the Benton appears to be 178 feet thick, and farther north, on the face of the Duck and Porcupine mountains, it continues of about the same, or slightly less, thickness. It is easily recognized, even when good naked exposures are absent, by its characteristic property of breaking into more or less minute graphite-like flakes, and not weathering immediately into a soft clay, as usually occurs in the less consolidated beds of the Pierre.

"It is generally quite destitute of fossils, but in a few places undeterminable fragments of oysters and Inocerami have been collected from the shale."

It is thus seen that the formation thins considerably from the west to the east.

In the well near Bow island, Alberta, section 15, township 11, range 11, west of the 4th meridian, the strata between the depths of 1,600 and 1,866 feet have been assigned to this formation. The first 200 feet consists of soft brown shale, caving easily, with a sandstone layer every few feet having a thickness of a few inches to 3 feet;

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1 Cairnes, D. D. Moose Mountain District, p. 30.
2 Malloch, G. S. Bighorn Coal Basin, Geol. Survey, Can., 1911, p. 36.
3 Geol. Survey, Canada, V, 210 E.

gypsum is found in the upper 50 feet. The remaining 66 feet consists of dark brown shales with sandstone layers close together and is about half sandstone and half shale.

In the well at Deloraine (altitude 1,644 feet) the 227 feet of strata from 1,595 to 1,822 feet have been assigned to the Benton.[1] It consists of a dark grey, non-calcareous clay; the upper portion is very bituminous and breaks into minute flakes, while the lower portion is lighter in colour, does not break into thin flakes, and contains minute angular grains of quartz sand.

At Morden (altitude 978) the 105 feet of dark grey shale extending from the depth of 215 feet to 320 feet is probably Benton.[2]

Niobrara.—This formation probably has a wide distribution in the southern part of the great plain of Canada.

In the Moose Mountain district[3] a sandstone series 50 to 150 feet thick overlies the Benton formation. It consists of three sandstone bands separated by, and somewhat intermixed with, dark shales. Each of the sandstone bands is capped in places by conglomerate. The series has been given the name Cardium sandstones. At the bottom of the overlying Claggett shales are several calcareous bands from a few inches to a foot in thickness. Portions of the sandstone series, as well as the upper part of the underlying shales, are also quite calcareous. Since these beds are calcareous and "since Colorado fossils are quite plentiful in both the sandstones and the shales, it appears practically certain that the calcareous rocks correspond to the Niobrara."

In Manitoba the Niobrara rests conformably on the Benton, and is a grey calcareous shale or marl, sometimes varying to a band of moderately hard limestone and weathering into steep or vertical cliffs.[4] At the top there is generally met a band of greyish, chalky limestone, often highly charged with pyrite. A characteristic feature of the formation is the presence of a large number of Foraminifera. Exposures are seen along the streams cutting the face of the escarpment running north through the Province. This formation yields the cement rock of Manitoba. The thickness varies from 130 to 200 feet, though it is apparently much thicker in places, and in the Swan River valley near Thunder hill it may be 540 feet.

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[1] Royal Soc. Can. IX (1891), Sec. IV, p. 93. Geol. Survey, Canada, VI, 2 A
[2] Royal Soc. Can. IX (1891), Sec. IV, p. 98.
[3] Cairnes. Moose Mountain District, p. 28.
[4] Tyrrell. Geol. Survey, Canada, V, 210 E.

Some exposures have been recognized in Saskatchewan. On Carrot river, 40 miles above Redearth Indian reserve, a soft, grey, bituminous shale dipping southwest at a low angle may be referable to the Niobrara.[1] The soft, grey shales of the Pasquia hills are also probably Niobraran. Some are almost black and carry enough bitumen that when the hydrocarbons are volatilized in a camp fire they burn with a bluish flame and give off a strong odour of petroleum. Typical Niobrara shale has also been found near the south end of Green lake.[2]

The strata assigned to the Niobrara in the Bow Island well are 500 feet in thickness, extending in depth from 1,100 to 1,600 feet. They consist in the upper 400 feet of dark brown shales with sandstone beds and of brown shales, while in the lower 100 feet they consist of green sandy shales. In the Deloraine well the Niobrara is assigned a thickness of 545 feet, extending in depth from 1,050 to 1,595 feet, and consisting of grey shale more or less calcareous. In the Morden well the Niobrara is 160 feet thick, and extends in depth from 55 to 215 feet. It consists in the upper part of dark grey shale and in the lower 120 feet of grey calcareous shale.

Eagle.—[3] "In the foot-hills the only exposure that can be correlated with the Eagle sandstone of Montana is a thin 50 foot bed of light coloured sandstone." This is the formation already described as the Cardium sandstones, of which Cairnes suggests one or more beds might be correlated with the Eagle formation. It has not been recognized elsewhere in the area under study.

Claggett.—This term is applied to that portion of the Pierre lying below the Belly River beds and corresponding to Dr. G. M. Dawson's "lower dark shales." It is found in the foot-hills, in the Moose Mountain district, and has a thickness of 150 to 300 feet. It consists of dark, marine shales so similar lithologically to the Benton shales that it is impossible to draw the line between the two except where the Cardium sandstones can be identified, or fossils are found.[4]

Concerning this formation, Dr. Dawson writes:—

[5]"The lower dark shales are clearly seen to underlie the yellowish portion of the Belly River series on Milk river at Pa-kow-ki coulee.

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[1] McInnes, W. Geol. Survey, Canada, Summary Report 1907, p. 43.
[2] Tyrrell. Geol. Survey, Canada, VIII, 20 D.
[3] Dowling. Coal Fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia, p. 25.
[4] Cairnes. Moose Mountain District, p. 30.
Geol. Survey, Canada, 1882–84, 117 C.

The main lithological difference which their upper portion shows, as compared with the Pierre, is the greater abundance of sandy and calcareous shales. The lower beds were not well seen, except in the country south of the Rocky Spring plateau, where sections of limited size appear to show that they are soft and very dark shales. The fossils are marine, and with the exception of a few large reptilian bones from the west flank of the West butte, all molluscs.

"In Rocky Spring plateau a thickness of 235 feet of these beds was examined. It is probable that their entire thickness is about 800 feet at the West butte."

In Manitoba this age may be represented by the lower part of the Pierre known as the Millwood shales, 664 feet thick. These will be described later.

Belly River.—This formation, which is a continuation northward of the Judith River formation of Montana, is found resting on the Claggett in the foot-hills. In the Moose Mountain district the maximum thickness measured along the Bow river is 1,025 feet, but farther south it is only 850 feet.[1] Here white sandstone strata, often cross-bedded, are very characteristic, and yellowish, grey, blue, and greenish-grey shales and clays are common, while brown, grey, and yellow weathering sandstones predominate.

On Peace river the formation is probably represented by the Dunvegan beds. These consist of greyish and yellowish, flaggy and massive sandstones, alternating with greyish and dark shales, usually more or less arenaceous, and holding small beds of ironstone and thin seams of lignite.[2] The thickness is 600 feet or more at Dunvegan and nearly 2,000 feet at Table mountain. It contains freshwater, brackish-water, and marine forms.

The most important exposure of the Belly River formation is that of a wide zone extending from the International Boundary in the southeastern part of Alberta northeast into Saskatchewan as far as the 52nd parallel, thence turning northwest, narrowing gradually, and passing beneath the Bearpaw shales in the vicinity of the Canadian Northern railway in Alberta. It passes beneath the Bearpaw to the east and west, and is clearly seen to rest upon the Claggett or lower dark shales on Milk river at Pakowki coulee.

A portion of the exposure running northeast lies in a great

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[1] Cairnes. Moose Mountain District, p. 27.
[2] McConnell. Geol. Survey, Canada, V, 55 D.

Belly River series capped by the Bearpaw, Ross Creek valley, near Irvine station, Canadian Pacific Railway.]

depression through which the Belly, Bow, Red Deer, and South Saskatchewan rivers drain, while the portion near the International Boundary and the portion running northwest from the 52nd parallel are exposed by the erosion of the overlying beds along broad anticlines.

The thickness in the northern part is not known, but a section of 600 feet, in which neither the top nor bottom can be seen, is exposed in a local anticline east of Sounding creek. The rocks here dip N. 5° W. at an angle of 30°.[1] Dawson gives the approximate maximum thickness for southern Alberta as 910 feet.[2] In township 1, range 27, west of the 3rd meridian, some local disturbance has exposed the beds of this series, and on account of the high angle of dip, 30° to 45°, a section of 894 feet is exposed.[3] There is little doubt that the upper part, if not all, of this section belongs to the Belly River formation.

The series in southern Alberta is divided by Dr. Dawson into an upper or pale portion and a lower or yellowish portion. The separation is merely for convenience of description and is probably not warranted in any other sense. It is difficult to draw any dividing line.

[4] "The pale upper portion of the Belly River series is well shown on the Belly above Coal Banks . . . . It is composed for the most part of sandy clays, with shales and sandstones, the latter often of considerable thickness, and usually rather soft or irregularly hardened. Layers of ironstone nodules, which are at times very large, are of frequent occurrence, and the beds generally have a characteristic bluish or greenish-grey tint, and are on the whole rather massive, and weather easily into bad-lands. In these features, with the occurrence of rolled clay pellets, and the rounded character of many of the included bones, there is evidence of a considerable amount of current or wave action."

"Near the top of this upper pale portion of the Belly River series marine or brackish-water molluscs are occasionally found, but it must be considered on the whole as a fresh-water formation."

The lower or yellowish portion, in contact with the greys of the upper portion, has a yellowish or brownish tint. It consists of sandy

[1] Tyrrell. Geol. Survey, Canada, II, 82 E.
[2] Geol. Survey, Can., 1882-84, 112 C.
[3] McConnell. Geol. Survey, Canada, I, 42 C.
[4] Dawson. Geol. Survey, Canada, 1882-84, 116 C.

clays, sandstones, and shales, which frequently blend with each other so completely as to render it difficult to give measured sections.

In describing the northern part of the exposure Tyrrell says:—

[1] "This series is represented by white or light grey clays and soft clayey sandstones, interbedded with bands and nodules of clay ironstone. These nodules are often highly calcareous, breaking with a smooth, sharp fracture . . . . .

"As has already been pointed out in the reports of Dr. Dawson and Mr. McConnell, this series, if followed toward the east, is found to lose gradually its clayey character, and to consist of purer and more massive sandstones, generally of a yellowish colour. When the beds are white and clayey, it is possible to trace with comparative ease and accuracy the line of junction between it and the overlying Pierre shales. This is especially the case along the valley of Red Deer river between long. 111° and 112° . . . . and also on Battle river for several miles below the Elbow.

"Farther east, however, where the beds become harder and much more sandy, the line between these two formations becomes much more difficult to trace out, as there is little or no difference between these sandstones and those with the character of the Fox Hill group, which are interbedded almost everywhere with the shales of the Pierre, though typical Fox Hill fossils are generally found in these in considerable abundance, while in the yellow sandstones that underlie the shales, no fossils of any kind have ever been found within this district."

Individual beds vary much in composition and texture within a short distance, so that neighbouring sections differ much in detail while harmonizing in their main features.

This is one of the important coal-bearing formations of the Northwest.

No exposures have been seen farther east, but two important divisions have been recognized in the Pierre in Manitoba, and it may be that the contact between these two divisions represents the Belly River horizon.

Bearpaw.—[2] "The Pierre-Foxhill of the writers of the geology of Saskatchewan and Alberta is without doubt that portion of the

[1] Geol. Survey, Canada, II, 128 E.
[2] Dowling. Coal Fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia, p. 26.

PLATE III.

Coal mine near Medicine Hat.

Pierre which is above the Belly River formation; but since it has been shown that the typical Pierre embraced beds below this shallow water and land deposit, new names have been suggested by Messrs. Stanton and Hatcher: Claggett for the lower shales, and Bearpaw for the upper."

The Bearpaw is of very wide distribution, and extends throughout nearly the whole of Alberta, southern Saskatchewan, and western Manitoba. It is exposed in the foot-hills, then passes beneath rocks of a later age lying in the great Alberta trough, and emerging from these forms a narrow zone to the west of the Belly River formation. East of the latter formation it probably extends to the Manitoba escarpment, from which its boundary runs northwest through Saskatchewan and northern Alberta. In the southern part of Saskatchewan and Manitoba it is overlain in places by rocks of a later age.

The Bearpaw is essentially an argillaceous formation, consisting of shales, neutral grey or brownish to nearly black in colour, with light grey to yellow, soft beds of sandstone. There are also layers and nodules of ironstone, and selenite crystals are common. [1] "On the Oldman river below Ryegrass flat, the upper portion of the series, for a thickness of about 40 feet, is coffee-coloured sandy shales in very regular beds, each of a few inches in thickness. Northeastward, on the Bow, these peculiar beds have increased to a thickness of 135 feet or rather more, and still farther in the same direction, on the Red Deer, have a volume of 500 feet and constitute a large part of the whole series. These beds include red-weathering ferruginous layers and also, in the last-mentioned locality, greyish sandy beds." In the Cypress Hills region, instead of those coffee-coloured shales we have thick beds of greyish and yellowish sandstones in the upper part of the formation.[2] In the northeastern part of Swift Current Creek plateau and north of Wood mountain the shales are lighter grey and more arenaceous than usual and pass in places into soft sandstones. On the South Saskatchewan, west of the Côteau, the formation is also more arenaceous than usual, and the shales alternate throughout with thick beds of yellowish sandstone. In central Alberta the formation consists of dark and light grey, very friable,

[1] Dawson. Geol. Survey, Canada, 1882–84, 115 C.
[2] McConnell. Geol. Survey, Canada, I, 25 C.

clay shales, weathering to a soft, tenacious clay; interbedded with these are bands of coarse-grained, yellow sandstone.[1]

In the southern part of Alberta and Saskatchewan, Dawson and McConnell observed in places at the top of the Pierre a thin sandstone formation, which they regarded as Foxhill. It is, however, not continuous. On St. Mary river it is 80 feet thick, and in the Cypress Hills region its maximum is 150 feet. It is a yellow sandstone, and in some places the transition to the underlying shales is abrupt, while in other places the lower part consists of alternating beds of sandstone and shale, and passes gradually into the underlying Pierre. Farther north this formation is not observed, but the sandstone interbedded with the shales on the South Saskatchewan and in central Alberta carry fossils referable to the Foxhill.

[2] In the foot-hills the Bearpaw formation consists of dark grey to brown shales or shaly clays of very uniform appearance. In places these are nearly black. Interbedded with them are coarser and lighter coloured sandy shales and sandstones. Of these some are not distinguishable except on close examination, while others, especially near the centre, are quite prominent. Beds and nodules of ironstone are numerous. Foxhill fossils are found at different horizons.

The formation is rich in fossils of a marine fauna.

The average thickness in Moose Mountain district is 650 feet. On Red Deer river the thickness is 750 feet. Dawson says there is reason to believe that these shales are abnormally thin in the vicinity of the Milk River ridge. The well at Kipp, according to Dowling, gives a thickness of 615 feet at that point. McConnell gives the thickness of the Pierre-Foxhill along the western outcrop west of the Cypress hills as 900 feet. Tyrrell gives its thickness in central Alberta as 600 to 700 feet.

Pierre in Manitoba.—This series has its eastern boundary in the Manitoba escarpment, and extends from Porcupine mountain to the United States. It is subdivided into two conformable formations: (*a*) the Millwood, overlain by (*b*) the Odanah.

The Millwood, of which a good exposure is seen at Millwood, on the Assiniboine, consists of dark grey, soft, clay shales, containing crystals of selenite and septarian ironstone nodules.[3] A few fossils have been found.

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[1] Tyrrell. Geol. Survey, Canada, II, 129 E.
[2] Cairnes. Moose Mountain District, p. 26.
[3] Tyrrell. Geol. Survey, Canada, V, 212 E.

The overlying Odanah formation, of which a good exposure is seen in the upper part of the valley of Edwards creek and at Odanah, near Minnedosa, consists of light grey, hard, clay shales, which are locally known as slate. A few fossils of a marine fauna have been found.

It may be that the Millwood and Odanah represent, respectively, the Claggett and Bearpaw of the west.

On the northern face of Riding mountain the Millwood is 450 to 500 feet thick, and the Odanah, of which the top was not seen, 300 feet. In southwestern Manitoba, however, the Millwood is about 650 feet and the Odanah 400 feet thick.

CRETACEOUS OF THE BIGHORN COAL BASIN.

A table of formations of the Cretaceous system of the Bighorn basin is given on page 31. The Kootanie and Dakota formations have been described under their respective headings. The other four, as a series and lithologically, closely resemble the corresponding formations of the Moose Mountain district as described by Cairnes. Fossil evidence, however, goes to show that they are not of the same age, and local names have been applied to them as follows:—

Brazeau formation.
Wapiabi shales.
Bighorn formation.
Blackstone shales.

Blackstone Shales.—No fossils have been found in these dark grey, calcareous shales, but they probably correspond with the lower part of the Benton.

Bighorn Formation.—This formation consists of siliceous and shaly sandstones, black and brown shales, and several bands of conglomerate. It belongs to the Colorado group, and is 390 feet thick.

Wapiabi Shales.—These shales are brown or dark grey, and somewhat arenaceous. Fossils found about 800 feet from the base indicate that the horizon is high in the Colorado group and near the base of the Montana. A thickness of 1,300 feet has been measured, and the total thickness is probably about 1,800 feet.

Brazeau Formation.—This formation consists of alternating beds of black and brown shales, with greenish-grey sandstones containing pebbles of chert. The section measured is nearly 1,700 feet, but this does not represent the true thickness of the formation, since the top has been removed by erosion.[1]

CRETACEOUS OF THE PEACE AND ATHABASKA RIVERS DISTRICT.

[2] "The Cretaceous section in the Peace-Athabaska country includes beds ranging in age from the Laramie to the Dakota, but the lithological section of the various divisions differs from that which obtains on the Great Plains, and also varies in different parts of the district. This feature of the formation, together with the further fact that most of the fossils collected are new to science, and, therefore, useless for the purpose of correlating the beds here with known horizons elsewhere, makes it difficult to classify the different terranes in a satisfactory manner, and also renders necessary the provisional use of some new names." The Montana, Colorado, and Dakota groups are represented. The Dakota has already been described in some detail.

Montana.—This group is represented on the Athabaska and its tributaries by about 50 feet of alternating sandstones and shales, and about 700 feet of the underlying upper portion of the LaBiche shales.[3] The LaBiche shales are exposed along the Athabaska from the mouth of Little Slave river to Pelican river. They are dark grey or brownish, coarsely laminated, soft and very plastic, and contain nodules and small lenticular beds of limestone, and occasionally thin beds of greyish and yellowish sandstone.[4] These shales are divided into an upper and a lower portion. The basis of division is in no respect lithological, but is wholly palæontological. The upper portion carries fossils that are typical Pierre and Foxhill species, while those of the lower portion have a Niobraran aspect. In the Peace River section the Montana is represented by the Upper or Smoky River shales and possibly by the lower part of the Wapiti River sandstone[5] The Smoky River shales are 200 feet thick, consist of dark greyish or bluish-black, thin-bedded shales holding nodules and beds of ironstone, and are equivalent to the upper portion of the LaBiche shales.

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[1] Malloch. Bighorn Coal Basin, p. 38.
[2] McConnell. Geol. Survey, Canada, V, 52 D.
[3] McConnell. Geol. Survey, Canada, V, 53 D.
[4] McConnell. Geol. Survey, Canada, V, 27 D.
[5] McConnell. Geol. Survey, Canada, V, 54 D.

The Dunvegan beds are probably of the same age as the Belly River of the south (page 40).

Colorado.—In this group McConnell included the lower part of the LaBiche shales (225 feet), the Pelican sandstone, Pelican shale, Grand Rapids sandstone, and Clearwater shale of the Athabaska.

The Pelican sandstone first appears beneath the LaBiche shales at the mouth of Pelican river. It has a slight dip to the south, is 40 feet thick, and is usually conspicuously white, but is tinged yellowish or brownish in places. This is underlain a few miles down the river by the Pelican shale, which is a prominent feature of the valley for many miles. The shale is 90 to 100 feet thick. It is very uniform in composition, is slightly darker and harder than the Pierre, and weathers into a talus of small flaky particles.[1] About half-way between Pelican river and House river the Grand Rapids sandstone shows beneath the Pelican shale. It is characteristically yellowish, although occasionally whitish. It is coarser grained than the Pelican sandstone, and some beds are a coarse grit or fine conglomerate. Seams of lignite from a few inches to 5 feet in thickness occur at intervals through the formation. The full thickness of this formation, 300 feet, is seen 8 miles below Grand Rapids at Point LaBiche. At this point the Clearwater shale appears beneath the Grand Rapids sandstone. This shale is less homogeneous than the Pelican shale, consists of dark and lead-grey shales and clays, and holds a considerable proportion of greyish sandstone, greenish glauconitic sandstone, and ironstone. At the head of Boiler rapids the base of the Clearwater shales appears and the top of the Tar sands is exposed. The shales at this point assume their usual thickness, 275 feet. They continue to overlie the Tar sands as far down as the Forks. The Tar sands have already been fully described (page 36).

On Peace river the Colorado group includes the Fort St. John shales, Peace River sandstones, and Loon River shales. The Fort St. John shales are exposed for some miles above and below Fort St. John. Down the river they are concealed for many miles by the Dunvegan beds, but emerge again 24 miles above Smoky River forks and are exposed as far as Battle river and beyond. They also form the upper part of Buffalo Head hills. They have a minimum thickness of 700 feet, and consist of brownish and dark greyish to black shales, holding calcareous nodules, and nodules, lenses, and beds of

[1] McConnell. Geol. Survey, Canada, V, 29 D.

ironstone.[1] They correspond in general with the lower part of the LaBiche shales.

The Peace River sandstone, about 400 feet thick, is probably the equivalent of the Pelican sandstone and shale and Grand Rapids sandstone. It appears beneath the Fort St. John shale immediately below the Smoky River forks, and is exposed down the Peace to 3 or 4 miles below Battle river. It consists of heavy massive beds of yellowish and greyish, soft, coarse sandstones, alternating with bands of thin-bedded sandstones and shales. There are a few lignite seams and many hard sandstone concretions varying from a few inches to 10 or 15 feet in diameter. In descending the river the formation becomes more argillaceous and decreases in thickness. It appears on Loon river, but in diminished volume.

The Loon River shales appear beneath the Peace River sandstones in Peace river, about 20 miles above Battle river, and are exposed nearly all the way down to Vermilion falls. They occur also on the lower part of Loon and Red rivers. Although no contact was seen, they probably rest directly on the Devonian limestone, no Tar sands being seen. They consist of dark grey to nearly black, soft shales, carrying calcareous and ironstone nodules and occasional beds of sandstone, impure limestone, and ironstone. They are 400 feet thick.

LARAMIE.

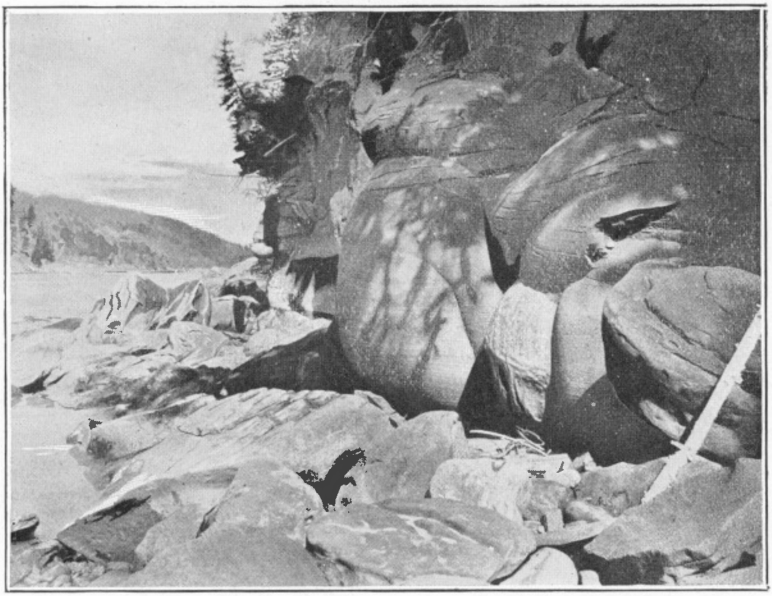
In placing under this heading the formations to be described, it is not the intention of the author to indicate in this way the precise age of the formations or to indicate the dividing line between the great geological systems. The grouping is for convenience in description and for the purpose of showing the stratigraphic relations of the formations.

Rocks of later age than the Bearpaw lie in the great Alberta trough which extends from the 49th parallel north as far as the 55th parallel and then bears to the northwest. More or less isolated patches are found in the southern part of Saskatchewan and areas of greater extent reach northward into Saskatchewan and Manitoba from the United States.

From a study of the southern part of Alberta, Dr. Dawson divided the Laramie rocks into three classes, as follows[2]:—

[1] McConnell. Geol. Survey, Canada, V, 55 D.
[2] Geol. Survey, Canada, 1882–84, 112 C.

PLATE IV.



Nodules in Grand Rapids sandstone, Grand Rapids, Athabasca river.

"Porcupine Hill beds. Sandstones, frequently thick-bedded and generally comparatively soft, with intercalated greyish and blackish shales and shaly clays. Freshwater..	2,500 feet.
"Willow Creek beds. Soft sandstones, shales, clays, and sandy clays, generally with a pronounced reddish or purplish tint. Freshwater..	450 "
"St. Mary River beds. Sandstones, shales, and shaly clays in frequent alternations, and generally well bedded. Freshwater, except near the base.. ..	2,800 "

[1] Tyrrell, in his study of the geology of central Alberta, divides these rocks into two series, the Paskapoo and the Edmonton. [2] McConnell also finds that the Laramie of southern Saskatchewan may be separated lithologically over most of the district into two distinct divisions, and [3] Dowling points to a similar division in the coal-field of the Souris river.

Edmonton.—The Edmonton series extends westward from the vicinity of the 112th meridian to the foot-hills and northward to beyond the 55th parallel. It rests conformably on the Bearpaw, and a large part of it is overlain by the Paskapoo. The exposure to the east of the Paskapoo is much wider than that to the west, and widens considerably towards the north. It consists of whitish or light grey clay and soft argillaceous sandstone, with nodules and layers of ironstone, and numerous coal seams. It is one of the important coal-bearing formations of the Northwest. It is a brackish water formation, and corresponds to the lower part of Dr. Dawson's St. Mary River beds. In central Alberta it attains a maximum thickness of 700 feet. The lower part of the Laramie of southern Saskatchewan is correlated with this series. It consists of 150 feet of feebly coherent, grey and pure white clays, arenaceous clays and sands, with a few beds of carbonaceous shales and lignites.[4]

Paskapoo.—This series overlies the central part of the Edmonton, and extends from near the International Boundary north beyond the 54th parallel. It includes Dr. Dawson's Porcupine Hills and Willow Creek series and all but the lower 700 to 900 feet of the St.

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1 Geol. Survey, Canada, II, 127 E.
2 Geol. Survey, Canada, I, 67 C.
3 Geol. Survey, Canada, XV, 15 F.
4 McConnell. Geol. Survey, Canada, I, 68 C.

Mary River series. It is a freshwater formation, and consists of yellowish sandstones and bluish-grey and olive arenaceous shales, with bands of ferruginous sandstone and concretionary blue limestone. In southern Saskatchewan the upper division of the Laramie is more arenaceous than the lower and is yellowish in colour. It consists of sands passing into soft sandstone, silts, and clays. The thickness varies a great deal owing to irregularity in deposition, and to subsequent erosion. In the outer edge of the foot-hills, on Little Red Deer river, a thickness of 5,700 feet was determined, but the bottom was not seen, and much has probably been removed from the top by erosion. The thickness evidently diminishes a great deal towards the east, for the Hand hills, which rise 1,000 feet above the general level of the surrounding country, are capped by Miocene deposits, while the Edmonton series is exposed at their base.[1] The upper portion of the Laramie in southern Saskatchewan has a maximum thickness of only 750 feet.

TERTIARY.

[2] *Oligocene.*—This is the formation described by McConnell as Miocene. Beds of this age cap the Hand hills and the more elevated parts of uplands extending from the west end of the Cypress hills to the east end of Swift Current Creek plateau. In the Hand hills and Cypress hills they rest unconformably on the Paskapoo, and upper portion of the Laramie, but near East End coulee they are underlain by the Bearpaw. [3] "The Miocene beds are characterized by the great quantity of waterworn pebbles, derived from the quartzite formations of the Rocky mountains, which are found in every part of the series. The pebbles are usually cemented together into massive beds of hard conglomerate, but also occur distributed irregularly through, or arranged in layers and lenticular beds in the sands and sandstones."

Pliocene.—Beds, probably of this age, and known as South Saskatchewan gravels, are found in pre-glacial depressions of southern Saskatchewan.[4] There is generally a single bed of conglomerate, 2 to 50 feet thick, composed of small quartzite pebbles either consoli-

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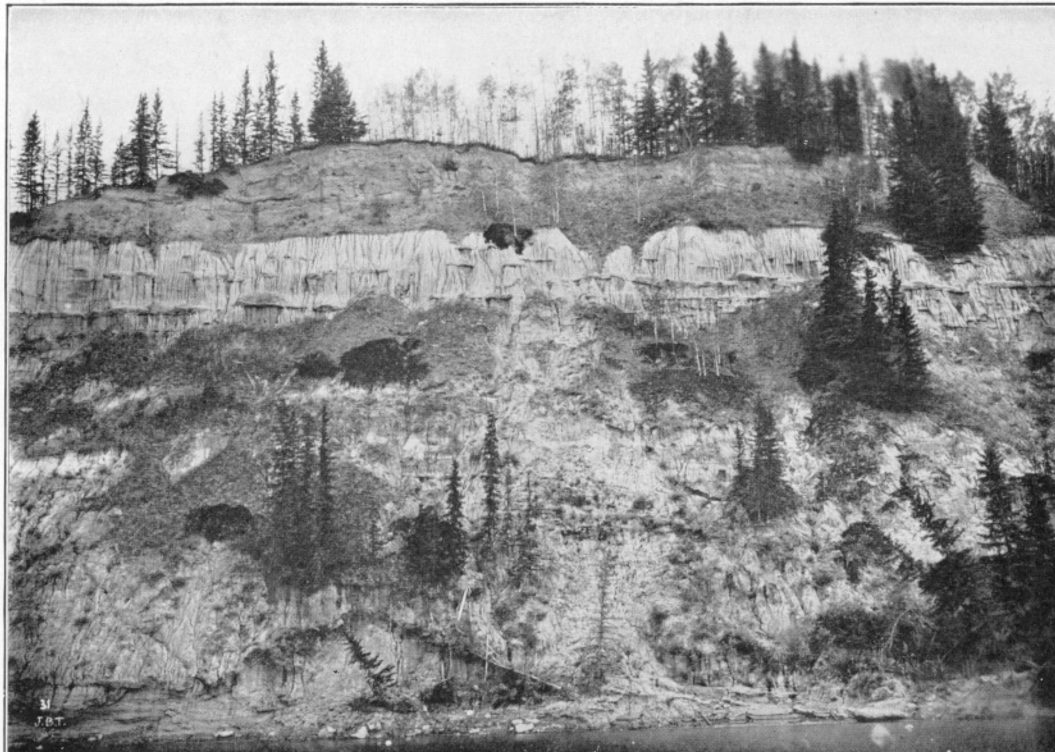
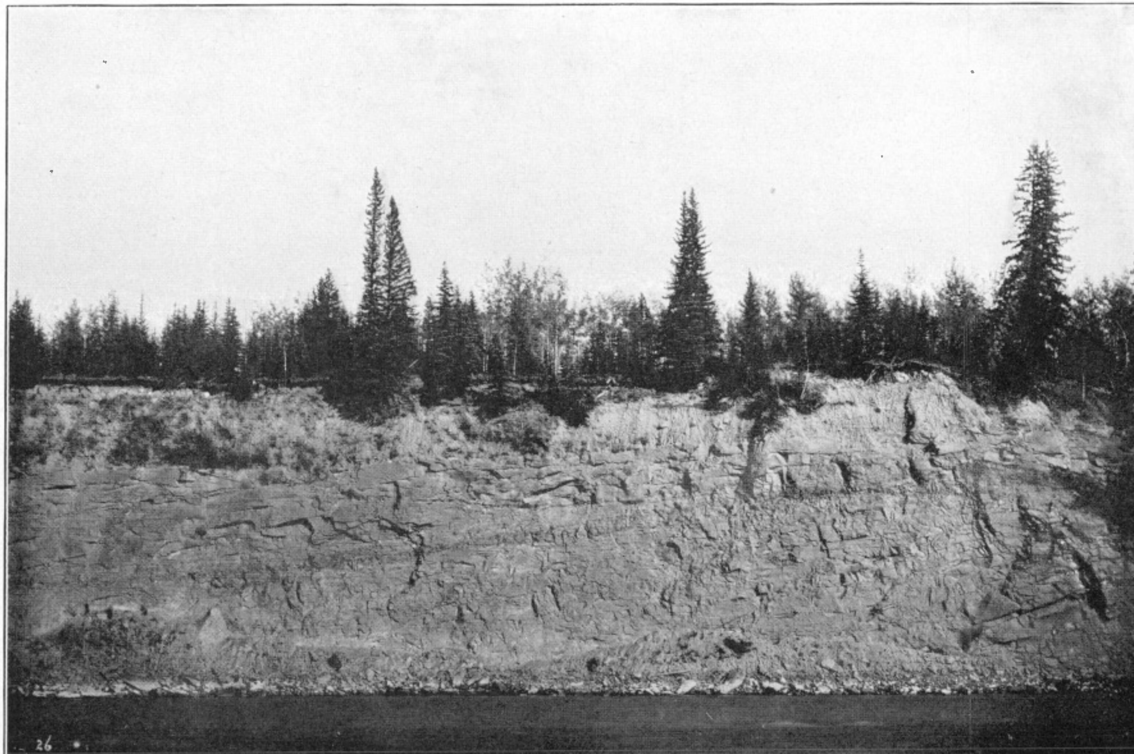
[1] Tyrrell. Geol. Survey, Canada, II, 76 E.
[2] Lambe, Lawrence, M., Cont. to Can. Palæontology, Vol. 3, Part 4.
[3] McConnell. Geol. Survey, Canada, I, 69 C.
[4] McConnell. Geol. Survey, Canada, I, 70 C.



Edmonton series, bank of North Saskatchewan river, 40 miles above Edmonton.

22012—p. 50.



Paskapoo sandstone, Saskatchewan river, two miles below Rocky Mountain House.

Oligocene conglomerate, Bone coulée, Cypress hills.

22012—p. 50.

dated by a calcareous or ferruginous cement, or lying loose in a sandy matrix. They underlie the Pleistocene deposits and always lie at a lower level than the Miocene, from which they are, in great part at least, probably derived.

PLEISTOCENE AND RECENT.

The unconsolidated mantle spread over the surface of the area studied consists of glacial and lacustrine deposits of Pleistocene and subsequent times, and varies much in texture and thickness. "The glaciation of the mountains spreads a mantle of till through the foothills. The till of the Keewatin glacier does not always reach the eastern margin of the Rocky Mountain till, and they are possibly of two distinct periods. The eastern derived till is thin on the uplands, and often appears to have been rearranged by deposition in water. Morainic deposits occur on the Côteau in eastern Saskatchewan, and in Manitoba. Glacial lake phenomena have been observed at several parts; but the Lake Agassiz beaches of Manitoba, and the upper Red river, have formed the subject of several interesting reports."[1]

Structural Geology.

The most important feature regarding the structure of the rocks of the plain is their horizontality. There is little marked folding of the strata from Manitoba west until the foot-hills are reached, and the dip seldom exceeds a few feet per mile.

In northern Alberta the general dip is towards the south. North of Crooked rapids, on the Athabaska, there is a very slight dip to the north, while to the south there is a dip southwest of 5 to 10 feet per mile. The Tar sands, the top of which is exposed in the valley of the Athabaska at Boiler rapids, were struck in a bore-hole at a depth of 750 feet at the mouth of Pelican river, about 50 miles to the south. Because of this southward dip good sections of the Cretaceous formations are exposed on the Athabaska and Peace rivers, where the strata are seen underlying one another and coming to the surface in succession on descending the rivers.

In Manitoba the dip of the strata is to the southwest, but is only a few feet per mile. In southern Saskatchewan there is a dip to the northeast of about 10 feet per mile. Some idea of the slight

[1] Dowling. Coal Fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia, p. 22.

dip of the strata can be had from the results of borings at Morden and Deloraine, and on the Vermilion river in Manitoba. If the top of the Niobrara, which has been recognized in all three wells, be taken as a horizon for comparison and be referred to the sea-level as a datum plane, the following table gives the relative elevation of the strata:—

—	Deloraine.	Morden.	Vermilion river.
Altitude	1,644	978	1,300
Depth of top of Niobrara in well	1,050	55	95
Height of top of Niobrara above sea-level	954	923	1,205

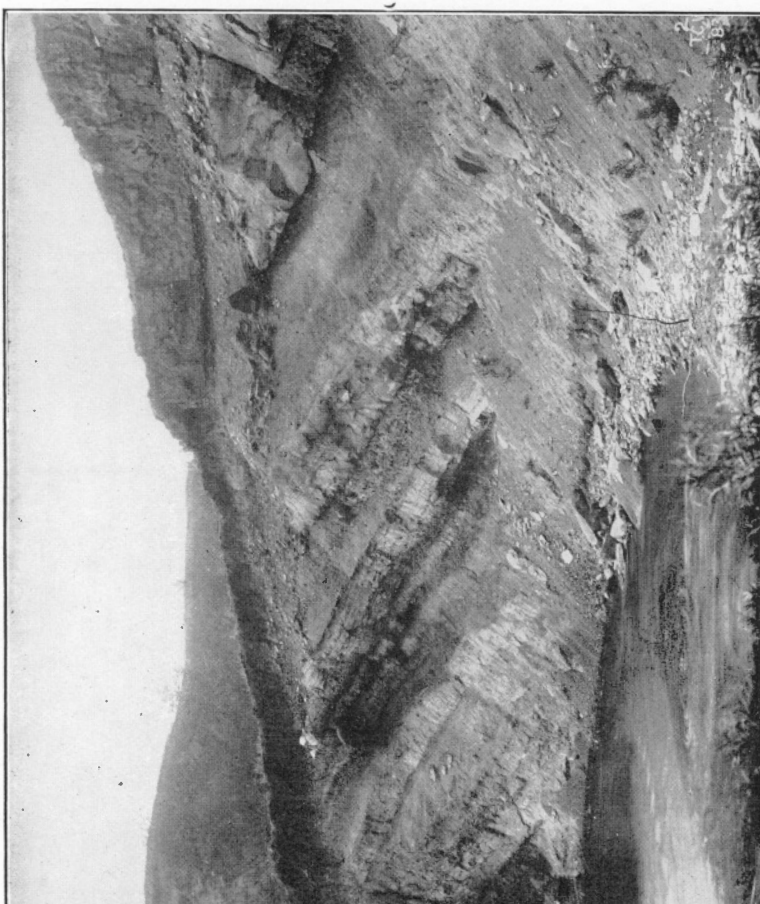
Deloraine lies about 115 miles west of Morden and 145 miles south of the boring on Vermilion river. According to this the dips are only 3 feet per mile west and less than 4 feet per mile south. These dips would, however, be somewhat increased if the bottom of the Niobrara were taken as the horizon for comparison, for while only 128 feet of Niobrara is recognized on Vermilion river, and 160 feet at Morden, the Deloraine well gives 545 feet.

Notwithstanding the generally horizontal character of the rocks, geologists have recognized in eastern Alberta and western Saskatchewan two very diffuse anticlines. The apex of one lies in the vicinity of the intrusions of Sweet Grass hills. Passing into Alberta it runs a few degrees west of north to the confluence of the Bow and Belly rivers. The other, which lies a long distance to the northeast of this, crosses the boundary between Saskatchewan and Alberta at about the 52nd parallel of latitude and runs northwest. Along these anticlines and the intervening erosion depression is exposed the wide belt of the Belly River formation, the lowest geological horizon to be found on the plains west of Manitoba, with the exception of a small area of the lower dark shales, and here will be found the nearest approach to the underlying Dakota formation in this part of the country.

Between these anticlines and the foot-hills is a very broad syncline, that widens greatly towards the north. In this is contained the large volume of Edmonton and Paskapoo sediments.

In the foot-hills and in the Rockies the strata are much folded

PLATE VIII.



Pincher creek. The disturbed belt.

22012—p. 52.

and faulted, the faults being thrusts with the down-throw on the east.

The general horizontality of the strata of the plains is relieved by more or less slight local undulation, and in some places the dip amounts to as much as 25 degrees or 30 degrees. Little is known in detail of these undulations, although they may have an important bearing on the distribution of oil or gas in the rocks.

Another important structural feature is the unconformity that represents the great lapse of time between the Devonian and Cretaceous periods. In Manitoba and northern Alberta the sandstones of the Dakota group of the Cretaceous system are found resting directly on the Devonian limestones, although no great unconformity in the attitude of the strata exists. In the west, however, this time interval is represented by sediments deposited during Carboniferous, Triassic, and Jurassic times. The Carboniferous formations are several thousand feet thick, but their extension eastward from the Rocky mountains is unknown. The Permo-Triassic Upper Banff shale is over 1,200 feet thick and its distribution is also unknown. The Jurassic Fernie shales and the Kootanie formation of the Cretaceous system are both known to thin rapidly towards the east, and it seems probable that neither is of any importance east of the foothills. It would, therefore, appear that the unconformity extends west from Manitoba some considerable distance with partial bridging by one or more of the above systems on approaching the disturbed area to the west.

[1] Historical Geology.

'The subsidence during Palæozoic times of parts of the central continental area is shown in the marine limestones outcropping in Manitoba and the Rocky mountains. Afterward the depressions in which the Mesozoic rocks were deposited first appeared in the longitude of the Rocky mountains, and Triassic and Jurassic deposits are there found. Early Cretaceous depositions occur in the same district following a shallowing of the sea, in which very little of the present continent was submerged. The unconformity between the Cretaceous and the Palæozoic floor, on which it was laid down, is shown in the fact that varying time intervals are there recorded. Thus, in Manitoba, Dakota beds lie on upper Devonian, and in the

[1] Dowling. Coal Fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia, p. 27.

Rainy River[1] district possibly on Archæan. In Stearns county, Dakota, the floor is Archæan; but on the southwest border, Jurassic, and probably lower Cretaceous, are separated by a probable unconformity. On the Athabaska river, marine beds of Dakota age rest on Devonian; while in the Rocky mountains there seems no visible break in the section through Carboniferous, Triassic, and Jurassic to the lowest known horizon of the Cretaceous. The floor then, on which the Cretaceous was laid down, was probably a plane of erosion, in which the formations occupy successive bands; the newer beds being those on the west.

'The Cretaceous covering appears to have been deposited also in a somewhat irregular manner owing to crustal movements. The Jurassic and lower Cretaceous do not appear to have covered the whole area, and indicate that the Jurassic sea invaded the area along a narrow depression, now elevated in the foothills and Rocky mountains. Land conditions prevailed throughout portions of the early Cretaceous, but the occasional submergence extended a short distance east of the mountains; and in the United States to the south, appears to have gone as far as the Black hills, and part of Montana. The greatest amount of detrital matter is to be found, and evidence also of an abundant flora, along the western portion of this early Cretaceous depression.

'A more general subsidence brought the sea farther northeast during Benton times, and covered the sandy deposits of the Dakota by a series of dark marine shales. In the western sections there is evidence of a possible shallowing at the top of the Benton; but in the east the sea continued to the close of the Niobrara.

'The deposits of the Montana group indicate marine conditions; but its inception shows shallow water along the western margin. In the east, deeper water prevailed throughout. A shallowing of the western part occurred about the middle of this period, and land conditions are there apparent. Land plants appear—preserved in coal seams. This area was again invaded by the sea, and these sandy deposits were covered by marine shales. The close of the Cretaceous is marked by an emergence from the sea; but during the periods of oscillation between land and shallow water conditions—when the surface remained near sea-level—an abundant flora appears along

[1] It has also been recently found that the Dakota beds rest directly upon the Pre-Cambrian rocks in Saskatchewan north of Prince Albert.

with brackish water forms of animal life. The coal-bearing beds of this phase of the retreat of the sea have been called the Edmonton formation in northern Alberta; the St. Mary River series in southern Alberta; and the lower part of the Laramie in Saskatchewan.

'Toward the close of the Laramie period the transfer of the great mass of deposits that had proceeded through Cretaceous times began to unsettle the equilibrium of the area from which they had been derived, and the crustal movements which ended in the forcing up of the Rocky mountains then commenced.

'This movement seems to have been caused by a great lateral force shoving the crust from the southwest, and anticlinal ridges no doubt appeared, but soon developed into fault lines along which the Palæozoic floor was pushed up from the west to form the mountain ridges. The amount of this displacement decreases in the ranges toward the east, and in the foothills brings only the middle Cretaceous beds to the surface.

'The erosion of the ridges thus formed supplied much of the material found in the Miocene[1] beds. The conglomerate of the upper portions are apparently derived from the quartzites of the mountains.'

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[1] Now known to be Oligocene.

ECONOMIC GEOLOGY.

General Statement.

As the object of this memoir is to discuss the oil and gas prospects of the Northwest, other mineral resources of the district such as the coal deposits will not be described.[1] With regard to the oil and gas prospects, the most important areas to be considered are: (*a*) the Athabaska River district, where the Dakota sandstones are impregnated with a bituminous substance, a petroleum product, and where gas is known to occur in abundance; (*b*) the country about Medicine Hat and westward where gas has been found at different horizons but in greatest abundance probably in the Dakota sandstone; (*c*) the Pincher Creek district, where there has been some prospecting for oil.

Athabaska River District.

In the Athabaska River district government drilling has proved the presence of an abundance of gas in the Dakota sandstones, and the Tar sands furnish evidence that at one time at least a portion of the same formation was saturated with petroleum.

The distribution of the Tar sands has already been given (page 35). They outcrop along the valley of the Athabaska and its tributaries for a distance of 90 miles below Boiler rapid. They are of Dakota age, rest unconformably on the Devonian limestone, and are overlain by the Clearwater shale as far down as the Forks. They must have consisted originally of almost unconsolidated sands and soft sandstones ranging in texture from a fine silt to a coarse grit, with a few lenticular beds of limestone, and lignite seams 2 or 3 feet thick.[2] These sands are impregnated by a tarry or bituminous substance. The bitumen is unequally distributed, and the rock varies in colour from grey to a dark brown and jet black, according to the quantity of bitumen contained. In a few places the quantity is only sufficient to stain the grains, but there is generally enough to render

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1 For a description of the coal deposits see "The Coal Fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia" by D. B. Dowling, Geol. Sur., Can., 1909.

2 McConnell. Geol. Survey, Canada, V, 34 D.

the mass more or less plastic. [1]'At a temperature of 60° Fahr. the mass is sufficiently plastic to bend considerably before breaking. When cut with a knife the shavings or chips curl up like those of hard soap. When worked in the hand it becomes softened, and may be moulded like putty, and is quite as brittle. In a fire of wood it soon ignites, burning for some time with a smoky flame, and then falling to powder.' During warm weather tar oozes from the rock and flows in places down the face of the banks of the Athabaska and over the limestone at their base. At ordinary temperatures this sandy tar has the consistency of hard cheese, and yields only slightly to the pressure of the foot, but on warm days it causes some inconvenience to those walking over it.

It is believed that the bituminous substance saturating the sands is really an inspissated petroleum, and that it is derived from a liquid petroleum by the evaporation of the more volatile hydrocarbons and by such chemical action as oxidation and polymerization. It is thought that this petroleum welled upward from the Devonian limestones into the porous Dakota sands where it was retained by the overlying shales. Erosion of these shales has exposed the petroliferous sands, and given opportunity for evaporation and chemical action, resulting in the tarry, coherent cement.

As already stated, it is believed that the Devonian limestone forms the source of the petroleum. [2]'The walls of the transverse joints and other spaces in the limestone were frequently observed to be blackened with petroleum, and at a place nearly opposite to the mouth of the Little Red river some irregular cavities contained inspissated pitch. These limestones were not found to yield petroleum on fresh fracture, although they had occasionally a bituminous smell, but traces of the oil were afterwards found in a bed of limestone on the Clearwater river, which would be much lower down in the formation.'

An analysis by Dr. Hoffmann of a specimen of the Tar sands collected by Dr. Bell gave the following result:—

Bitumen..	12·42 per cent.
Water (mechanically mixed).. ..	5·85 "
Siliceous sands...	81·73 "

The Barber Asphalt Paving Company has kindly furnished the

[1] Bell. Geol. Survey, Canada, 1882–83–84, 15 CC.
[2] Bell. Geol. Survey, Canada, 1882–83–84, 24 CC.

following results of analyses of samples sent from the Athabaska region in 1905:—

	No. 1.	No. 2.
Material	Bituminous sand	Seepage
Bitumen by CS_2	19·4 %	56·2 %
Vegetable refuse	0·0	3·8
Quart. sand	80·6	40·0
Character of bitumen	Heavy maltha	Very heavy maltha.

As this part of Alberta becomes settled and railway facilities are provided these Tar sands may grow into commercial importance. The supply is almost inexhaustible. The beds vary in thickness from 140 to 220 feet, and although they have not been fully explored it has been estimated that they have a distribution of at least 1,000 square miles. The discovery, however, of the Tar sands in the bore-hole at Pelican river, since this estimate was made, shows a much wider distribution than was at first suspected.

Since the bitumen has probably been derived from petroleum by evaporation and chemical changes, it was thought that at some distance from their outcrop the sands would be saturated with the liquid petroleum. To test this conjecture boring operations were undertaken by the Dominion Government during the nineties. As the strata dip to the south at a low angle the boring was undertaken to the south of the outcrop of the Tar sands.

The first operations were at Athabaska Landing. Work was begun there in 1894, and during that year a depth of 1,011 feet was attained; in 1895 it was carried, with difficulty, to a depth of 1,731 feet, and in 1896 a further depth of 39 feet was attained, when it was found impossible to go deeper. Great difficulty was encountered on account of the caving of the shale. At a depth of 1,770 feet it was believed that the drill was in the Clearwater shales, but since the Dakota sandstone was not reached the boring does not prove the existence or non-existence of petroleum at that horizon. Gas in small quantities was encountered at several horizons. (Log on page 68).

In 1897 drilling was started at Victoria on the Saskatchewan, and near the mouth of Pelican river on the Athabaska. At Victoria the hole was drilled 705 feet in 1897, was extended to 1,650 feet in 1898, and to 1,840 feet in 1899. Much trouble was encountered by the caving of shales, and at a depth of 1,840 feet the casing became so tightly wedged that it was impossible to move it either up or down and operations ceased. (For log, see page 91). The Tar-sand

Tar sands, Athabasca river, below Little Red river.

horizon has been estimated to lie at a depth of about 2,100 feet at this point, and, therefore, within about 250 feet of the bottom of the hole.

In the case of the work started near the mouth of Pelican river in 1897 the bore-hole was carried to a depth of 821 feet 6 inches that year, while in 1898 it was continued to a depth of 837 feet. After passing through 86 feet of sand and gravel, 99 feet of Pelican shales, 280 feet of Grand Rapids sandstones, and 285 feet of Clearwater shales, the Tar sands were met at a depth of 750 feet and penetrated 87 feet. (For driller's log, see page 86). Small quantities of gas and heavy petroleum were met at different horizons above the Tar sands. The Tar sands themselves were found to consist of soft sandstone saturated with heavy petroleum or maltha. Strong flows of gas were struck at 750 and 773 feet, and at 820 feet a tremendous flow was struck, the roaring of which could be heard at a distance of 3 miles or more. The flow was so strong that no progress could be made in drilling, and work was abandoned until 1898, when it was thought the force of the gas would be decreased sufficiently to permit of further operations.

[1] But though there was a seeming decrease of pressure, upon operations being resumed in 1898, 'the seeming decrease was found to be in a great measure due to the closing up of the outlet at the bottom of the casing by an asphalt-like mixture, composed of maltha or petroleum tar and sand. In fact when boring operations were resumed on June 17, the difficulty was found to be intensified by the accumulations of this asphalt-like maltha in the bottom of the bore.

'The rapid expansion of the gas produced a very low temperature, and this chilled and solidified the tar, or maltha, until it became as adhesive as wax. As the tools cut it loose the gas would carry it up through the bore, until from bottom to top it was almost one mass of sand and tar. The only way it could be extracted from the sand-pump was by heating the latter over a fire; even then very little could be got out at one time, it being so thick that it was almost impossible to force it up into the pump. I used different sorts of tools to cut it off the walls and clean it out, but the longer we worked at the bore the greater the quantity of tar accumulating on the sides of the casing and tools.' By using smaller casing the hole was carried to a depth of 837 feet, when another flow of gas

[1] Geol. Survey, Canada, XI, 32 A.

was met, nearly equal in volume to that met at 820 feet, and the work was stopped.

The finding of the heavy bitumen in the Dakota sandstones at a point so far from their natural outcrop was acknowledged to be a disappointment, as it was hoped that petroleum of a commercial quality would be found. The failure to find a liquid petroleum at Pelican river, however, does not disprove its existence at other points. Much has, no doubt, escaped, but the hardening of the tarry substance at the points of issue may have served in places as a seal to prevent the escape of all the liquid. Its escape may also have been prevented in some places by a decrease in the porosity of the sandstone, while in other places it is very probable that anticlines occur into which petroleum may have risen and been retained.

Some boring operations have been conducted at Fort McMurray and at other points on the Athabaska, but logs of these have not been obtained.

There are indications of a wide distribution of oil in northern Alberta. On Peace river and Lesser Slave lake bitumen has been found at a number of places lining cracks in nodules, and at Tar island, in Peace river, small quantities of tar are brought to the surface by a spring. On the northwest quarter of section 30, township 56, range 25, west of the 4th meridian, some small veins of hardened pitch and layers of sand saturated with pitch have also been found in the drift deposits.[1] Besides these, natural gas springs have been found at different points on the Athabaska and Peace rivers. The northern part of Alberta offers a promising field for the testing of oil and gas possibilities. The southward dip of the rocks must be remembered, and the consequent necessity of going to greater and greater depths with increased distance from the northern outcrop of the Tar sands.

The Mackenzie Valley.

According to McConnell[2] the 'Devonian rocks throughout the Mackenzie valley are nearly everywhere more or less petroliferous, and over large areas afford promising indications of the presence of oil in workable quantities.' Petroleum springs have been observed in several places, as on Great Slave lake and near Fort Good Hope. In the bay immediately east of the Big Island fishery in Great Slave lake

[1] Dawson. Geol. Survey, Canada, XI, 29 A.
[2] Geol. Survey, Canada, IV, 31 D.

a spring rises from below the surface of the water. About 200 yards from the shore of another bay at the west end of the same lake three springs are found at the base of a low cliff of cavernous dolomite. This dolomite is everywhere permeated with bituminous matter which oozes up through cracks and forms small pools. Petroleum springs are also reported half-way between the bay and Fort Rae.

On the right bank of Peel river 10 miles below the lower canyon a 3 foot vertical fissure cutting across sandstone and shales is filled with a light, soft, carbonaceous substance which burns readily with a red flame, leaving very little ash. It has its origin, probably, in the bitumen of the rocks that it cuts.[1]

In a great many places throughout the Mackenzie valley the rocks are highly charged with petroleum. On Slave river, 30 miles below Chipewyan, the limestone beds contain inspissated petroleum in fissures; bituminous shales and limestones are seen at several points around the west arm of Great Slave lake; the rocks at the 'Rock by the River Side,' at Bear Rock, and at the Ramparts on Mackenzie river, are highly bituminous. Near old Fort Good Hope the river is bordered for several miles with shales completely saturated with oil; these shales have been reddened in many places by the burning of the oil. About 23 miles below Grand View are shales that will burn when thrown on the fire. The slates and associated limestones occurring in the upper and lower canyons of Peel river are more or less petroliferous, and inspissated petroleum oozes from these in several places.

The above indications point to the possibility of the occurrence of numerous oil pools in the Mackenzie valley. Although the petroliferous rocks are exposed, it is by no means a foregone conclusion that all or even the greater portion of the hydrocarbons have escaped. The shales that form the middle member of the Devonian series may serve in many places as an impermeable covering to underlying petroliferous limestones, and conditions may also be such that all the petroleum from the upper limestone beds has not evaporated.

Southern Alberta.

Our information regarding the gas field of southern Alberta is very limited. Some wells drilled at Medicine Hat to depths of 700 to 1,000 feet supply the town with light and fuel. There are also

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[1] Camsell, C. Geol. Survey, Canada, XVI, 47 CC.

productive gas wells at Dunmore Junction, Stairs, Suffield, Langevin, Bassano, and Bow Island, and in many of these it is believed that the gas veins are encountered in sandstone beds in the Niobrara shales.[1] [2] At Medicine Hat the supply at the depth of 700 feet was small, but several wells sunk to a depth of about 1,000 feet have procured a good flow of gas. In the first of these deeper wells a flow of 1,500,000 cubic feet was obtained and a rock pressure of 600 pounds. (Logs, page 82). Gas has also been struck at both of these horizons at Dunmore Junction, at the lower horizon at Stairs, and at the upper at a depth of 650 feet at Suffield. At Langevin gas was struck at about 1,060 and 1,155 feet (Log, page 79), and at Cassils at a depth of 825 feet in a brown sandstone (Log, page 74).

The most important field is that opened in the vicinity of Bow Island. Mr. Eugene Coste, the president and managing director of the Canadian Western Natural Gas, Light, Heat, and Power Company, Limited, has kindly furnished the Geological Survey with a statement of the capacities of wells that have been sunk in the Bow Island district by that Company up to February 21, 1912:—

No. 1 well............	10,000,000	cubic feet	per 24	hours.
" 2 "	7,000,000	"	"	"
" 3 "	15,000,000	"	"	"
" 4 "	29,000,000	"	"	"
" 5 "	1,250,000	"	"	"
" 6 "	4,200,000	"	"	"
" 7 "	7,000,000	"	"	"
" 8 "	12,500,000	"	"	"

The pressure in these wells is 800 pounds per square inch. The wells have a depth of 1,890 to 1,930 feet, and gas is struck in three or four streaks in the sandstone of the last 40 feet. This is believed to be the Dakota sandstone. All these wells, except No. 1, were drilled subsequent to April, 1911. The Company was at the time of writing (February 21, 1912) continuing to drill in the Bow Island district, and was also drilling at Bassano. (For log of Bow Island well, see page 70).

Two wells have been sunk at Calgary to a depth of 3,400 feet each. Well No. 1 was sunk on the Sarcee Indian reserve, 12 miles

[1] Brock. Geol. Survey, Canada, Summary Report 1909, p. 45.
[2] Mining and Metallurgical Industries of Canada, p. 302. Mines Branch, Dept. of Mines, Canada.

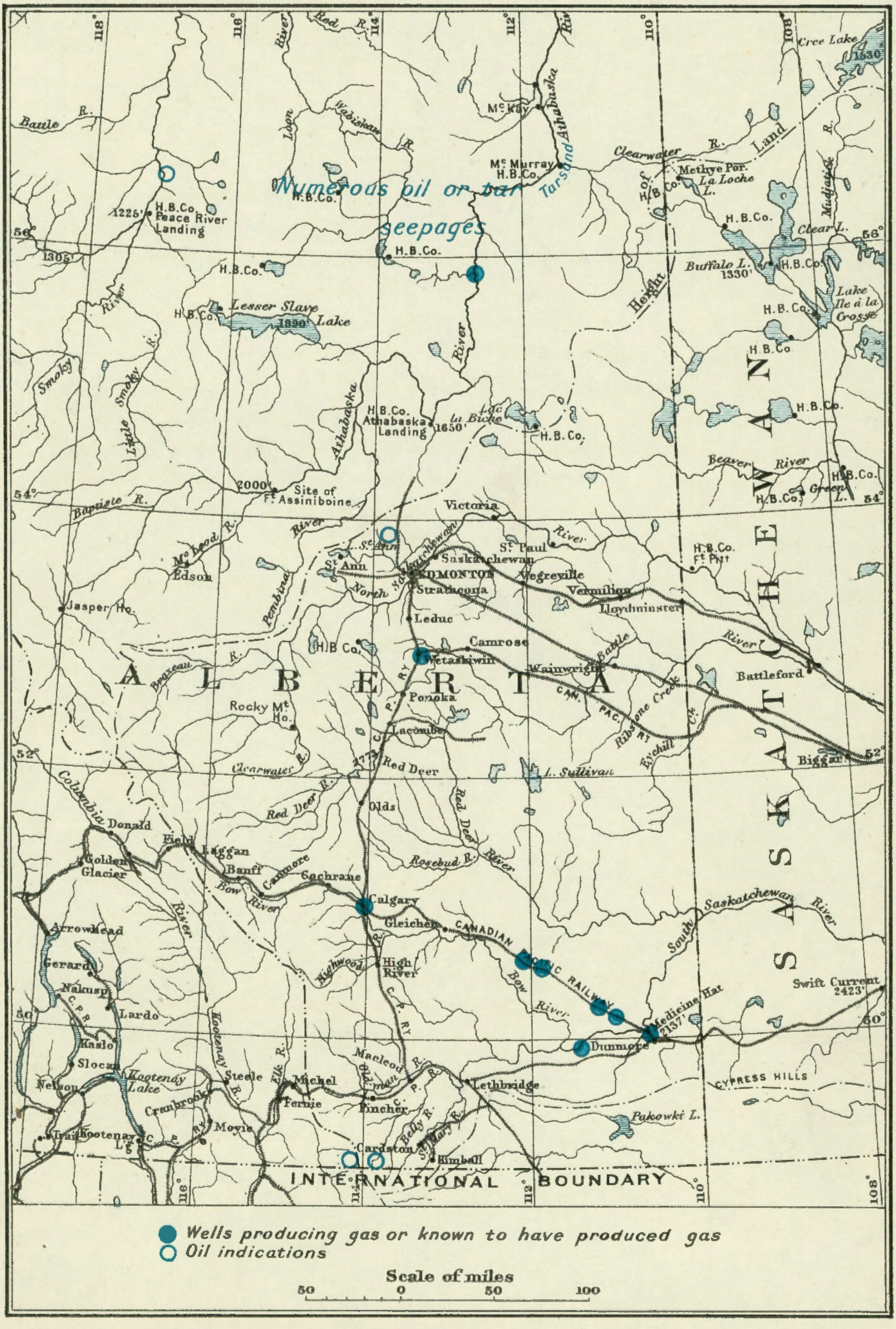

Fig. 1.—Diagram showing the position of gas fields and of oil indications.

southwest of Calgary, but no gas was struck. Well No. 2 was sunk on Col. Jas. Walker's property, east Calgary, near the Bow river. (Log, page 71). In this well gas was struck at 670 to 700 feet, at 839 to 849 feet, at 1,440 to 1,445 feet, at 1,572 feet, and at 2,760 feet, and there is still a small flow. In both wells the formations passed through consisted of shales and sandstones, and coal horizons were encountered at great depths. In well No. 1 the top of the Belly River formation has been accepted as lying at 2,969 feet from the surface, so that this formation was penetrated 440 feet. In well No. 2 the bottom of the Edmonton series was struck at about 1,953 feet, and the top of the Belly River at about 2,454 feet. In neither was the more promising horizon, the Dakota, reached.

Some drilling has been done at Edmonton, and one well reached a depth of approximately 1,800 feet (Log, page 76), but a much greater depth would be necessary at this place to reach the sands that were found so productive of gas at Pelican river. There has also been some drilling at Morinville to the north of Edmonton, and in one well a depth of at least 3,200 feet was reached.

A small amount of natural gas is being utilized at Wetaskiwin, and newspaper reports state that gas has been struck at a depth of 235 feet near Ranfurly, township 51, range 12, west of the 4th meridian, and at Tofield at a depth of 1,050 feet.

Prospecting has been carried on at a few other places, but as a rule no great depth has been attained, the most promising horizon has not been reached, and the operations have been unsuccessful.

For those engaged in boring operations the importance of a knowledge of the geological structure cannot be over-emphasized. If, as has been pointed out, the Dakota sandstone is the chief reservoir of gas and oil in the Northwest, a knowledge of the structure is necessary for the purpose of forming some general idea of the thickness of strata that must be penetrated at any particular point in order to reach this horizon. It may be well, therefore, to recapitulate here the broader structural features of Alberta.

A very broad anticline crosses the boundary in the vicinity of the Sweet Grass hills, and runs to near the confluence of the Bow and Belly rivers. Another broad anticline crosses the boundary between Alberta and Saskatchewan at about latitude 52 degrees and runs northwest. West of these is a broad syncline occupying a large part of Alberta. Along the anticlines and the intervening erosion valley of the South Saskatchewan is exposed the Belly River series, the lowest horizon exposed in this part of the district, with the exception of a small area of the lower dark shales. Here lies the nearest approach to the Dakota formation. This formation is overlain to the west by the Bearpaw, this farther west by the Edmonton, and the Edmonton by the Paskapoo. Thus in going west an ever-increasing thickness of sediments must be passed through in order to reach the Dakota sandstones, so that at Calgary they were not reached at a depth of 3,400 feet, although at Bow island they probably lie within 1,900 feet of the surface. At Victoria, on the Saskatchewan river, a hole was bored to a depth of 1,840 feet without success, and it is estimated that the Tar sands are approximately 2,100 feet deep at this point.

There must also be taken into consideration the possibility of the eastward extension of those sediments found in great thickness in the mountains, interposed between the Devonian and Cretaceous systems. These sediments are found to decrease in volume towards the east, and their extension to any great distance in that direction is problematical. If the Devonian limestone is the source of the gas and oil, the intervention of these impervious sediments would prevent the hydrocarbons from rising into the porous Cretaceous strata and thus reaching a horizon near enough to the surface to be accessible.

Pincher Creek District.

The following is taken from the Summary Report of the Geological Survey for 1909:—

"[1] In southwestern Alberta, in the Pincher Creek district, oil is being prospected for in two areas, on the south branch of the south fork of Oldman river, and on Oil creek, a tributary of Waterton lakes. The Survey has done no recent work in this district, but in the first field the rocks are, so far as can be learned, Cretaceous. The rocks on Oil creek were regarded by Dawson as Cambrian, a view which Daly supports, but Dr. Walcott, of the Smithsonian Institution, believes them to be Pre-Cambrian—corresponding to the Belt terrane of Bailey Willis. On Oil creek a green schist is exposed from which there is a seepage of oil. The oil has a paraffin base, is of excellent quality, and free from sulphur. The Pincher Creek Oil

[1] Brock. Geol. Survey, Canada, Summary Report, 1909, p. 44.

Company has two shallow wells in this shale which have not been shot. These yield one-half to two barrels of oil per day, according to information deemed reliable. As this shale outcrops at the surface, apparently over a fairly wide extent of country, it would seem that by sinking a number of shallow wells into it and torpedoing them to form catchment basins, a considerable quantity of oil might be collected from it. Three other companies are prospecting here; one has a well down 1,020 feet, which is stated to have yielded at the outset 300 barrels per day. A second well, at a depth of 1,170 feet, is estimated by the drillers to be capable of producing 25 barrels per day. These wells have not yet been shot. Three companies are prospecting on the south fork of the Oldman river: one has three holes down, the deepest of which is reported to be down 1,400 feet.'

D. B. Dowling, of the Survey, has kindly furnished the following notes:—

The 1,020 foot well, reported to yield 300 barrels per day at first, decreased in yield to less than 2 barrels per day and was abandoned.

The Western Oil, Coal, and Coke Company put down a 1,500 foot hole on section 29, township 1, range 30, but without favourable results. The same Company also drilled on section 23 at Cameron falls near Waterton lake. They went through 700 feet of limestone and then 1,200 feet of Cretaceous, buried beneath the older limestone by an overthrust fault: result—a dry hole. The same Company drilled between the village of Pincher Creek and the Canadian Pacific Railway station; at a depth of 1,500 feet the bottom of the hole was in reddish Laramie shale.

[1]"These districts lie within the front range of the mountains. Some uncertainty as to the oil prospects of this section is introduced by the occurrence of heavy overthrust faults which may have allowed oil reservoirs that once existed to drain off. Outside the mountains near Pincher creek, an anticline, parallel to the mountains, appears to exist. While this structure is favourable for oil reservoirs, the thickness of the upper Cretaceous rocks presents difficulties, and there is a possibility that the Fernie shales and Carboniferous rocks may extend out from the mountains and form an impervious blanket which prevented the oil from reaching the Dakota horizon. The driller should be prepared to go as deep as 3,500 feet, and the soft

[1] Brock. Geol. Survey, Canada, Summary Report, 1909, p. 44.

shales, etc., of the upper Cretaceous present many difficulties in such deep boring. At Calgary borings would probably have to exceed 4,000 feet to test the possibilities of the district.'

[1] Selwyn reports traces of oil in dark shales west of the main watershed, on Akamina brook, 4 miles north of the 49th parallel and 15 miles west 10 degrees south from the occurrence on Cameron Falls creek. Oil seepages also occur on Sage creek, a tributary of the Flathead.

Saskatchewan and Manitoba.

A little drilling to considerable depths has been done at different points in southern Saskatchewan and in Manitoba, and gas is reported to have been struck on section 1, township 4, range 7, west of the 2nd meridian, near Estevan. In most cases, it is probable that the Dakota sandstones were not reached. This formation, however, was penetrated by the drill on the Vermilion river (Log, page 90), and at Morden (Log, page 84), and Deloraine (Log, page 75), all of Manitoba. Unfortunately all three were dry wells so far as gas and oil are concerned, and in the last two the Dakota sandstones were found to yield saline water. How far westward this condition prevails throughout this formation is not known.

The chief structural features to be taken into consideration by the drillers are the southwestern dip of the strata in Manitoba, and the eastern dip to the east of the broad anticline along which the Belly River formation is exposed in the western part of Saskatchewan. Very little is known about local variations in dip, which might favour the formation of reservoirs for gas or oil.

It must also be borne in mind that the sinking of one or two dry wells in any locality does not prove the absence of oil or gas in that locality. Experience has shown that the distribution of these hydrocarbons is often spotted, and dry wells are often surrounded by productive wells. This peculiarity is probably due to variation in the porosity of the oil or gas-bearing strata.

As a source of oil and ammonia by distillation the bituminous shales of the Pasquia hills may be worth investigating. Of these McInnes writes:—

[2] 'The only exposures of rock in place met with on the mountain were found in gulches eroded by streams flowing down the hillslopes.

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[1] Geol. Survey, Canada, V, 11 AA.
[2] Geol. Survey, Canada, Summary Report 1907, p. 45.

They consist for the most part of soft, grey, fissile shales that contain a considerable amount of bituminous matter, enough to cause them to burn freely, with the emission of a strong odour of petroleum when heated in the camp fire. The best exposures were found in the valley of the Nabi river, where a section in ascending order, as nearly as it could be made out, gave:—

'Thirty-five to forty feet of thick-bedded, soft, grey, bituminous shale or thin-bedded sandstone, holding the remains of fishes which seem to be *Enchodus shumardi,* large bivalves probably *Inoceramus problematicus,* and *Foraminifera.* Though the first named species range widely in the Cretaceous of northern Manitoba, they occur most freely perhaps in the Niobrara.

'Six inches of harder, compact, impure limestone filled with fine shells that are probably *Ostrea congeste.*

'One hundred and twenty feet or more of soft, fissile, light grey (almost black when wet), bituminous shales holding the comminuted remains of fishes and many species of *Foraminifera.* Dr. Whiteaves, after preliminary examination, states that these fossils are clearly Cretaceous and very probably Niobrara. Mr. Wait found that these shales on ignition leave 70·17 per cent ash. From this the hydrocarbon content can be approximately inferred, as one-half or more of the remaining percentage would consist of hygroscopic and combined water.' Subsequently a sample of this shale taken at random was analysed by the Mines Branch, with the following result:—

Sulphate of ammonia..	33·5	lbs. per ton.
Crude oil..........	40·05	imp. gals. per ton.

Logs.

In connexion with the study of the logs, it must be remembered that the formations vary a great deal horizontally. Especially is this the case in formations composed of shales and sandstones, so that the log of one well passing through these will differ in detail from that of another well in the vicinity although the two will be similar in their general features. Much difficulty is experienced in determining from the log of a well the thickness of the different Cretaceous divisions. This is due to the scarcity of good horizon markers and to the gradual transition from one division to another. Then, too, the classification of these rocks has been based on surface exposures, which differ much in appearance from fresh rock, especially when the latter is in the finely divided condition in which it comes from the drill. Nevertheless in making a study of the log of a new well it is probably advisable to take into consideration the thickness of the geological formations as obtained from surface exposures at not too remote a distance. For convenience in this regard a grouped series of tables of formations is given. The logs that are now published for the first time have been obtained as a rule by Mr. Dowling during his work in the Northwest, or by Mr. Ingall, who is in charge of the water and borings branch of the Survey.

1. Athabaska Landing. 683-A. of Oil Schedule

DRILLER'S LOG.

	Feet.
Drift	0–14
Grey shale, soft and caving badly	14–245
(At 23 ft., 136 ft., and 245 ft., hard streaks were met. Below the hard streak at 245 a strong flow of gas.)	
Soft shale	245–400
(A heavy flow of gas at 334 ft., a hard streak at 338 ft.)	
Shale, slightly harder	400–425
(At 425 a hard stratum about 1 ft. thick).	
Grey shale	425–500
Darker shale, soft, caving badly	500–550
Shale with streaks of sand rock 1 to 2 ft. thick	550–580
Dark shale, very soft	580–825
(At 780 ft. salt water was struck, and a strong flow of gas).	
Shale, harder and bluer	825–900
Soft, dark shale	900–1,015
Hard, light shale	1,015–1,037
Dark shale	1,037–1,090
Sandstone, carrying water	1,090–1,130
Dark shale, caving badly	1,130–1,170
Dark shale with layers of sandstone	1,170–1,207
Dull reddish shale and sandstone	1,207–1,233
Dark, soft shale	1,233–1,237
Light grey shale, very hard	1,237–1,242
Light grey shale, soft	1,242–1,247
Dark shale, soft	1,247–1,255
Sandstone, very hard	1,255–1,260
Soft, dark shale	1,260–1,285
Hard sandstone	1,285–1,310
Dull reddish shale and sandstone, soft	1,310–1,323
Reddish shale	1,323–1,338
Sandstone and dark shale	1,338–1,350
Dull reddish shale and a little sandstone	1,350–1,391
Sandstone with layers of dark shale	1,391–1,435
Hard sandstone with soft streaks	1,435–1,448
Sandstone and dark shale	1,448–1,461
Dark shale (thin streaks of lignite)	1,461–1,491
Light, hard shale	1,491–1,531
Shale, not so hard	1,531–1,540
	1,540–1,566
Hard sandstone	1,566–1,576
Hard shale	1,576–1,601

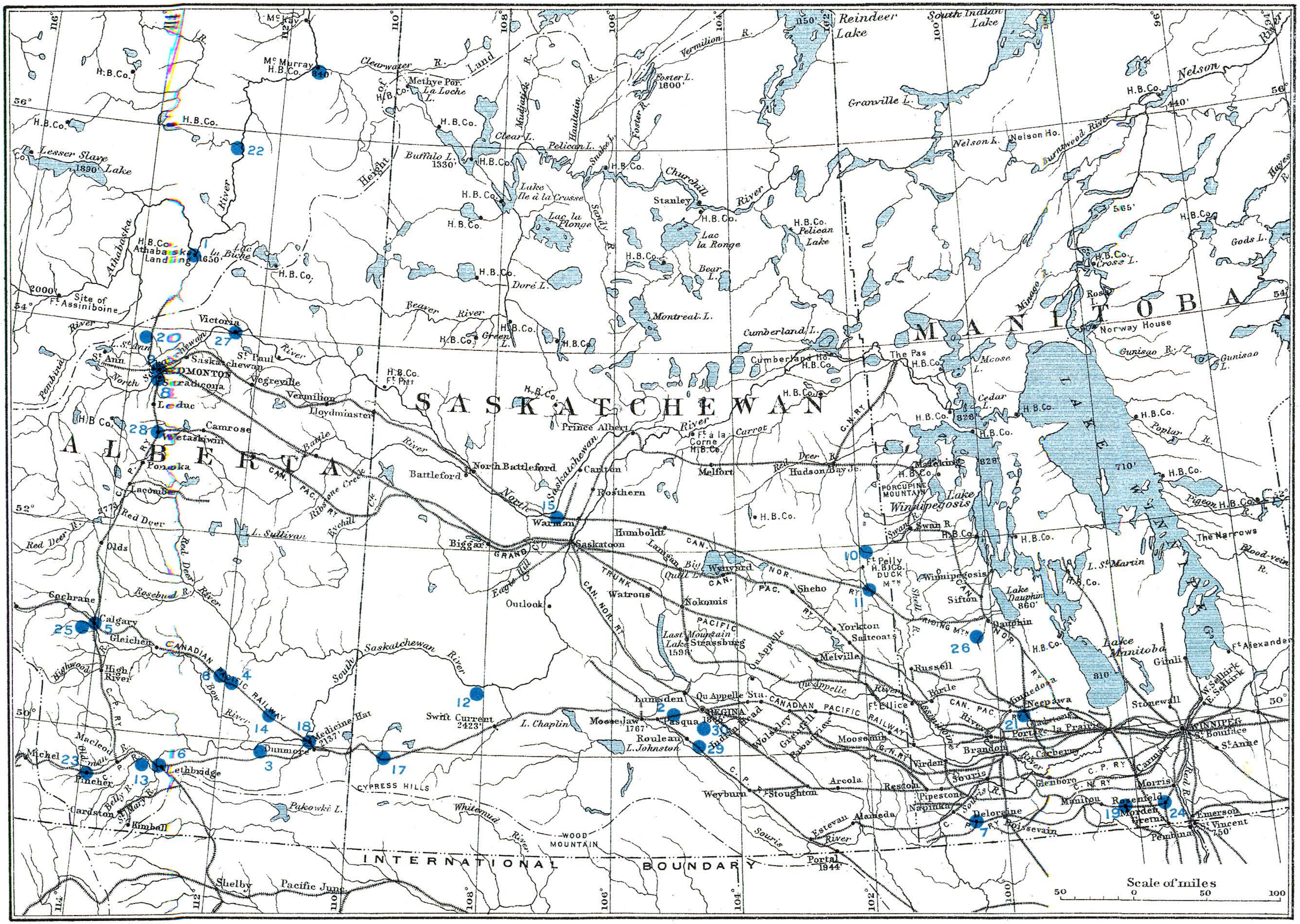

Fig. 2.—Diagram showing position of wells referred to in the text.
Numbers refer to records in the text.

TABLE OF FORMATIONS.[1]

Yellowhead Pass (McEvoy).

		Feet.
Laramie.	Paskapoo (49). Edmonton (49).	
Cretaceous.	Pierre and Foxhill (42).	
Devono-Carboniferous.		
Cambrian.	Castle Mountain group (14). Bow River series (13).	
Pre-Cambrian.	Shuswap.	

Cascade Coal Basin (Dowling).

Cretaceous.		
Jurassic.	Fernie shales (28).	1,600
Permo-Triassic.	Upper Banff shale (25).	1,200-1,300
Carboniferous.	Rocky Mountain quartzite (25). Upper Banff limestone (25). Lower Banff shale (25). Lower Banff limestone (25).	1,600 2,500-3,000 1,000-1,500 2,000
Devonian.	Intermediate series (21).	

Rocky Mountains Along Main Line of Canadian Pacific Railway (McConnell).

Cretaceous.	Kootanie to Benton.	
Carboniferous passing into Devonian.	Upper Banff shale (25). Upper Banff limestone (25). Lower Banff shale (25). Lower Banff limestone (25).	
Devonian.	Intermediate series (21).	1,500
Silurian.	Halysites beds (20).	1,300
Ordovician.	Graptolitic shales (16). Castle Mountain group (upper part) (14). }	1,500 } 7,700+
Cambrian.	Castle Mountain group (lower part) (14). } Bow River group (13).	10,000

Moose Mountain District (Cairnes).

Cretaceous.	Montana.	Edmonton(49). Bearpaw (42). Belly River (40). Claggett (39).	650 850 250
	Colorado.	Cardium sandstone (36). Benton (37).	50 725
	Dakota.	(33).	950
	Kootanie.	(33).	375
Jurassic.		Fernie shales (28).	225
Carboniferous and Devonian.			

[1] Numbers in brackets refer to the page on which formation is described.

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Peace River (McConnell).

		Feet.
Laramie.	Wapiti River sandstone (46).	
Montana.	Foxhill sandstone. Smoky River shales (46).	
	Dunvegan sandstone (47).	600+
Colorado.	Fort St. John shales (47). Peace River sandstones (48). Loon River shales (48).	700 400 400
Devonian.		

Athabaska River (McConnell)

Laramie.		
Montana.	Foxhill sandstone. †LaBiche shales (upper part) (46).	700
Colorado.	LaBiche shales (lower part) (46). Pelican sandstone (47). Pelican shales (47). Grand Rapids sandstone (47). Clearwater shales (47).	225 40 90 300 275
Dakota.	Tar sands (35).	140-220
Devonian.		

† See log No. 1.

Central Alberta (Tyrrell).

Oligocene.	(50).	270
Laramie.	Paskapoo (49). Edmonton (49).	5,700 700
Montana.	Foxhill and Pierre (42). Belly River (40).	600 600+

Southern Alberta (Dawson).

Laramie.	Porcupine Hill beds. Willow Creek. St. Mary River.	2,500 450 2,800
Cretaceous.	Foxhill sandstones (42). Pierre shales (42). Belly River series (40). Lower dark shales.	80 750 910 800

Northern Saskatchewan.

		Feet.
Keweenawan.	Athabasca sandstone.	400

Central Saskatchewan.

Cretaceous.	Dark shales. Dakota.
Devonian.	
Silurian.	
Ordovician.	
Pre-Cambrian.	

South Saskatchewan (McConnell).

Pliocene.	(50).	2-50
Oligocene.	(50).	50-500
Laramie.	Upper part (48). Lower part (48).	750 150
Montana.	Foxhill and Pierre (42). Belly River (40).	900 894

Manitoba (Tyrrell and Dowling).

Cretaceous.	Montana.	Odanah series (44). Millwood series (44).	400 664
	Colorado.	Niobrara (38). Benton (37).	130-540 160
	Dakota.		13-200
Devonian.	Upper or Manitoban (22). Middle or Winnipegosan (22). Lower (22).		210 200 100
Silurian.	Niagara (20).		200
Ordovician.	Utica ?	Stony Mountain formation (19).	190
	Trenton.	Upper Mottled limestone (18). Cat Head limestone (18). Lower Mottled limestone (18).	130 70 70
	Black River?	Winnipeg sandstone (17).	10-100
Pre-Cambrian.			

	Feet.
Hard shale with soft streaks	1,601–1,613
Hard shale	1,613–1,626
Very hard. Ironstone boulder	1,626–1,633
Hard shale (a little gas about 1,650)	1,633–1,682
Hard and soft shale alternating	1,682–1,689
Shale and sandstone alternating	1,689–1,722
Shale with a little sandstone	1,722–1,731
Shale, soft and dark	1,731–1,736
Hard sand-rock	1,736–1,747
Shale	1,747–1,752
Shale and sandstone	1,752–1,759
Shale	1,759–1,763
Hard, supposed sandstone	1,763–1,767
[1] Soft shale	1,767–1,770

[2] Dawson gives the following section at Athabaska Landing obtained from a natural exposure and from the bore-hole, the zero datum being the top of the bore-hole or about 1,660 feet above sea-level:—

Height. Feet.		*Thickness of Formation.* Feet.
	Top of bank.	
180	Yellowish sandstones, thin beds, with some ironstone: *Foxhill* or *Laramie*	15
165	Probably all grey shales, with some thin sandstone layers; not well exposed.	
Depth.		
0	Top of bore-hole.	
1,090	Grey and blackish shales, often very soft, with occasional thin, hard, layers of sandstone or iron stone. Much gas at different levels between 245 feet and 780 feet: *LaBiche shales*	1,255
1,130	Grey sandstone, with a flow of soft water: *Pelican sandstone*	40
1,233	Dark shales, often soft, a little sandstone: *Pelican shales*	103
1,461	Grey sandstones and grey reddish and blackish shales; the sandstone sometimes very hard and probably nodular, as in outcrop at Grand Rapids: *Grand Rapids sandstone*	228
1,770	Dark and light-grey shales, generally hard, with some sandstone layers, particularly towards the base: *Clearwater shales*	309 (or more)
	Total	1,950

[1] Geol. Survey, Canada, Summary Reports, 1894-5-6.
[2] Geol. Survey, Canada, XII, 14 A.

2. Belle Plaine.[1] 10-S.

Altitude, 1,877 feet above sea-level.

	Thickness of Beds. Feet.
Dark clay loam	3
Yellow clay	11
Blue clay	80
Blue shale	150
Black shale	75
Grey shale	125
Brown limestone	6
Grey shale	444
Reddish sand rock	20
Grey shale	190
Hard white sand rock	2
Grey shale, with thin layers of sand rock	200
Grey, soft shale	175
Black shale	70
Total	1,551

3. Bow Island, Section 15, Township 11, Range 11, West 4th Meridian. 16-A.

Altitude, 2,275 feet above sea-level.

—	—	Thickness of layer. Feet.	Depth of bottom of layer. Feet.
Drift	Clay and gravel	54	54
Belly River and lower part of Pierre Shales, 1,046 feet.	Grey and brown shales with shells of limestone and sandstone from a few inches to 2 feet thick. (Struck 15,000 feet of gas at 670 and 15,000 feet at 1,100 feet).	1,046	1,100
Niobrara, 500 feet	Dark brown shale with thin sandstone shells	255	1,355
	Sandstone shells, very hard	20	1,375
	Brown shales	125	1,500
	Green sandy shale	12	1,512
	Hard, grey sandstone. (15,000 feet of gas at 1,525 feet.)	13	1,525
	Green sandy shale	75	1,600
Benton, 266 feet	Soft, brown shale with gypsum in first 50 feet and with grey sandstone shells every few feet from a few inches to 3 feet thick	200	1,800
	Dark brown shale with sandstone shells close together about half sandstone and half shale	66	1,866
Dakota, 50 feet	Hard sandstone	20	1,886
	Soft, dark shale	10	1,896
	Grey sandstone, gas sand	19	1,915
	Dark shale	1	1,916

[1] Dawson, Roy. Soc. Can., Vol. IV (1886), Sec. IV, p. 94.

Struck 110,000 feet of gas at 1,884 feet.

Struck gas in great quantity from 1,898 to 1,915 feet; at 1,908 feet the well measured 4,400,000 feet (Orton's table). On February 17, measured well after blowing one month, showed 4,000,000 feet (Orton's table); drilled again and at 1,915 feet the well measured 7,000,000 feet. Closed well in 4 inch tubing with Dresser packer in 8 inch pipe. On February 23, rock pressure showed 750 pounds. On March 17, rock pressure was 800 pounds.

4. Brooks.

S.E. ¼ sec. 33, tp. 18, range 14, west of the 4th meridian.
Owner, Canadian Pacific Railway Company.

	Thickness. Feet.	*Depth.* Feet.	
Sandy clay with some sandstone	386	386	Pierre-Foxhill.
Sandstone and two coal seams ......494 Shale, grey 540	1,034	1,420	Belly River.
Dark shale	305	1,725	Lower dark shales (Claggett).
Sandstone, fine	50	1,775	Eagle.
Sandy shale and dark grey shale	815	2,590	Niobrara-Benton.
Sandstone	205	2,795	Dakota.

A flow of about 20,000 cubic feet of gas per day.

5. Calgary. P. 236-A.

Well No. 2 of the Calgary Natural Gas Co., on Col. Jas. Walker's land, East Calgary near the Bow river.

	Thickness. Feet.	*Depth.* Feet.
Surface deposits, gravel and boulders	54	54
Sandstone	20	74
Soft shale, blue	37	111
Sandstone, hard and fine	8	119
Soft shale, white	7	126
Lime crystal, quartzite	11	137
Soft shale	6	143
Slate, white	2	145
Shell, sand, hard	2	147
Shale, white	4	151
Shell, sand	1	152
Slate, white, hard	6	158
Shell, lime, hard	2	160
Slate, white, soft	18	178
Shell, sand	2	180
Shale, blue, soft	35	215
Sand	13	228
Slate, soft	24	252
Sand, grey, hard and soft alternating	16	268
Slate, white	7	275
Sand	5	280
Slate, soft	10	290
Slate, grained	10	300
Sand, grey, hard	35	335

	Thickness. Feet.	*Depth.* Feet.
Slate, soft	5	340
Sand, hard	12	352
Slate, dark, grained, lig. culm	8	360
Sand, grey, hard, with pebble	70	430
Slate, soft	2	432
Sand, grey	8	450
Slate, grey and black carrying traces of coal	57	507
Sand, medium hard	5	512
Slate, black	3	515
Sand, black	15	530
Slate, hard, brown	20	550
Slate, white	25	575
Sand, grey, fine	10	585
Slate, white	5	590
Sand, grey	6	596
Slate, soft	1	597
Sand, hard	13	610
Sand, grey, soft	27	637
Sand, grey, sharp	11	648
Slate	12	660
Sand and slate in alternating layers of 10 to 12 feet	78	738
Slate	35	773
Sand, grey, soft	19	792
Slate, dark, soft	9	801
Sand, dark grey	37	838
Slate	5	843
Shale, sand with pebble, conglomerate	15	858
Slate	4	862
Sand	13	875
Sand, blue, hard	43	918
Slate	10	928
Sand	26	954
Slate	2	956
Sand	7	963
Slate, black, grained	30	993
Sand, blue, hard	20	1,013
Slate	12	1,025
Sand, blue, hard	63	1,088
Slate	42	1,130
Sand, dark grey	14	1,144
Slate	3	1,147
Sand, grey	34	1,181
Slate	2	1,183
Sand, dark grey and sharp	49	1,232
Slate	4	1,236
Sand, grey, fine, hard	7	1,243
Shale	42	1,285
Sand, fine, dark blue turning grey	103	1,388
Shale, hard, grey turning to soft and black, then brown.	80	1,468
Sand	5	1,473
Shale, brown	15	1,488
Slate, white	74	1,562
Limestone	36	1,598
Sand, grey, sharp	75	1,673
Slate, white turning to brown	93	1,766
Sand, dark grey, fine	55	1,821
Slate, grey	52	1,873
Shale, brown	25	1,898
Coal	13	1,911
Sand, dark grey	42	1,953
Shale, black, grained	17	1,970
Sand, hard, fine	15	1,985
Shale, brown	6	1,991

	Thickness. Feet.	Depth. Feet.
Sand, black, hard	74	2,065
Shale, brown	10	2,075
Shell, sand	3	2,078
Shale, brown	8	2,086
Shell, sand	4	2,090
Shale, brown	32	2,122
Sand, dark grey	20	2,142
Shale, brown	13	2,155
Shell, very hard and flinty	2	2,157
Shale, brown	10	2,167
Sand, grey	5	2,172
Shale, brown	7	2,179
Shell, sand	2	2,181
Shale, brown	11	2,192
Shell, hard	5	2,197
Sand, brown	5	2,202
Shale, sandy brown, with some culm or bitumen	40	2,242
Slate, white and sand shells with pebble	10	2,252
Sand, light grey then dark grey, hard and soft, with pebble at bottom	110	2,362
Shale, brown	12	2,374
Shell, hard, brown	4	2,378
Coal, semi-bituminous	1	2,379
Shale, sandy	9	2,388
Shale, brown	6	2,394
Sand slate, black and shaly, calcareous matter with sand and dark brown pebble	16	2,410
Sand with white quartz crystals	8	2,418
Sand, grey, hard pebble, trace of culm	3	2,421
Shale, sandy, with shells of bitumen	31	2,452
Gypsum, calcareous	2	2,454
Shale, sandy	4	2,458
Shale, dark and soapy	25	2,483
Slate black with sand shells	5	2,488
Slate, black, flaky, with bituminous coal seams	14	2,502
Shell, hard and flint like	6	2,508
Shale, black and flaky	4	2,512
Slate, shaly	12	2,524
Shell, flinty, hard	4	2,528
Slate, shaly	5	2,533
Shell, sandy	2	2,535
Slate, shaly	9	2,544
Shell, hard and gritty	3	2,547
Slate shale	7	2,554
Shell, sandy	4	2,558
Slate, shaly	2	2,560
Coal	5	2,565
Shale, sandy, culm	4	2,569
Shell, sandy	3	2,572
Shale, sandy, pebbled	6	2,578
Sand, with streaks of shale, a little gas	32	2,610
Shale, black and sandy	13	2,623
Shell, sand	3	2,626
Shale, black, with some coal	10	2,636
Sand shale, coal showing	8	2,644
Sand, black and white, with pebble	12	2,656
Coal shale or culm	2	2,658
Coal seam	7	2,665
Shale, sandy	1	2,666
Sand, coarse then fine	16	2,682
Slate	1	2,683
Sand, grey then darker	19	2,702
Shale, black and sandy	17	2,719

	Thickness. Feet.	Depth. Feet.
Shell, sand	2	2,721
Shale, black, sandy	18	2,739
Sand, black and hard	3	2,742
Sand, with shale	10	2,752
Sand, fine, black, very hard	9	2,761
Sand, coarse, *gas sand*	11	2,772
Coal with tarry-like sand just above it	4	2,776
Shell sand, blue, hard	3	2,779
Slate, black	15	2,794
Soapstone	1	2,795
Sand, coarse, grey	5	2,800
Coal, bituminous	1	2,801
Slate, sandy	9	2,810
Shale, brown	9	2,819
Sand, coarse, grey	15	2,834
Coal, bituminous	3	2,837
Slate, dark brown	8	2,845
Shell, sand	3	2,848
Shale, dark brown, soft	20	2,868
Coal, bituminous	4	2,872
Slate shale, with soapstone	6	2,878
Sand, coarse and grey	19	2,897
Slate, black	1	2,898
Sand, hard, black	6	2,904
Coal, bituminous	3	2,907
Slate shale, hard	42	2,949
Coal, bituminous	3	2,952
Shale, slate and coal	15	2,967
Total depth of well		3,414
Bottom of Edmonton series about		1,953
Top of Belly River series about		2,454

There is a small production of gas from this well.

Analysis of the Gas.

Carbon dioxide	0·0
Carbon monoxide	0·0
Oxygen	0·1
Heavy hydrocarbons	1·80
Hydrocarbons of marsh gas series	86·70
Hydrogen	5·40
Nitrogen	6·00
	100·00

6. **Cassils.** 684 A.

Altitude, 2,493 feet above sea-level.

[1] There is some uncertainty about this log. The first three beds probably represent drift, and layers 4 to 8 inclusive appear to represent the Pierre. Gas was struck in layer 14.

	Feet.	
1. Dark clay loam	2	52 Drift.
2. Yellow clay	10	
3. Blue clay	40	
4. Blue shale	110	242 Pierre.
5. Grey shale	38	
6. Drab sand rock	3	
7. Blue shale	85	
8. Brown shale	6	

[1] Dawson, Roy. Soc. Can. IV, (1886), IV, 98.

	Feet.	
9. Coal	2	706 Belly River.
10. Grey shale	134	
11. Brown sand rock	3	
12. Black shale	257	
13. Grey shale	135	
14. Brown sand rock. Gas	5	
15. Blue shale	85	
16. Grey sandy shale	40	
17. Grey shale	45	
Total	1,000	

Dawson says layers 9 to 17 are probably Belly River, though the 'black shale' of No. 12 is anomalous.

7. [1] Deloraine. 11 - M.

About 100 yards north of the railway station.

Altitude, 1,644 feet above sea-level.

—		—	*Thickness of bed.*	*Depth of bottom of bed.*
			Feet.	Feet.
Pleistocene 91 feet		1. Black soil	3	3
		2. Clay, with some small pebbles	30·5	33·5
		3. Hard blue clay, with pebbles	56·5	90
		4. Fine black sand and gravel	4	94
Pierre	Odanah, 292 feet.	5. Light blue-grey shale	56	150
		6. Black sand, with water	0·5	150·5
		7. Blue shale	235·5	386
	Millwood, 664 feet.	8. Soapstone, with thin layers of lime rock.	401	787
		9. Blue clay, with round 'boulders'	188	975
		10. Dark blue-grey shale	75	1,050
Niobrara, 545 feet		11. Grey shale	25	1,075
		12. Mottled grey calcareous shale	200	1,275
		13. Dark non-calcareous, or but very slightly calcareous shale	135	1,410
		14. Grey calcareous shale	185	1,595
Benton		15. Dark non-calcareous shale	205	1,800

[2] In 1892, this hole was deepened to 1,943 feet, of which the lower 121 feet were in the Dakota sandstone. In this formation saline water was struck.

[1] Tyrrell, Roy. Soc. Can., IX (1891), IV, 93.
[2] Geol. Survey, Canada, VI, 2 A.

8. **Edmonton.** 163 A

THE NORTHWEST GAS AND OIL COMPANY, LTD.

DRILLER'S NOTES.

Well No. 1 at the south end of 1st Street.

Depth.
Feet.

20—Alluvial soil, sand, and gravel.
30—Sand and gravel.
40—Through the gravel into tenacious mud and clay.
55— " " " " "
75—Thin film of culm.
85—Mud. Considerable gas.
100—Three-foot seam of lignite.
120—Mud.
150—Hard pan clay, slate wall.
175—Tenacious dark grey clay.
200—Hard clay and sharp sand, 6 feet of coal.
210—Thin seam of coal.
250—Dark grey slate.
300—From 250 to ~90 feet soft blue shale with thin layers of sandstone.
350—Eight feet of hard coal. Black slate rock and shale to 450.
500—Black shale with sand rock to 600 feet.
675—Formation same as above.
720—Twenty feet of sandstone.
730—Slate.
750—Slight flow of brackish water.
790—Hard slate.
800—A flow of dry gas.
840—Slate continues through the gas area.
887—Dark grey slate, with sharp grey sand shale.
900—Dark shale.
1,000—Slate and soft clay to bottom of well at 1,150 feet.
A boulder bed from 1,125 to 1,150 feet.

Well No. 2 on North Side of Jasper Avenue. 164 A

9. DRILLER'S NOTES.

Depth.
Feet.

Through alluvial soil for 16 feet, then sand and gravel to 35 feet, and soft clay to a depth of 50 feet.
50—Soft clay and shale continue.
90—A 12 inch seam of coal. Slate formation. Five feet of gravel.
125—Slate and shale.
150—Slate and shale continue to 215 feet.
215—Coal, 8 feet thick.
230—Black slate and shale from 223 to 260 feet.
A 9 foot seam of hard coal.
260—Black rock 10 feet thick.
270—Grey sand and shale continuing for 30 feet.
300—Black slate rock and clay in alternate layers to 400 feet.
400—Black grey shale and sand.
435—Brown sand with layers of black slate for 30 feet.
465—Black slate and shale continue.
500—Black slate and shale of varying degrees of hardness from 470 to 560 feet.
560—Formation is changed for soft grey sand followed by seam of grey slate 10 feet thick. Grey sand and slate alternating to 610 feet.
630—A small flow of gas was struck in a dark, soft, slate formation which continued to 700 feet.

Depth.
Feet.

750—Dark shale to 790 feet.
810—Formation continues the same.
850—Formation continues dark slate and shale. A small flow of brackish water.
910—A small flow of gas from 910 to 940 feet.
940—Very soft, dark shale to 1,000 feet.
1,020—Soft clay or shale, alternating with thin layers of rock.
1,080—A hard rock to 1,118 feet.
1,118—Soft, dark rock and shale to 1,160 feet.
1,160—Dark grey sand rock reached, of the nature of a boulder bed.
1,189—Boulder bed apparently ended and a soft, blue shale was entered.
1,196—A second boulder bed of 5 feet, followed by hard, blue sand rock for about 12 feet.
1,213—Soft shale from 1,208 to 1,243 feet.
1,243—Five fet of dark grey sand yielding a small quantity of oil, salt-water, and gas. Soft, grey shale with layers of dark grey sand continued to 1,306 feet.
1,306—From 1,306 to 1,358 very little change in the formation.
1,358—Dark shale with frequent layers of coal and sand down to 1,412 feet. This well was continued to a depth of about 1,800 feet but the log is not available.

10. Fort Pelly. 14-5.

Drilled by Mr. Fairbank of Petrolia in 1874-5, for the Dominion government, near Fort Pelly.

Total depth, 501 feet.

At 28 feet, fresh water was struck.

At 259 feet, a calcareous band 9 feet thick was passed through.[1]

10a. [2] Gleichen.

Altitude, 2,926 feet above sea-level.

	Thickness. Feet.	*Depth.* Feet.
Sand and clay	8	8
Quicksand	20	28
Blue clay, with gravel and boulders	39	67
Black sand	11	78
Blue clay	22	100
Cement gravel	15	115
Soapstone	40	155
White sand, small flow of water	5	160
Soapstone	94	254
Black sand	7	261
Loose soapstone	74	335
White lime	3	338
Black shale	40	378
Putty rock	12	390
Lime and loose shale	10	400
Soapstone	35	435
Sand rock	9	444
Black shale	20	464
Gravel soapstone with sand and water	38	502

[1] Geol. Survey, Can., Report of Progress, 1875-76, p. 292.
[2] Dawson, Roy. Soc. Can., Vol. IV, Sec. IV, p. 99.

11. Kamsack. 15-5

Township 29, range 32, west of 1st meridian.

	Thickness. Feet.	Depth. Feet.
Blue clay	50	50
Shale	721	771
Very hard rock	2	773

It is reported that at 618 feet a coal seam about 8 feet thick was struck.

12. Keithville. 16-S

One mile east of Keithville in S.W. ¼ of N.W. ½ of sec. 35, tp. 18, range 16, west 3rd meridian.

Owner, Benjamin F. Emerick.

Contractor, Robt. H. Balgeman.

Drilled in 1910.

DRILLER'S LOG.

	Thickness. Feet.	Depth. Feet.
Top soil	10	10
Yellow clay	90	100
Blue clay	56	156
Coarse yellow sand	4	160
Quicksand	20	180
Sand and gravel	13	193
Clay, sand and gravel	10	203
Yellow sand, and clay	2	205
Clay	5	210
Sand and clay	25	235
Blue clay	65	300
Yellow sand	13	313
Sand and clay	20	333
Sand	4	337
Blue clay	77	414

13. Kipp. 171-A

Well drilled by the West Canadian Coal Mining Company at Kipp station, on sec. 34 or 35, tp. 9, range 23, west 4th meridian. Well completed in June, 1910.

Started 10 feet above water level and 50 feet below the sandstone overlying the Bearpaw.

		Thickness of beds. Feet.	Depth. Feet.
	River silt	20	20
Bearpaw	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
Belly River	Sandstone	27	592
	Coal	3	595
	Shale	5	600
	Sandy shale	15	615
	Shale and sandstone	43	658

The 565 feet of the Bearpaw passed through in the well, together with the 50 feet above the top of the well, makes a total thickness of 615 feet for this series at this point.

14. Langevin. 140 - A

Altitude, 2,471 feet above sea-level.

[1] The log here given is taken from the results of two borings, the first 1,155 feet being from one and the remaining 271 feet from the other. The terms employed are chiefly those of the borers' log.

Depth from surface. Feet.		*Description of beds.*	*Thickness of bed.* Feet.	
		Clay loam	30	Probably drift deposits.
37		Quicksand	7	
49		Clay	12	
59		Quicksand	10	
68		Clay and sand	9	
75		Quicksand	7	
83		Clays	8	
88		Quicksand	5	
104	General grey and pale tints, according to Mr. W. A. Simpson.	Sandstone	16	Probably lower part of Belly River series.
113		Soapstone (grey, fine-grained clay)	9	
118		Lime rock (fine calcareous sandstone) (small supply of water)	5	
126		Hard-pan (dark shale)	8	
133		Coarse sand	7	
193		Soapstone (greyish clay)	60	
200		Lime rock (fine calcareous sandstone)	7	
209		Sandstone	9	
		Small coal seam	.	
227		Soapstone	18	
232		Sandstone	5	
271		White clay	39	
322		Soapstone	50	
327		Lime rock	5	

[1] Dawson. On certain borings in Manitoba and the North West Territory. Roy. Soc., Can., Vol. IV (1886), Sec. IV, p. 95.

Depth from surface. Feet.		*Description of beds.*	*Thickness of beds.* Feet.	
464	Beds generally shales of dark to black tints.	Loose shaly soapstone	137	Probably 'Lower Dark Shales' of Report 1882–84 passing down into Benton (?)
469		Brown ferruginous clay	5	
474		Dark lime rock	5	
463		Small coal seam	..	
524		Soapstone	50	
531		Gravel (small supply of water)	7	
537		Sandstone	6	
541		Lime rock	4	
548		Sandstone	7	
558		Hard-pan (dark shale)	10	
593		Clays	35	
943		Loose shaly soapstone (fine grey clay)	350	
951	Generally grey tints. One bed of very black shale about 30 thick at 1,000. Fragment of Baculite from about here.	Lime rock (fine calcareous sandstone)	8	
1041		Hard soapstone	90	
1061		Sand and soapstone, with bands of hard pan and supply of gas	20	
1111		Sandstone, with streaks of hard gravel	50	
1151	Generally dark to black tints.	Gravel and clay	40	
1155		Hard lime. Great flow of gas	5	
1426		Shales and "lime rock" (probably calcareous limestone) with layers of very dark, soft shale in second hole, to bottom	271	
		Totals	1426	

15. Langham.

Township 39, range 7, west 3rd meridian.

Drilled by the Mackenzie, Mann Company, and in 1905 was at a depth of 1,358 feet.

It is stated that the well was in soft shale from top to bottom. Salt water at 1,340 feet.

16. Lethbridge.

Drilled for the town by Jas. Peat and Son.

	Thickness. Feet.	*Depth.* Feet.
Sand	12	12
Gravel	40	52
Hard pan and gravel	138	190
Hard pan	20	210
Sand and gravel	59	269
Soapstone	25	294
Gravel	5	299
Shale	111	410
Sandstone	24	434
Soapstone and shale	46	470
Sandstone	30	500
Shale and sandstone	121	621

	Thickness. Feet.	*Depth.* Feet.
Shale	36	657
Soapstone and sandstone	10	667
Soapstone and shale	73	740
Black shale	12	752
Soapstone	15	767
Black shale	143	910
Sandstone	25	935
Limestone	15	950
Black shale	36	986
Limestone	6	992
Black shale	158	1,150
Grey shale	30	1,180
Black shale	10	1,190
Sandstone	9	1,199
Black shale	20	1,219
Grey shale	9	1,228
Sandstone	9	1,237
Black shale	54	1,291
Sandstone	9	1,300
Dark shale	80	1,380
Shale, lighter	70	1,450
Dark shale	60	1,510
Hard dark shale	5	1,515
Sandstone	5	1,520
Green shale, very hard	4	1,524
Very soft shale	32	1,556
Sand rock	47	1,603
Greenish shale	100	1,703
Dark shale	142	1,845
Dark shale with streaks of white	95	1,940
Calcareous shale	125	2,065
Dark shale	80	2,145
Light grey shale	30	2,175
Dark shale	45	2,220

A coal seam was struck at 300 feet.

The well probably did not reach the Dakota formation.

17. Maple Creek.

Drilled by the Maple Creek Gas, Oil, and Coal Co., Ltd., on sec. 15, tp. 11, range 26, west 3rd meridian. In December, 1909, the well had reached a depth of 1,860 feet. Coal at 196 feet and a 7 foot seam at 292 feet. Gas at 1,120 feet and at two other points between 1,120 and 1,500 feet.

17a. [1] McLean Station.

	Thickness. Feet.	*Depth* Feet.
Black loam	1	1
Yellow clay	25	26
Blue clay	65	91
Gravel and sand	12	103
Blue clay and sand	85	188

[1] Dawson, Roy. Soc. Can., Vol. IV, Sec. IV, p. 92.

	Thickness. Feet.	Depth. Feet.
Gravel and sand	10	198
Blue clay and gravel	98	296
Sand and gravel	52	348
Boulders	6	354
Blue clay and gravel	96	450
Gravel and sand	35	485
Boulders	5	490
Clay and sand	5	495

It is probable that the bottom of the drift deposits was not reached.

18. Medicine Hat.

Record of boring at Medicine Hat, furnished by W. Whyte, of the Canadian Pacific railway, in a letter to Dr. Dawson, dated October 17, 1898.

Description of material passed through.	*Colour.*	*Thickness of layers or beds.*	*Depth of bottom layers or bed of from surface.*
Gravel and sand		37	37
Shale	Dark.	129	166
Sandstone	"	17	183
Sand shale	"	17	200
Sandstone and shale mixed	"	43	243
Shale	"	47	290
Sandstone	"	28	318
Sand shale	"	342	660

Struck gas and salt water at 177 feet.
Struck gas at 558, 643, and 651 feet.

The following notes regarding wells in this field are given by Heinrich Ries in the Summary Report of the Geological Survey for 1910, page 179.

The Medicine Hat gas field continues to yield steadily, and wells are located as far from Medicine Hat as Redcliff in one direction, and Dunmore Junction (now Coleridge) in the other, but the limits of the field are not definitely known.

According to Mr. A. K. Grimmer, city engineer of Medicine Hat, about eighteen wells have been drilled at this locality, of which about eight were sunk by the city. Of the latter group three had a depth of 1,000 feet, while the others varied from 300 to 650 feet. The deeper ones show a pressure of about 650 pounds per square inch.

There are three important wells from which the city is drawing its supply, located as follows:—

(1.) Corner Main street and West Allowance: 1,000 feet deep, $4\frac{5}{8}$ inch casing, 550 pounds capped pressure; volume 1,000,000 cubic feet per twenty-four hours.

(2.) Corner North River street and Third avenue: 1,000 feet deep, 6 inch casing, 560 pounds capped pressure; volume 1,250,000 cubic feet per twenty-four hours.

(3.) On Bridge street, known as Big Chief: 1,000 feet deep, 6 inch casing, 560 pounds capped pressure; volume, 3,000,000 cubic feet per twenty-four hours.

In addition to this the city has four wells to a depth of 700 feet, and the private wells in the city are as follows:—

(1.) Central Canada Packing Company: 750 feet deep, 2 inch casing. This is a wet well, was never in good condition, and is not in use.

(2.) C. Colter, Second avenue: 700 feet deep, 3 inch casing, and 270 pounds pressure when capped.

(3.) C. Colter, Main street: 400 feet deep, 3 inch casing, and 100 pounds pressure when capped. Not in use.

(4.) H. Yuill, South Railway street: 850 feet deep, $4\frac{5}{8}$ inch casing, and 270 pounds pressure when capped.

(5.) Canadian Pacific railway: 1,000 feet deep, 6 inch casing, with 2 inch tube and packer. This has a pressure of 560 pounds when capped, and a volume of 1,250,000 cubic feet in twenty-four hours.

(6.) Hargraves well, at end of highway bridge in city; this well is 1,042 feet, has a pressure of 560 pounds when capped, and a discharge of 2,800,000 cubic feet in twenty-four hours.

On May 31, 1910, the city began drilling a well at a point 2 miles east of Medicine Hat, in the N.E. $\frac{1}{4}$ of N.E. $\frac{1}{4}$ of sec. 30, tp. 13, R. 5, W. 4th. This well has a diameter of 10 inch casing, and a depth of 937 feet. It was completed August 30, after striking a good flow of gas, with a pressure of 560 pounds at the end of twenty-four hours. A small flow of gas was struck at 550 feet, and continued down to 660 feet.

18a. Moosejaw. 54 - S

Well sunk by the Corporation.

	Thickness. Feet.	Depth. Feet.	
Clay	5	5	Pierre.
Gravel	14	19	Pierre.
Hard, grey clay	396	415	Pierre.
Hard clay, mouse grey	10	425	Pierre.
Hard clay	35	460	Pierre.
Sandy clay	20	480	Pierre.
Hard grey clay	75	555	Pierre.
Sandy clay, grey	45	600	Pierre.
Hard grey clay	177	777	Pierre.
Hard, grey sandy clay	13	790	Pierre.
Hard grey clay	100	890	Pierre.
Grey sand	20	910	Probably Belly River.
Sandrock, shale	10	920	Probably Belly River.
Shale and clay	10	930	Probably Belly River.
Sand and hard grey clay	30	960	Probably Belly River.
Sand	8	968	Probably Belly River.
Sand, pepper and salt	42	1,010	Probably Belly River.
Grey sand and clay	10	1,020	
Grey clay and shale	10	1,030	Niobrara-Benton.
Hard grey clay	30	1,060	Niobrara-Benton.

Struck water, which is somewhat sulphury, and some gas.

19. [1]Morden. 7-M.

Altitude, 978 feet above sea-level.

Boring about 150 yards northwest of the railway station.

		Thickness of layer. Feet.	Depth of bottom of layer. Feet.[1]
Alluvium, 15 feet	1. Light sandy soil	8	8
	2. Quicksand	3	11
	3. Quicksand, red	1	12
	4. Fine gravel, red	3	15
Till 16 feet	5. Lead coloured clay, with pebbles	10	25
	6. Limestone boulder, with fine scratches	2·5	27·5
	7. Small boulders and shale	3·5	31
Pierre (Millwood series) 24 feet	8. Dark-grey shale	24	55
Niobrara, 160 feet	9. Hard streak	0·5	55·5
	10. Dark-grey shale	4·5	60
	11. Hard streak	3	62
	12. Dark-grey shale	6	68
	13. Hard streak	1	69
	14. Dark-grey shale	11	80
	15. Hard streak, mixture of stones and shale	1	81
	16. Dark-grey shale	4	85
	17. Black shale, very gritty	1	86
	18. Dark-grey shale	7	93
	19. Black shale, hard and gritty	1	94
	20. Grey calcareous shale	121	215
Benton, 105 feet	21. Dark-grey shale	35	250
	22. Soapstone	3	253
	23. Dark-grey shale	67	320

[1] Tyrrell. Roy. Soc., Can. IX (1891), IV, p. 98.

		Thickness of layer.	Depth of bottom of layer.
		Feet.	Feet.
Dakota, 92 feet....	24. White sand, with water............	4	324
	25. White sand with particles of coal....	54	378
	26. White shale.................... } 27. White sand .... }	2	380
	28. Soft-grey shale	10	390
	29. Black shale	10	400
	30. Grey shale with sandstone....	12	412
Devonian, 188 feet	31. Red and grey shale........	88	500
	32. Porous limestone at	... .	500
	33. Red and grey shale...........	100	600

Water at depth of 324 feet strongly charged with sodium chloride.

20. Egg Lake, Morinville, Alta. 133

Drilled in 1910 by the California-Alberta Oil Company.
Log furnished by the Company.

	Feet.	Feet.
Surface deposits	50	
Chocolate coloured shale, hard to drill....................	50	to 70
Gravel, very coarse, flow of water	70	" 75
Water and 18 to 22 inch seam of lignite..................	75	" 80
Brown shale, black slate, pyrite, and dark sandstone....	80	" 160
Shale, slate, and coal in thin seams.....................	160	" 260
Sandstone, with water	265	" 270
Brown shale and dark grey sandstone	270	" 300
First gas with pungent odour (cased off) at................		300
Blue and green soapstone shale. Still gas and a little oil.	300	" 320
Green soapstone shale	340	" 360
Sandstone with gas of petroleum odour at		360
Gas and some light oil (cased off) at.......................		375
Very hard shell at		380
Pungent gas, pressure for one month averaged 70 pounds; yield 370,000 cub. ft. per day at.....................		387
Light grey sandstone. Gas still flowing.................	387	" 400
14 inch pipe driven to		421
In same sand, with gas and oil at		423
This saturated sand is probably 6 feet thick.		
Brown shale and hard shells	430	" 435
Salt water at		435
Sandstone, shale, slate, and a few hard shells.............	435	" 490

At 423, the tools came up covered with oil, and every bailer brought up from one to two pints.

The following analysis of the gas was also furnished by the Company:—

Sulphuretted hydrogen..	0·0
Carbonic acid..	0·0
Illuminates..	0·1
Oxygen..	0·5
Carbon monoxide..	0·3
Hydrogen..	8·7
Methane (marsh gas)..	90·2
Nitrogen..	0·2

21. Neepawa. 10-M

Township 14, range 15, west 1st meridian.

A well was carried to a depth of 382 feet into the Niobrara formation.

22. Pelican River. 684

DRILLER'S LOG.

	Feet.
Sand and gravel	1–86
Very soft, dark-bluish shale	86–101
Soft sandstone	101–105
Very soft, dark-bluish shale. At 185 feet slightly saline water	105–185
Rather hard, reddish-brown shale	185–225
Sandstone. At 225 feet water	225–234
Sandstone and brown shale	234–245
Hard, grey shale. At 253 feet more water and gas	245–253
A light greenish-grey shale	253–280
Soft, greenish-grey shale, cement like	280–290
Brown shale, with strata of grey shale	290–308
Brown shale	308–310
Hard sandstone. More gas and water	310–311
Brown shale and sandstone in alternate strata	311–328
Sandstone	328–340
Brown shale	340–353
Hard sand-rock, with layers of softer rock	353–365
(At 355 feet struck maltha and gas).	
Sandstone, rather hard	365–410
Brown shale	410–427
Hard, brown shale	427–450
Sandstone. More gas and water	450–465
Grey shale	465–526
Ironstone	526–532
Grey shale	532–553
Sandstone	553–556
Very hard, probably ironstone	556–558
Very hard sandstone	558–563
Brown shale	563–573
Grey shale, streaks of sandstone	573–590
Grey shale, brown shale and sandstone in alternating strata; the cuttings show traces of maltha	590–620
Grey shale. Strong flow of gas at 625 feet; considerable maltha coming away with the water	620–625
Very hard sandstone	625–643
Soft grey shale	643–648
Hard sandstone	648–652
Soft grey sandy shale	652–665
Ironstone	665–675
Soft, grey shale	675–684
Hard sandstone	684–685
Soft, dark-grey shale	685–703
Hard sandstone	703–713
Soft, grey, sandy shale	713–718
Hard sandstone	718–723
Sandstone	723–733
Soft, grey shale	733–743
Soft, grey shale, with streaks of soft sandstone. Strong flow of gas at 750. A heavy oil mixed all through the sandstone and shale	743–758

	Feet.
Soft, dark-grey shale, and soft sandstone. Heavy oil throughout. At 773, a heavier flow of gas	758–781
Alternate strata of soft grey shale and soft sandstone. Increased quantities of heavy petroleum. Gas increasing in volume	781–800
Same as foregoing. At 820, a tremendous flow of gas of which the rear could be heard 3 miles or more	800–820
Soft sandstone. Hard streak, and light flow of gas at 830	820–830
Soft sandstone	830–836
[1] Iron-pyrites nodules embedded in cementlike sandstone. Very strong flow of gas	836–837

[2] Dr. Dawson gives the following section from this well:—

Depth from Surface. Feet.		*Thickness of Formation.* Feet.
86	—Sand and gravel (surface deposits)	86
185	—Dark bluish-black soft shales, with some sandstone in upper part. *Pelican shales*	99
465	—Greyish sands and sandstones, and brownish and greyish shales. *Grand Rapids sandstones*	280
750	—Greyish and brownish shales, alternating with thin beds of hard sandstone and ironstone. *Clearwater shales*	285
837	—Sands and clays often saturated with heavy oils and tar. *Tar sands*	87 (or more)

23. Pincher Creek. 170

S.E. ¼ sec. 27, tp. 6, range 30, west 4th meridian.

Drilled in 1907 by the Western Oil and Coal Company. Depth, 1,510 feet.

24. [3] Rosenfeld. 13

Altitude, 770 feet above sea-level.

		Thickness of Bed. Feet.
1.	Black soil	4
2.	Fine silt or clay	111
3.	Sand and gravel	10
4.	Boulder clay ('hard-pan')	12
5.	Boulders	6
6.	Grey shale	62
7.	Limestone	15
8.	Red shale	5
9.	Grey shale	10
10.	Limestone	30
11.	Fine, grey sandstone	40
12.	Chalky limestone	30
13.	Red shale	160

[1] Geol. Survey, Canada, Summary Reports, 1897, 1898.
[2] Geol. Survey, Canada, X, 19 A.
[3] Dawson. Roy. Soc., Can., Vol. IV (1886), Sec. IV, p. 86.

		Thickness of Bed. Feet.
14.	Cream-coloured limestone	305
15.	Red shale	75
16.	Soft sandstone	50
17.	Dark-red shale	50
18.	Reddish and greenish shale	25
19.	Bluish and grey shale	20
20.	Red shale	15
21.	'Granite'	2
	Total	1,037

Small flows of brine were struck below Nos. 10 and 14, and from No. 16 the brine produced a flowing well.

25. Sarcee Indian Reserve, Twelve Miles Southwest of Calgary.

THE CALGARY NATURAL GAS COMPANY'S WELL No. 1. 243-A

The following is a log considerably condensed by the author:—

	Thickness of Beds. Feet.	Depth of Bottom of Beds. Feet.
Drift	64	64
Sandstone and shale alternating	88	152
Blue shale and grey sandstone	53	205
Blue clay shale	41	246
Sandstone with pebble	10	256
Shale with thin sandstone shells	45	301
Sandstone and shale	21	322
Blue clay shale	79	401
Grey to blue shales and sandstones alternating	73	474
Grey sandstone and shale alternating	398	872
Sand, 'lime'	22	894
White to grey sandstone and shale	84	978
Shell, 'red lime'	5	983
White shale and sandstone in alternating layers 3 to 30 feet thick	160	1,143
Sandstone, white and black in alternating layers	101	1,244
Black shale with sandstone shells	227	1,471
Sandstone, hard and soft, grey and black, with a few beds of shale	565	2,036
Black, coarse sandstone with pebble	21	2,057
Hard shale with pebble	64	2,121
Sandstone, dark and light grey, coarse and fine	100	2,221
Shale and sandstone alternating	76	2,297
Hard, grey sandstone	74	2,371
Sandstone and shale	54	2,425
Black and grey sandstone alternating	251	2,676
Soft, blue sandy shale	15	2,691
Sandstone, dark grey, hard and soft alternating	65	2,756
Light and dark grey sandstones alternating, with pebble	205	2,961
Top of Belly river at		2,969

	Thickness of Beds. Feet.	*Depth of Bottom of Beds.* Feet.
Dark grey sandstone and shales intermixed with coal, 1st coal horizon	35	2,996
Sandstone with pebble	5	3,001
Sandstone, grey, coarse and fine	49	3,050
Sandstone, shale and coal	21	3,071
Black sandstone	64	3,135
Black, sandy shale	25	3,160
Grey sandstone	25	3,185
Black sandy shale	17	3,202
Hard, light grey sandstone, with pebble	60	3,262
Dark brown shale	4	3,266
Hard, brown to white sandstone with pebble.	40	3,306
Black shale	19	3,325
Light grey sandstone	30	3,355
Dark shale	10	3,365

25a. **Taber.** 141-A

Drillers, Sullivan Machinery Co.

Log from diamond drill cores.

	Thickness. Feet.	*Depth.* Feet.
Sandy clay and small boulders	41	41
Gravel and small boulders	10	51
Shale and sandstone	20	71
Shale and bands of limestone	24	95
Taber coal seam at 90 feet.		
Dark shale	9	104
Sandstone	2	106
Shale	3	109
Shaly sandstone	2	111
Shale	14	125
Sandstone	5	130
Mixed limestone and sandstone	5	135
Dark shale	10	145
Sandstone	4	149
Shale	11	160
Mixed sandstone and shale	24	184
Shale	6	190
Sandstone	5	195
Shale	19	214
Sandstone	57	271
Shale	2	273
Dark shale	3	276
Sandy shale	32	308
Mixed shale and sandstone	12	320
Black shale	10	330
Mixed shale and sandstone	7	337
Shale	36 6 in.	373 6 in.
Shaly coal	0 6 "	374
Shale	2 4 "	376 4 "
Coal	0 8 "	377
Dark shale	1	378
Mixed sandstone and shale	17	395
Mixed black slate and coal	1 10 "	396 10 "
Shale	8 2 "	405
Limestone	0 6 "	405 6 "
Sandstone	5 6 "	411

	Thickness. Feet.	*Depth.* Feet.
Shale	180	591
Sandy shale	11	602
Conglomerate	2	604
Sandy shale	4	608
Sandstone	19	627
Coal	0 2 "	627 2 "
Fireclay	0 1 "	627 3 "
Dark shale	7 9 "	635
Sandstone	7	642
Shale	4	646
Sandy shale	12	658
Sandstone	12	670
Fireclay	3	673
Coal	0 3 "	673 3 "
Sandstone	70 9 "	744
Light shale	0 6 "	744 6 "
Sandstone	65 6 "	810
Mixed sandstone and shale	28	838
Shale	67	905
Shale with sandstone partings	25	930

The above is the depth reached in July, 1912, and operations were being continued.

25b. Tofield. 121-A

1902

Gas is reported to have been struck in 1912 at a depth of 1,050 feet, about the top of the Belly River formation. The bottom of the Edmonton formation lies at a depth of about 200 feet, at which point some coal was struck.

26. [1] Vermilion River, Man. 12-M

Township 23, range 20, west of the principal meridian.
Altitude above sea, 1,300.

		Thickness of layer. Feet.	*Depth of bottom of layer.* Feet.
Pierre (Millwood Series).	1 Soft, dark-grey clay shale	95	95
Niobrara	2 Fragmental limestone	4	99
	3 Grey calcareous shale	124	223
Benton	4 Dark-grey fissile shale	178	401
Dakota	5 Coarse sandstone, with pyrites	19	420
Devonian	6 Compact white limestone	120	540
	7 Blue-grey clay shale	10	550
	8 White gypsum	15	565
	9 Red shale	110	675
	10 Shale and limestone	68	743
	11 Red shale at bottom		

[1] Tyrrell, Roy. Soc., Canada, IX (1891), IV, 103.

27. Victoria. 142A

DRILLER'S LOG.

Sand	1–10
Light-grey shale, with traces of sand	10–20
Grey sandy shale	20–30
Light-grey sandy shale	30–50
Light-grey shale, no sand	50–100
Grey shale, darker in colour	100–110
Grey shale, lighter	110–120
Grey shale brownish	120–130
Ironstone layer	130–131
Light-grey shale	131–140
Light brownish-grey shale, quite hard (At 156 struck a small vein of gas).	140–180
Dark-brownish shale, with streaks of ironstone	180–260
Dark-brown shale. Strata of sandstone	260–270
Grey shale. Ironstone stratum	270–280
Grey shale with 3 foot ironstone stratum	280–290
Hard brownish-grey shale	290–300
Hard, grey shale	300–310
Softer, dark-grey shale	310–340
Harder dark-grey shale	340–350
Hard, brownish-grey shale	350–390
Hard, light-grey shale with 2 feet of ironstone	390–410
Brown shale	410–420
Brownish-grey shale	420–470
Very hard, grey shale	470–480
Light brownish-grey shale. At 495 feet water, slightly saline, and gas	480–500
Ironstone stratum	500–508
Light brownish-grey shale	508–520
Grey shale, losing brown tone	520–530
Ironstone stratum	530–535
Hard, light-grey shale	535–540
Grey shale, with stratum of ironstone	540–550
Bluish-grey shale	550–554
Dark bluish-grey shale	554–560
Dark bluish-grey shale with ironstone stratum and fragments of pyrite	560–570
Very soft, grey shale	570–620
Very soft, grey shale with 3 feet of sandstone or ironstone	620–630
Bluish-grey shale, very soft	630–705
Soft, dark shale	705–960
Soft, dark shale, with layers of sand and a little gas	960–970
Soft, dark shale	970–1,000
Soft, dark shale, with streaks of sandstone	1,000–1,020
Dark shale. Gas	1,020–1,030
Dark shale. Increased gas	1,030–1,090
Soft, black shale	1,090–1,230
Soft, black shale with streaks of sandstone	1,230–1,250
Soft, black shale	1,250–1,320
Brown shale, with sandstone layers	1,320–1,340
Soft, dark shale	1,340–1,390
Bluish shale, with thin streaks of sandstone	1,390–1,410
Black shale	1,410–1,428
Hard sandstone	1,428–1,430
Black shale	1,430–1,460
Bluish shale	1,460–1,500
Bluish shale, streaks of sandstone with gas	1,500–1,565
Hard sandstone	1,565–1,575
Dark shale mixed with sandstone	1,575–1,585
Hard sandstone	1,585–1,600
Shale and sandstone strata mixed	1,600–1,645

Hard sandstone	1,645–1,650
Sandstone	1,650–1,665
Dark shale	1,665–1,669
Very hard sandstone	1,669–1,680
[1]Dark-blue shale with strata of hard sandstone 1 to 4 feet thick	1,680–1,840

Regarding the results obtained at Victoria [2] Dawson writes:—

'The section met with in the Victoria bore-hole is evidently intermediate in character between that of the Athabaska and that of Southern Alberta, but more closely corresponds with the former. The Belly River brackish-water and fresh-water formation that forms so important an intercalation at or about the base of the Pierre proper in the south cannot here be recognized. . . . .

'On the other hand, the upper part of the Victoria section seems to correspond very closely with the Pierre proper of Southern Alberta, showing, as in the Red Deer River sections, about 500 feet of brownish or "coffee-coloured" shales at the top, but having, apparently, in the aggregate a somewhat greater volume. It appears to be a little thicker than the upper part of the LaBiche shales assigned to the Pierre on palæontological grounds by Mr. McConnell.

'In the sections on the Athabaska, including the borings at Athabaska Landing and Pelican River, the persistence of the Pelican and Grand Rapids sandstones renders it possible to fix equivalency of horizons with considerable accuracy, but neither of these sandstone intercalations occur in recognizable form at Victoria, and it does not appear to be possible to draw any line of demarcation until a depth of about 1,500 feet is reached, at which depth it seems probable that beds representing the Grand Rapids sandstones may be entered. . . . . .

'From all the evidence now available, it would appear that the Victoria bore-hole penetrated to within about 250 feet of the top of the "Tar-sands," should these occur here, this horizon being at a depth of about 2,100 feet from the surface. At Athabaska Landing the bore-hole probably reached to within a very few feet of the top of the "Tar-sands," which may there occur at a depth of 1,800 feet.'

28. **Wetaskiwin.** 124

Thickness of Beds. Feet.		*Depth of Bottom of Beds.* Feet.
10	Soil and sand	10
82	Blue clay	92
1	Sandstone	93
27	Blue shale	120
2	Sandstone	122
13	Blue shale	135
½	Sandstone	135½
4½	Blue shale	140

[1] Geol. Survey, Canada, Summary Reports, 1897, 1898, 1899.
[2] Geol. Survey, Canada, XII, 12 A.

Thickness of Beds. Feet.	*Depth of Bottom of Beds.* Feet.
½—Sandstone	140½
23—Blue shale	163½
1½—Sandstone	165
111—Shale with small sandstone strata	276
44—Sandstone	320
20—Sandstone and shale strata	340
8—Shale	348
15—Sandstone	363
40—Brown shale	403
2—Sandstone	405
8—*Coal*	413
95—Brown shale	508
8—Sandstone	516
42—Shale and sandstone strata	558
27—Grey shale (Gas.)	585
5—Sandstone	590
150—Grey shale	740
4—*Coal*	744
44—Dark shale	788
6—Sandstone	794
31—Dark shale	825
3—*Coal*	828
10—Light shale	838
50—Dark shale	888
6—Very light shale	894
6—Dark shale	900
5—Light shale	905
32—Dark shale	937
6—Coal and shale strata	944

29. Wilcox. 9-8

Well 4 miles east of Wilcox, Sask., on N.E. ¼, sec. 24, tp. 13, range 20, west of 2nd meridian.

	Thickness. Feet.	*Depth.* Feet.
Clay	45	45
Boulder clay	52	97
Blue shale	213	310
Grey shale	420	730
Black sand	4	734
Grey shale	30	764
Black sand	86	850
Shale	36	886
Sandy shale	5	891
Grey shale	169	1,060
Dark shale	224	1,284
Grey shale	67	1,351
Sand	9	1,360
Shale	25	1,385
Rock and shale alternately	22	1,407
Hard rock	19	1,426
Shale	4	1,430
Hard rock and shale alternately	20	1,450

30. **Section 13, Township 15, Range XIX, West 2nd Meridian.** 11-5

Drillers, Abray and Patterson.
Drilled in, 1909 and 1910.
Depth, 2,410 in grey shale.

31. **Bottineau County, North Dakota.**

The discovery in 1907 of surface gas at depths of 154 to 200 feet in Bottineau county, North Dakota, led to the boring of a deep well on the Parker farm about 9½ miles south of Westhope. On account of its nearness to the international boundary the log of the well is given.[1]

	Thickness. Feet.	*Depth.* Feet.
Soil	2	2
Yellow clay and gravel	30	32
Blue clay	122	154
Gravel with sand below	16	170
White slate	35	205
Black sand seam (Pierre?)	3	208
Soft blue shale (caving) (Pierre?)	242	450
Black 'slate' (Pierre?)	50	500
Blue shale (caving) (Pierre)	205	705
Yellow hard rock (limestone) (Niobrara)	5 inches.	
Blue shale	145 feet.	850
Sandy shale	10 "	860
Blue shale to bottom (Benton?)	320 "	1,180

Analysis of surface gas, made by Professor E. J. Babcock of the University of North Dakota:—

Hydrogen	0·5
Methane	82·7
Ethylene and other illuminants	0·2
Carbon monoxide	1·2
Oxygen	3·0
Nitrogen	12·4
	100·0

B. T. U. (calculated) 886 per cubic foot.
The oxygen and nitrogen are probably in the form of air.

[1] Fifth Biennial Report North Dakota Geological Survey, 1908, pp. 247-248.

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CANADA

DEPARTMENT OF MINES

GEOLOGICAL SURVEY BRANCH

HON. ROBERT ROGERS, MINISTER; A. P. LOW, DEPUTY MINISTER;
R. W. BROCK, DIRECTOR.

SELECTED LIST OF REPORTS AND MAPS

(SINCE 1885)

OF SPECIAL ECONOMIC INTEREST

PUBLISHED BY

THE GEOLOGICAL SURVEY

Report of the Mines Section:—

No. 245.	Report of Mines Section,	1886.	No. 662.	Report of Mines Section,	1897
272	" "	1887.	698	" "	1898
*300	" "	1888.	718	" "	1899
301	" "	1889.	744	" "	1900
334	" "	1890.	800	" "	1901
335	" "	1891.	835	" "	1902
360	" "	1892.	893	" "	1903
572	" "	1893–4.	*928	" "	1904
602	" "	1895.	971	" "	1905
625	" "	1896.			

Mineral Production of Canada:—

No. *414.	Year 1886.	No. *422.	Year 1893.	No. 719.	Year 1900.
*415	" 1887.	*555	" 1894.	719a	" 1901.
*416	" 1888.	*577	" 1895.	813	" 1902.
*417	" 1889.	*612	" 1896.	861	" 1903.
*418	" 1890.	*623	" 1886-96.	896	" 1904.
*419	" 1891.	*640	" 1897.	924	" 1905.
*420	" 1886-91.	*671	" 1898.	981	" 1906.
*421	" 1892.	*686	" 1899.		

Mineral Resources Bulletin:—

No. *818.	Platinum.	No. 860.	Zinc.	No. 881.	Phosphate.
851.	Coal.	869.	Mica.	882.	Copper.
*854.	Asbestos.	872.	Molybdenum and Tungsten.	913.	Mineral Pigments.
857.	Infusorial Earth.	*877.	Graphite.	953.	Barytes.
858.	Manganese.	880.	Peat.	984.	Mineral Pigments (French).
859.	Salt.				

Report of the Section of Chemistry and Mineralogy:—

No. *102.	Year 1874-5.	No. *169.	Year 1882-3-4.	No. 580.	Year 1894.
*110	" 1875-6.	222	" 1885.	616	" 1895
*119	" 1876-7.	246	" 1886.	651	" 1896.
*126	" 1877-8.	273	" 1887-8.	695	" 1898.
*138	" 1878-9.	299	" 1888-9.	724	" 1899.
*148	" 1879-80.	333	" 1890-1.	821	" 1900.
*156	" 1880-1-2.	359	" 1892-3.	*958	" 1906

* Publications marked thus are out of print.

REPORTS.

GENERAL.

745. Altitudes of Canada, by J. White. 1899.
*972. Descriptive Catalogue of Minerals and Rocks, by R. A. A. Johnston and G. A. Young.
1073. Catalogue of Publications: Reports and Maps (1843-1909).
1085. Descriptive Sketch of the Geology and Economic Minerals of Canada, by G. A. Young, and Introductory by R. W. Brock. Maps No. 1084; No. 1042 (second edition), scale 100 m. = 1 in.
1086. French translation of Descriptive Sketch of the Geology and Economic Minerals of Canada, by G. A. Young, and Introductory by R. W. Brock. Maps No. 1084; No. 1042 (second edition), scale 100 m. = 1 in.
1107. Part II. Geological position and character of the oil-shale deposits of Canada, by R. W. Ells.
1146. Notes on Canada, by R. W. Brock.

YUKON.

*260. Yukon district, by G. M. Dawson. 1887. Maps No. 274, scale 60 m = 1 in.; Nos. 275 and 277, scale 8 m. = 1 in.
*295. Yukon and Mackenzie basins, by R. G. McConnell. 1889. Map No. 304, scale 48 m. = 1 in.
687. Klondike gold fields (preliminary), by R. G. McConnell. 1900. Map No. 688, scale 2 m. = 1 in.
884. Klondike gold fields, by R. G. McConnell. 1901. Map No. 772, scale 2 m. = 1 in.
*909. Windy Arm, Tagish lake, by R. G. McConnell. 1906. Map No. 916, scale 2 m. = 1 in.
943. Upper Stewart river, by J. Keele. Map No. 938, scale 8 m. = 1 in. } Bound together.
951. Peel and Wind rivers, by Chas. Camsell. Map No. 942, scale 8 m. = 1 in. } Bound together.
979. Klondike gravels, by R. G. McConnell. Map No. 1011, scale 40 ch. = 1 in.
982. Conrad and Whitehorse mining districts, by D. D. Cairnes. 1901. Map No. 990, scale 2 m. = 1 in.
1016. Klondike Creek and Hill gravels, by R. G. McConnell. (French.) Map No. 1011, scale 40 ch. = 1 in.
1050. Whitehorse Copper Belt, by R. G. McConnell. Maps Nos. 1026, 1,041, 1,044, 1,049.
1097. Reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon, and North West Territories, by Joseph Keele. Map No. 1099, scale 8 m. = 1 in.
1011. Memoir No. 5 (Preliminary): on the Lewes and Nordenskiöld Rivers coal-field, Yukon, by D. D. Cairnes. Maps Nos. 1103 and 1104, scale 2 m. = 1 in.
1228. Memoir No. 31: Wheaton district, by D. D. Cairnes.

BRITISH COLUMBIA.

212. The Rocky mountains (between latitudes 49° and 51° 30′), by G. M. Dawson. 1885. Map No. 223, scale 6 m. = 1 in. Map No. 224, scale 1½ m. = 1 in.
235. Vancouver island, by G. M. Dawson. 1886. Map No. 247, scale 2 m. = 1 in.
236. The Rocky mountains, geological structure, by R. G. McConnell. 1886. Map No. 248, scale 2 m. = 1 in.
263. Cariboo mining district, by A. Bowman. 1887. Maps Nos. 278-281.
*271. Mineral wealth, by G. M. Dawson.
*294. West Kootenay district, by G. M. Dawson. 1888-9. Map No. 303, scale 8 m. = 1 in.
*573. Kamloops district, by G. M. Dawson. 1894. Maps Nos. 556 and 557, scale 4 m. = 1 in.

*Publications marked thus are out of print.

574. Finlay and Omineca rivers, by R. G. McConnell. 1894. Map No. 567, scale 8 m. = 1 in.
743. Atlin Lake mining division, by J. C. Gwillim. 1899. Map No. 742, scale 4 m. = 1 in.
939. Rossland district, by R. W. Brock. Map No. 941, scale 1,600 ft. = 1 in.
940. Graham island, by R. W. Ells. 1905. Maps No. 921, scale 4 m. = 1 in.; No. 922, scale 1 m. = 1 in. (Reprint).
986. Similkameen district, by Chas. Camsell. Map No. 987, scale 400 ch. = 1 in.
988. Telkwa river and vicinity, by W. W. Leach. Map No. 989, scale 2 m. = 1 in.
996. Nanaimo and New Westminster districts, by O. E. LeRoy. 1907. Map No. 997, scale 4 m. = 1 in.
1035. Coal-fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia, by D. B. Dowling.
1093. Geology, and Ore Deposits of Hedley Mining district, British Columbia, by Charles Camsell. Maps Nos. 1095 and 1096, scale 1,000 ft. = 1 in.; No. 1105, scale 600 ft. = 1 in.; No. 1106, scale 800 ft = 1 in.; No. 1125, scale 1,000 ft. = 1 in.
1121. Memoir No. 13: Southern Vancouver island, by Charles H. Clapp. Map No. 1123—17 A, scale 4 m. = 1 in.
1175. Memoir No. 21: Geology and ore deposits of Phoenix, Boundary district, by O. E. LeRoy. Maps Nos. 1135 and 1136, scale 400 ft. = 1 in.
1204. Memoir No. 24-E: Preliminary Report on the Clay and Shale Deposits of the Western Provinces, by Heinrich Ries and Joseph Keele. Map No. 1201—51 A, scale 35 m. = 1 in.
1206. Memoir No. 26: Tulameen Mining district, by Charles Camsell. Maps No. 1195-45 A, scale 1 m. = 1/62500; No. 1196-46 A, scale 1 m. = 1/62500; No. 1197-47 A; No. 1198-48 A, scale 1 m. = 1 in.

ALBERTA.

*237. Central portion, by J. B. Tyrrell. 1886. Maps Nos. 249 and 250, scale 8 m. = 1 in.
324. Peace and Athabaska Rivers district, by R. G. McConnell. 1890-1. Map No. 336, scale 48 m = 1 in.
703. Yellowhead Pass route, by J. McEvoy. 1898. Map No. 676, scale 8 m. = 1 in.
*949. Cascade coal-fields, by D. B. Dowling. Maps (8 sheets Nos. 929-936, scale 1 m. = 1 in.
968. Moose Mountain district, by D. D. Cairnes. Maps No. 963, scale 2 m. = 1 in.; No. 966, scale 1 m.= 1 in.
1035. Coal-fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia, by D. B. Dowling. Map No. 1010, scale 35 m. = 1 in.
1035a. French translation of coal-fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia, by D. B. Dowling. Map No. 1010, scale 35 m. = 1 in.
1115. Memoir No. 8-E: Edmonton coal-field, by D. B. Dowling. Maps Nos. 1117-5 A and 1118-6 A, scale 2640 ft. = 1 in.
1130. Memoir No. 9-E: Bighorn coal basin, Alta., by G .S. Malloch. Map No. 1132, scale 2 m. = 1 in.
1131. Memoir No. 9-E (French translation): Bighorn coal basin, Alta., by G. S. Malloch. Map No. 1132, scale 2 m. = 1 in.
1204. Memoir No. 24-E: Preliminary Report on the Clay and Shale Deposits of the Western Provinces, by Heinrich Ries and Joseph Keele. Map No. 1201—51 A, scale 35 m. = 1 in.
1220. Memoir No. 29-E: Oil and Gas Prospects of the Northwest Provinces of Canada, by W. Malcolm. Map No. 1221 (55 A), scale 35 m. = 1 in.

SASKATCHEWAN.

213. Cypress hills and Wood mountain, by R. G. McConnell. 1885. Maps Nos. 225 and 226, scale 8 m. = 1 in.

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*Publications marked thus are out of print.

601. Country between Athabaska lake and Churchill river, by J. B. Tyrrell and D. B. Dowling. 1895. Map. No. 957, scale 25 m. = 1 in.
868. Souris River coal-field, by D. B. Dowling. 1902.
1035. Coal-fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia, by D. B. Dowling. Map No. 1010, scale 35 m. = 1 in.
1204. Memoir No. 24-E: Preliminary Report on the Clay and Shale Deposits of the Western Provinces, by Heinrich Ries and Joseph Keele. Map No. 1201—51 A, scale 35 m. = 1 in.
1220. Memoir No. 29-E: Oil and Gas Prospects of the Northwest Provinces of Canada, by W. Malcolm. Map No. 1221 (55 A), scale 35 m. = 1 in.
1225. Memoir No. 30: The Basins of Nelson and Churchill rivers, by W. McInnes. Map No. 1226, scale 15 m. = 1 in.

MANITOBA.

264. Duck and Riding mountains, by J. B. Tyrrell. 1887-8. Map No. 282, scale 8 m. = 1 in.
296. Glacial Lake Agassiz, by W. Upham. 1889. Maps Nos. 314, 315, 316.
325. Northwestern portion, by J. B. Tyrrell. 1890-1. Maps Nos. 339 and 350, scale 8 m. = 1 in.
704. Lake Winnipeg (west shore), by D. B. Dowling. 1898. Map No. 664, scale 8 m. = 1 in. } Bound together.
705. Lake Winnipeg (east shore), by J. B. Tyrrell. 1898. Map No. 664, scale 8 m. = 1 in. }
1035. Coal-fields of Manitoba, Saskatchewan, Alberta, and Eastern British Columbia, by D. B. Dowling. Map No. 1010, scale 35 m. = 1 in.
1204. Memoir No. 24-E: Preliminary Report on the Clay and Shale Deposits of the Western Provinces, by Heinrich Ries and Joseph Keele. Map No. 1201–51 A, scale 35 m. = 1 in.
1220. Memoir No. 29-E: Oil and Gas Prospects of the Northwest Provinces of Canada, by W. Malcolm. Map No. 1221 (55 A), scale 35 m. = 1 in.

NORTH WEST TERRITORIES.

217. Hudson bay and strait, by R. Bell. 1885. Map No. 229, scale 4 m. = 1 in.
238. Hudson bay, south of, by A. P. Low. 1886.
239. Attawapiskat and Albany rivers, by R. Bell. 1886
244. Northern portion of the Dominion, by G. M. Dawson. 1886. Map No. 255, scale 200 m. = 1 in.
267. James bay and country east of Hudson bay, by A. P. Low.
578. Red lake and part of Berens river, by D. B. Dowling. 1894. Map No. 576, scale 8 m. = 1 in.
*584. Labrador peninsula, by A. P. Low. 1895. Maps Nos. 585-588, scale 25 m. = 1 in.
618. Dubawnt, Kazan, and Ferguson rivers, by J. B. Tyrrell. 1896. Map No. 603, scale 25 m. = 1 in.
657. Northern portion of the Labrador peninsula, by A. P. Low.
680. South Shore Hudson strait and Ungava bay, by A. P. Low. Map No. 699, scale 25 m. = 1 in. } Bound together.
713. North Shore Hudson strait and Ungava bay, by R. Bell. Map No. 699, scale 25 m. = 1 in. }
725. Great Bear lake to Great Slave lake, by J. M. Bell. 1900.
778. East coast, Hudson bay, by A. P. Low. 1900. Maps Nos. 779, 780, 781, scale 8 m. = 1 in.
786–787. Grass River region, by J. B. Tyrrell and D. B. Dowling. 1900.
815. Ekwan river and Sutton lakes, by D. B. Dowling. 1901. Map No. 751, scale 50 m. = 1 in.
819. Nastapoka islands, Hudson bay, by A. P. Low. 1900.
905. The Cruise of the *Neptune*, by A. P. Low. 1905.

* Publications marked thus are out of print.

1006. Report of a Traverse through the Southern Part of the North West Territories, from Lac Seul to Cat lake, 1902, by A. W. G. Wilson. 1080. Report on a Part of the North West Territories, drained by the Winisk and Upper Attawapiskat rivers, by W. McInnes. Map No. 1089, scale 8 m. = 1 in.	Bound together.

1069. French translation: Report on an exploration of the East coast of Hudson bay, from Cape Wolstenholme to the south end of James bay, by A. P. Low. Maps Nos. 779, 780, 781, scale 8 m. = 1 in.; No. 785, scale 50 m. = 1 in.
1097. Reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon, and North West Territories, by Joseph Keele. Map No. 1099, scale 8 m. = 1 in.
1225. Memoir No. 30: The Basins of Nelson and Churchill rivers, by W. McInnes. Map No. 1226, scale 15 m. = 1 in.

ONTARIO.

215. Lake of the Woods region, by A. C. Lawson. 1885. Map No. 227, scale 2 m. = 1 in.
*265. Rainy Lake region, by A. C. Lawson. 1887. Map No. 283, scale 4 m. = 1 in.
266. Lake Superior, mines and mining, by E. D. Ingall. 1888. Maps No. 285, scale 4 m. = 1 in.; No. 286, scale 20 ch. = 1 in.
326. Sudbury mining district, by R. Bell. 1890-1. Map No. 343, scale 4 m. = 1 in.
327. Hunter island, by W. H. C. Smith. 1890-1. Map No. 342, scale 4 m. = 1 in.
332. Natural Gas and Petroleum, by H. P. H. Brumell. 1890-1. Maps Nos. 344-349.
357. Victoria, Peterborough, and Hastings counties, by F. D. Adams. 1892-3.
627. On the French River sheet, by R. Bell. 1896. Map No. 570, scale 4 m. = 1 in.
678. Seine river and Lake Shebandowan map-sheets, by W. McInnes. 1897. Maps Nos. 589 and 560, scale 4 m. = 1 in.
723. Iron deposits along the Kingston and Pembroke railway, by E. D. Ingall. 1900. Map No. 626, scale 2 m. = 1 in.; and plans of 13 mines.
*739. Carleton, Russell, and Prescott counties, by R. W. Ells. 1899. (*See* No. 739, Quebec.)
741. Ottawa and vicinity, by R. W. Ells. 1900.
790. Perth sheet, by R. W. Ells. 1900. Map No. 789, scale 4 m. = 1 in.
961. Sudbury Nickel and Copper deposits, by A. E. Barlow. (Reprint). Maps Nos. 775, 820, scale 1 m. = 1 in.; Nos. 824, 825, 864, scale 400 ft. = 1 in.
962. Nipissing and Timiskaming map-sheets, by A. E. Barlow. (Reprint). Maps Nos. 599, 606, scale 4 m. = 1 in.; No. 944, scale 1 m. = 1 in.
965. Sudbury Nickel and Copper deposits, by A. E. Barlow. (French).
970. Report on Niagara Falls, by J. W. Spencer. Maps Nos. 926, 967.
977. Report on Pembroke sheet, by R. W. Ells. Map No. 660, scale 4 m = 1 in.

980. Geological reconnaissance of a portion of Algoma and Thunder Bay district, Ont., by W. J. Wilson. Map No. 964, scale 8 m. = 1 in. 1081. On the region lying north of Lake Superior, between the Pic and Nipigon rivers, Ont., by W. H. Collins. Map No. 964, scale 8 m. = 1 in.	Bound together.

992. Report on Northwestern Ontario, traversed by National Transcontinental railway, between Lake Nipigon and Sturgeon lake, by W. H. Collins. Map No. 993, scale 4 m. = 1 in.

* Publications marked thus are out of print.

998. Report on Pembroke sheet, by R. W. Ells. (French). Map No. 660, scale 4 m. = 1 in.
999. French translation Gowganda Mining Division, by W. H. Collins. Map No. 1076, scale 1 m. = 1 in.
1038. French translation report on the Transcontinental Railway location between Lake Nipigon and Sturgeon lake, by W. H. Collins. Map No. 993, scale 4 m. = 1 in.
1059. Geological reconnaissance of the region traversed by the National Transcontinental railway between Lake Nipigon and Clay lake, Ont., by W. H. Collins. Map No. 993, scale 4 m. = 1 in.
1075. Gowganda Mining Division, by W. H. Collins. Map No. 1076, scale 1 m. = 1 in.
1082. Memoir No. 6: Geology of the Haliburton and Bancroft areas, Ont., by Frank D. Adams and Alfred E. Barlow. Maps No. 708, scale 4 m. = 1 in.; No. 770, scale 2 m. = 1 in.
1091. Memoir No. 1: On the Geology of the Nipigon basin, Ont., by A. W. G. Wilson. Map No. 1090, scale 4 m. = 1 in.
1114. French translation. Geological reconnaissance of a portion of Algoma and Thunder Bay district, Ont., by W. J. Wilson. Map No. 964, scale 8 m. = 1 in.
1119. French translation: On the region lying north of Lake Superior, between the Pic and Nipigon rivers, Ont., by W. H. Collins. Map No. 864, scale 8 m. = 1 in.

(1114 and 1119: Bound together.)

1160. Memoir No. 17-E: Geology and economic resources of the Larder Lake district, Ont., and adjoining portions of Pontiac county, Que., by M. E. Wilson. Maps No. 1177—31 A, scale 1 m. = 1 in.; No. 1178—32 A, scale 2 m. = 1 in.

QUEBEC.

216. Mistassini expedition, by A. P. Low. 1884-5. Map No. 228, scale 8 m. = 1 in.
240. Compton, Stanstead, Beauce, Richmond, and Wolfe counties, by R. W. Ells. 1886. Map No. 251 (Sherbrooke sheet), scale 4 m. = 1 in.
268. Megantic, Beauce, Dorchester, Lévis, Bellechasse, and Montmagny counties, by R. W. Ells. 1887-8. Map No. 287, scale 40 ch. = 1 in.
297. Mineral resources, by R. W. Ells. 1889.
328. Portneuf, Quebec, and Montmagny counties, by A. P. Low. 1890-1.
579. Eastern Townships, Montreal sheet, by R. W. Ells and F. D. Adams, 1894. Map No 571, scale 4 m. = 1 in.
591. Laurentian area north of the Island of Montreal, by F. D. Adams. 1895. Map No. 590, scale 4 m. = 1 in.
670. Auriferous deposits, southeastern portion, by R. Chalmers. 1895. Map No. 667, scale 8 m. = 1 in.
707. Eastern Townships, Three Rivers sheet, by R. W. Ells. 1898.
*739. Argenteuil, Ottawa, and Pontiac counties, by R. W. Ells. 1899. (*See* No. 739, Ontario).
788. Nottaway basin, by R. Bell. 1900. *Map No. 702, scale 10 m = 1 in.
863. Wells on Island of Montreal, by F. D. Adams. 1901. Maps Nos. 874, 875, 876.
923. Chibougamau region, by A. P. Low. 1905.
962. Timiskaming map-sheet, by A. E. Barlow. (Reprint). Maps Nos. 509, 606, scale 4 m. = 1 in.; No. 944, scale 1 m. = 1 in.
974. Report on Copper-bearing rocks of Eastern Townships, by J. A. Dresser. Map No. 976, scale 8 m. = 1 in.
975. Report on Copper-bearing rocks of Eastern Townships, by J. A. Dresser. (French).
998. Report on the Pembroke sheet, by R. W. Ells. (French).
1028. Report on a Recent Discovery of Gold near Lake Megantic, Que., by J. A. Dresser. Map No. 1029, scale 2 m. = 1 in.
1032. Report on a Recent Discovery of Gold near Lake Megantic, Que., by J. A. Dresser. (French). Map No. 1029, scale 2 m. = 1 in.

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* Publications marked thus are out of print.

1052. French translation report on Artesian wells in the Island of Montreal, by Frank D. Adams and O. E. LeRoy. Maps No. 874, scale 4 m. = 1 in.; No. 375, scale 3,000 ft. =1 in.; No. 876.
1064. Geology of an Area adjoining the East Side of Lake Timiskaming, Que., by Morley E. Wilson. Map No. 1066, scale 1 m. = 1 in.
1110. Memoir No. 4: Geological Reconnaissance along the line of the National Transcontinental railway in Western Quebec, by W. J. Wilson. Map No. 1112, scale 4 m. = 1 in.
1144. Reprint of Summary Report on the Serpentine Belt of Southern Quebec, by J. A. Dresser.
1160. Memoir No. 17-E: Geology and economic resources of the Larder Lake district, Ont., and adjoining portions of Pontiac county, Que., by M. E. Wilson. Maps No. 1177-31 A, scale 1 m. = 1 in.; No. 1178-32 A, scale 2 m. = 1 in.
1186. Memoir No. 35: Reconnaissance along the National Transcontinental railway in Southern Quebec, by J. A. Dresser. Map No. 1180-34A, scale 8 m.=1 in.

NEW BRUNSWICK.

218. Western New Brunswick and Eastern Nova Scotia, by R. W. Ells. 1885. Map No. 230, scale 4 m. = 1 in.
219. Carleton and Victoria counties, by L. W. Bailey. 1885. Map No. 231, scale 4 m. = 1 in.
242. Victoria, Restigouche, and Northumberland counties, N.B., by L. W. Bailey and W. McInnes. 1886. Map No. 254, scale 4 m. = 1 in.
269. Northern portion and adjacent areas, by L. W. Bailey and W. McInnes. 1887-8. Map No. 290, scale 4 m. = 1 in.
330 Temiscouata and Rimouski counties, by L. W. Bailey and W. McInnes. 1890-1. Map No. 350, scale 4 m. = 1 in.
661. Mineral resources, by L. W. Bailey. 1897. Map No. 675, scale 10 m. = 1 in. New Brunswick geology, by R. W. Ells. 1887.
799. Carboniferous system, by L. W. Bailey. 1900. } Bound together.
803. Coal prospects in, by H. S. Poole. 1900. }
983. Mineral resources, by R. W. Ells. Map No. 969, scale 16 m. = 1 in.
1034. Mineral resources, by R. W. Ells. (French). Map No. 969, scale 16 m. = 1 in.
1113. Memoir No. 16–E: The Clay and Shale deposits of Nova Scotia and portions of New Brunswick, by H. Ries and J. Keele. Map No. 1153, scale 12 m. = 1 in.

NOVA SCOTIA.

243. Guysborough, Antigonish, Pictou, Colchester, and Halifax counties, by Hugh Fletcher and E. R. Faribault. 1886.
331. Pictou and Colchester counties, by H. Fletcher. 1890-1.
358. Southwestern Nova Scotia (preliminary), by L. W. Bailey. 1892-3. Map No. 362, scale 8 m. = 1 in.
628. Southwestern Nova Scotia, by L. W. Bailey. 1896. Map No. 641, scale 8 m. = 1 in.
685. Sydney coal-field, by H. Fletcher. Maps Nos. 652, 653, 654, scale 1 m. = 1 in.
797. Cambrian rocks of Cape Breton, by G. F. Matthew. 1900.
871. Pictou coal-field, by H. S. Poole. 1902. Map No. 833, scale 25 ch. = 1 in.
1113. Memoir No. 16–E: The Clay and Shale deposits of Nova Scotia and portions of New Brunswick, by H. Ries and J. Keele. Map No. 1153, scale 12 m. = 1 in.

MAPS.

1042. Dominion of Canada. Minerals. Scale 100 m. = 1 in.

YUKON.

*805. Explorations on Macmillan, Upper Pelly, and Stewart rivers, scale 8 m. = 1 in.
891. Portion of Duncan Creek Mining district, scale 6 m. = 1 in.

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* Publications marked thus are out of print.

894. Sketch Map Kluane Mining district, scale 6 m. = 1 in.
*916. Windy Arm Mining district, Sketch Geological Map, scale 2 m. = 1 in.
990. Conrad and Whitehorse Mining districts, scale 2 m. = 1 in.
991. Tantalus and Five Fingers coal mines, scale 1 m. = 1 in.
1011. Bonanza and Hunker creeks. Auriferous gravels. Scale 40 chains = 1 in.
1033. Lower Lake Laberge and vicinity, scale 1 m. = 1 in.
1041. Whitehorse Copper belt, scale 1 m. = 1 in.
1026. 1044–1049. Whitehorse Copper belt. Details.
1099. Pelly, Ross, and Gravel rivers, Yukon and North West Territories. Scale 8 m. = 1 in.
1103. Tantalus Coal area, Yukon. Scale 2 m. = 1 in.
1104. Braeburn-Kynocks Coal area, Yukon. Scale 2 m. = 1 in.

BRITISH COLUMBIA.

278. Cariboo Mining district, scale 2 m. = 1 in.
604. Shuswap Geological sheet, scale 4 m. = 1 in.
*771. Preliminary Edition, East Kootenay, scale 4 m. = 1 in.
767. Geological Map of Crowsnest coal-fields, scale 2 m. = 1 in.
*791. West Kootenay Minerals and Striæ, scale 4 m. = 1 in.
*792. West Kootenay Geological sheet, scale 4 m. = 1 in.
828. Boundary Creek Mining district, scale 1 m. = 1 in.
890. Nicola coal basin, scale 1 m. = 1 in.
941. Preliminary Geological Map of Rossland and vicinity, scale 1,600 ft. = 1 in.
987. Princeton coal basin and Copper Mountain Mining camp, scale 40 ch. = 1 in.
989. Telkwa river and vicinity, scale 2 m. = 1 in.
997. Nanaimo and New Westminster Mining division, scale 4 m. = 1 in.
1001. Special Map of Rossland. Topographical sheet. Scale 400 ft. = 1 in.
1002. Special Map of Rossland. Geological sheet. Scale 400 ft. = 1 in.
1003. Rossland Mining camp. Topographical sheet. Scale 1,200 ft. = 1 in.
1004. Rossland Mining camp. Geological sheet. Scale 1,200 ft. = 1 in.
1068. Sheep Creek Mining camp. Geological sheet. Scale 1 m. = 1 in.
1074. Sheep Creek Mining camp. Topographical sheet. Scale 1 m. = 1 in.
1095. 1A—Hedley Mining district. Topographical sheet. Scale 1,000 ft. = 1 in.
1096. 2A—Hedley Mining district. Geological sheet. Scale 1,000 ft. = 1 in.
1105. 4A—Golden Zone Mining camp. Scale 600 ft. = 1 in.
1106. 3A—Mineral Claims on Henry creek. Scale 800 ft. = 1 in.
1123. 17A—Reconnaissance geological map of southern Vancouver island. Scale 4 m. = 1 in.
1125. Hedley Mining district: Structure Sections. Scale 1,000 ft. = 1 in.
Deadwood Mining camp. Scale 400 ft. = 1 in. (Advance sheet.)
1135. 15A—Phoenix, Boundary district. Topographical sheet. Scale 400 ft. = 1 in.
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Beaverdell sheet, Yale district, scale 1 m. = 1 in. (Advance sheet.)
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1196. 46A—Geological map of Tulameen. Scale 1 m. = 1/62500.
1197. 47A—Sketch map of Law's camp.
1198. 48A—Geological map of Tulameen coal area. Scale 1 m. = 1 in.

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