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CONTENTS

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SUMMARY REPORT, 1921, PART B

HAY AND BUFFALO RIVERS, GREAT SLAVE LAKE, AND ADJACENT COUNTRY[1]

By A. E. Cameron

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Illustration

INTRODUCTION

The presence of asphaltum and oil-bearing rocks in the Mackenzie basin and on the shores of Great Slave lake has been known ever since the earliest explorers visited that part of the Northwest Territories, but the remoteness of the region has retarded the study and exploitation of these resources. The continually increasing demand for petroleum products, however, and particularly the excitement caused by the reported strike of large oil fields near Calgary, aroused considerable interest in the possibility of discovering new fields on Peace and Athabaska rivers and farther north. In 1914-15 many claims were staked for petroleum and natural gas in the vicinity of Nintsi (Windy) point on the north shore of Great Slave lake where tar pools have been known from early times. The writer was instructed to examine the district about the western arm of Great Slave lake and, in particular, to endeavour to determine whether the rocks show any of the conditions favourable for the accumulation of oil.

The summer field seasons of 1916 and 1917 were spent in examining the district. A study of the shorelines of Great Slave lake occupied the major part of the season of 1916; in 1917 an exploration was made of some of the principal rivers flowing into the lake from the south. The more important geographical results of these explorations were the traverses of Hay river from where it is crossed by the 6th meridian of the Dominion Land Surveys, to its outlet on Great Slave lake; of Buffalo river and its source, Buffalo lake; of the lower parts of Kakisa river and of the north shore of Great Slave lake from the outlet at Mackenzie river to the north arm of the lake. Mackenzie river from where it leaves Great Slave lake to the mouth of Kakisa river with its numerous islands was also surveyed and some very necessary corrections were made in

[1] In order to include conveniently in one volume as much new information as possible regarding the occurrence of petroleum in the Mackenzie River region, at this time when so much interest in being taken in exploration for petroleum, this report by Mr. Cameron is included in the Summary Report for 1921, although the field work was done some years previously. Following it are reports by E. J. Whittaker, M. Y. Williams, and G. S. Hume upon more northerly sections of the region and one by D. B. Dowling dealing with more general aspects of the problem of finding petroleum in the Mackenzie region.
Director.

previous maps of this part of the river. These surveys were made with a micrometer telescope and compass, and were checked by sextant observations for latitude.

LOCATION AND EXTENT OF AREA

The area examined lies between latitudes 58° 20′ north and 62 degrees north and longitudes 111 degrees and 118 degrees west. This immense area, comprising approximately 61,400 square miles, is one of the largest blocks of practically unexplored areas of the Dominion. It embraces a large part of the valley of Hay river, the whole of the drainage system of Buffalo river, and the large basin of the west arm of Great Slave lake. It lies partly in the province of Alberta and partly in the Northwest Territories.

Field work was of necessity limited to traversing the more important waterways. Information regarding the interior of the country was gathered from the few reports that have been written and from personal communication with the inhabitants. South of the 60th parallel of latitude the Topographical Surveys Branch, Department of the Interior, has several base and meridian lines and the reports of the surveyors contain good accounts of the topography of the country. North of the 60th parallel, the country, except narrow strips in the vicinity of travelled routes, still remains largely a land unknown.

ACKNOWLEDGMENTS

G. L. Kidd conducted the instrumental work of the surveys in a most capable manner. The thanks of the writer are due to many residents of the district for assistance and general kindnesses, especially to the Reverend A. J. Vale and the Reverend G. W. Bowring of the Anglican Mission school at Hay river, to the Reverend Father Bousso of the Roman Catholic mission at Hay river, to the staffs of the various Hudson's Bay Company's posts, and to officials of the Forestry Branch, Department of the Interior.

Acknowledgment is also due to Charles Camsell and E. M. Kindle, of the Geological Survey, for many helpful suggestions and kindly criticism in the preparation of this report. Mr. Camsell directed and supervised the field work, and in 1916 made an extensive journey over the area, visiting the field party in August of that year. Mr. Kindle and E. J. Whittaker made a collection of fossils from the area in 1917. The results of study of these and of the collections made by the writer in 1916, together with Mr. Kindle's suggestions regarding the correlation of strata, have made it possible to compile the geology of the area, shown on the accompanying 50-mile map (No. 1585).

PREVIOUS WORK[1]

Almost all the earlier explorers of the country made some reference to the physical geography and geology of parts of Great Slave lake. Samuel Hearne crossed the eastern arm of the lake in 1772, Alexander Mackenzie traversed the west arm in 1789, and Franklin, Richardson, Back, and others spent some time in the vicinity of the lake. These explorers, however, were more interested in the country to the north and their reports carry little information regarding the country near the lake.

In 1886, R. G. McConnell[2] made a geological examination of the south shore from Slave river to Mackenzie river, and ascended Hay river as far as Alexandra falls. He traversed the north shore of the lake from Mackenzie river

[1] The name Little Buffalo river has been changed by the Geographic Board to Livock river, but has been retained in this report, as the accompanying map had been published before the change was made.

[2] McConnell, R. G., "Report on Exploration in the Yukon and Mackenzie Basins," Geol. Surv., Can., Ann. Rept., new ser., pt. D, vol. IV, 1888-89.

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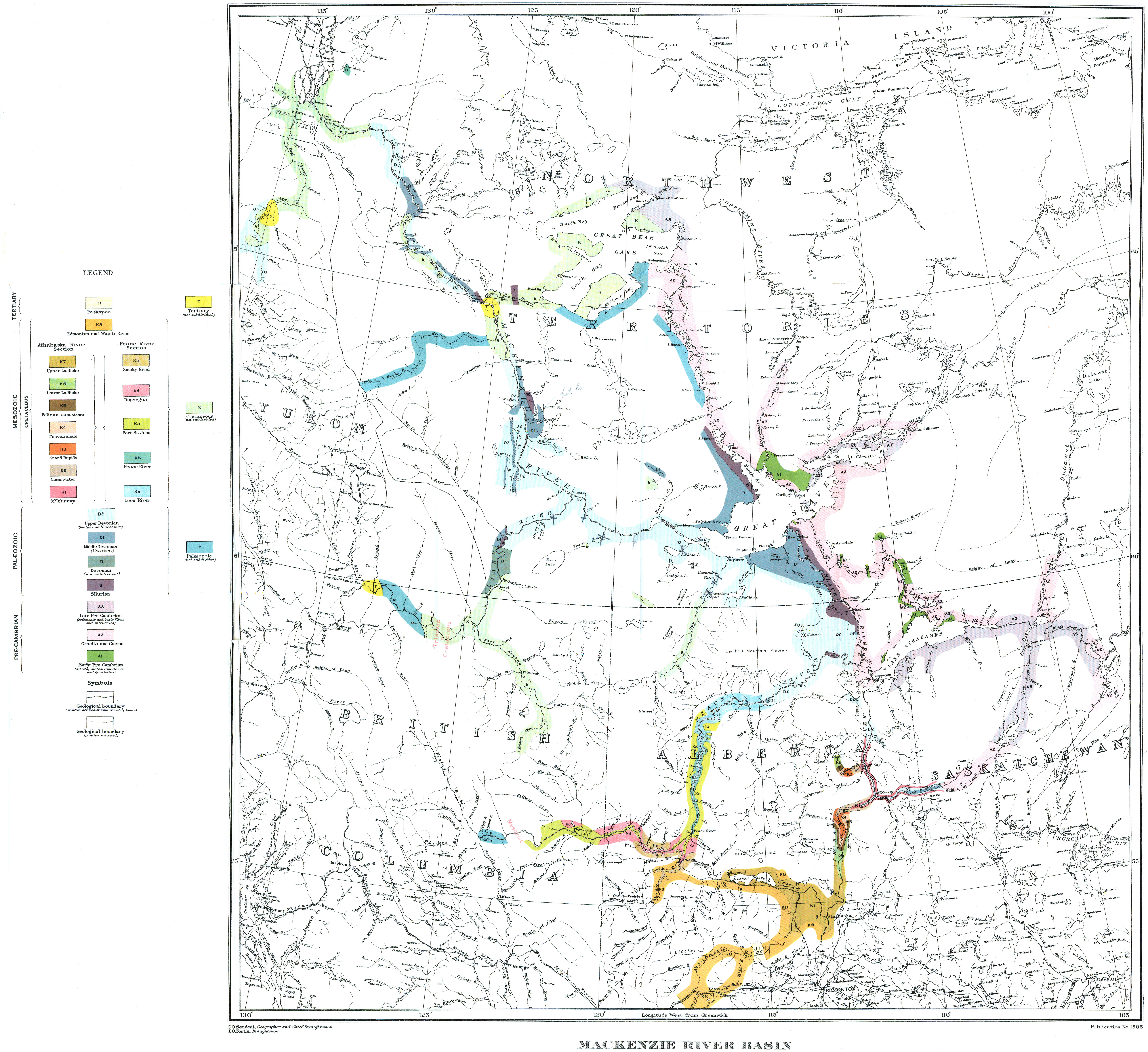

MACKENZIE RIVER BASIN

NORTHWESTERN CANADA

Scale, 1/3,168,000

Miles: 50 25 0 50 100 150 200

Kilometres: 100 50 0 100 200 300

50 MILES TO 1 INCH

as far east as Nintsi point. The published report of these explorations contains the most detailed information relative to the geology and physical geography of the region.

Wm. Ogilvie[1] in 1887 surveyed the south shore of the lake from Mackenzie river to Slave river.

During the seasons of 1899 to 1902 Robert Bell and J. M. Bell[2] surveyed and made a geological examination of the east arm of the lake and the east shore of the north arm, but the north shore of the west arm though traversed by Mackenzie in 1789, and probably by Franklin and Richardson in 1825, had never been surveyed previous to 1916.

Slave river has been the main waterway for travel to the north country since the earliest times. At the time of Mackenzie's explorations fur traders had already established a trading post on Great Slave lake. Peace river was ascended by Mackenzie[3] in 1792 on his journey across the continent from Montreal to the Pacific ocean. Petitot[4] claims to have discovered Kakisa (Beaver) river in 1875 and about the same time Alexandra falls on Hay river were named by Bishop Bompas. Whether the bishop ascended Hay river from Great Slave lake or descended it from Vermilion is not known. In the early nineties a small party of prospectors bound for the Yukon descended Hay river to the lake, building a small cabin and wintering on the portage at Alexandra falls. In 1902 C. Camsell[5] ascended Little Buffalo river from a point near Fort Smith to the divide between that river and Jackfish river, and descended Jackfish river to Peace river. Sergeant Mellor, of the Royal Northwest Mounted Police, made a patrol up Buffalo river and across Buffalo lake in 1909.[6] Prospectors have also been up the river, according to Indian reports, and the ruins of their cabins are still to be seen along the river. Sergeant McLeod[7] of the Royal Northwest Mounted Police, who made a winter patrol in 1911 from Vermilion across the Caribou Mountain plateau and down Buffalo river to Great Slave lake, was the first white man to traverse this region. In 1911, Hulbert Footner,[8] a journalist, descended Hay river from Vermilion portage to Alexandra falls. In 1914, J. R. Akins[9] ran the 29th base-line of the Dominion Land Surveys across the lower end of Caribou Mountain plateau, and in 1916 projected the 6th meridian[10] north to the northern boundary of Alberta at the 60th parallel of latitude.

GENERAL CHARACTER OF THE DISTRICT

Caribou mountains, which lie south of the 60th parallel of latitude, form the principal watershed between the waters tributary to Peace river and those tributary to Hay and Buffalo rivers. They are in reality the escarpment bordering a large, gently rolling plateau elevated about 3,000 feet above sea-level, and

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[1] Ogilvie, Wm., "Exploration Surveys of Parts of Lewes, Tat au Duc, Porcupine, Bell, Trout, Peel, and Mackenzie Rivers," 1887-88, Dept. of Interior, report of 1890.

[2] "Mackenzie Basin," Geol. Surv., Can., Ann. Rept., new ser., pt. A, vol. XII, 1899; also Ann. Rept., new ser., pt. E, vol. XII, 1899.

[3] Mackenzie, Alexander, "Voyages from Montreal on the River St. Lawrence Through the Continent of North America to the Frozen and Pacific Oceans in the Years 1789 and 1793."

[4] Petitot, Emile, Autour du Grand Lac des Esclaves.

[5] Camsell, C., "Region Southwest of Fort Smith," Geol. Surv., Can., Ann. Rept., new ser., pt. A, vol. XV, 1902-03, p. 143.

[6] Mellor, Sergt., "Patrol Along the South Shore of Great Slave Lake in Connection with the Location of the Wood Buffalo," Report of Royal Northwest Mounted Police, 1910.

[7] McLeod, Sergt., "Vermilion to Hay River on Great Slave Lake," Report of Royal Northwest Mounted Police, 1911.

[8] Footner, Hulbert, "New Rivers of the North," 1914.

[9] Akins, J. R., "29th Base Line between 5th and 6th Meridian," Report of Dept. of the Interior, Topographical Surveys Branch, 1914.

[10] Akins, J. R., "6th Meridian between 27th Base and Northern Boundary of Alberta," Rept. of Dept. of Interior, Topographical Surveys Branch, 1916.

from 2,100 to 2,500 feet above the surrounding country. This plateau extends southward to within 15 miles of Peace river and the northern escarpment is clearly visible from Buffalo lake from which it is not more than 30 miles distant. Camsell[1] reports the eastern limit to be about 8 or 10 miles west of Jackfish river. The western limit is not visible from the valley of Hay river, but probably extends to within 30 miles of that stream. These boundaries give the plateau an area of approximately 9,600 square miles. Very little is known concerning this area. The 29th base-line of the Dominion Land Surveys crosses the southern edge of the plateau and Akins[2] reports the slopes as heavily wooded with spruce and jackpine and the top as lightly wooded with stunted spruce and covered with moss. Sergeant McLeod[3] states that a number of lakes lie on the top of the plateau, one of which is about the size of Lesser Slave lake. He traversed the plateau from south to north and reports it to have a typical rolling topography characterized by low hills of glacial drift and muskeg or swampy lowlands. Small moss-fringed lakes abound and are drained by numerous swift-flowing creeks. The banks and valleys of the streams are composed of clays and gravels and their beds are full of boulders of igneous rocks washed out of the glacial boulder clay.

Southwest of the Caribou Mountain plateau and connected with it by the height of land between Peace and Hay rivers is another small plateau, 2,500 feet in elevation, called Watt mountains. The intervening height of land between Peace and Hay rivers is about 1,500 feet in elevation and is formed largely of glacial drift.

Peace river from Fort Vermilion downstream approximately marks the southern boundary of the area under discussion. Just above Fort Vermilion the river lies in a deep valley, but within a short distance the banks fall away, and from Vermilion to near the confluence of Jackfish river it flows through a broad, gently rolling plain which on the north rises gradually to Caribou mountains. Towards the height of land between Watt and Caribou mountains this plain is characterized by large, open prairie sections separated by areas carrying a light growth of poplar and willow. Numerous prairie sections, also, are said to diversify the plain area to the east lying between Caribou mountains and Peace river. These areas are well watered by numerous streams tributary to Peace river, the most important being Paddle or Boyer river, and Caribou, Lawrence, Deer, and Jackfish rivers.

Very little is known of the district lying to the east of Caribou mountains and north of Peace river. In the vicinity of Little Buffalo and Jackfish rivers, Camsell[4] reports the country to be a gently rolling upland breaking abruptly at the 200-foot escarpment of the salt plains near Fort Smith. Numerous muskeg and swampy areas occur between low hills of glacial drift covered with jackpine and poplar.

With the exception of the traverse of Buffalo river and Buffalo lake made by the writer in 1917 and described in detail in later pages of this report, the whole of the vast territory lying between Great Slave lake and Caribou mountains and between Hay and Slave rivers is virtually unexplored. Sergeant McLeod[5] reports the country seen when looking northward from the summit of

[1] Camsell, C., "Region Southwest of Fort Smith," Geol. Surv., Can., Ann. Rept., 1902-03, p. 149.

[2] Akins, J. R., "29th Base-Line between 5th and 6th Meridians," Ann. Rept., Dept. of Interior, Topographical Surveys Branch, 1914-15, p. 67.

[3] McLeod, Sergt., R. W., "Vermilion to Hay River, Jan., 09," Royal Northwest Mounted Police report, 1909, p. 178.

[4] Camsell, C., "Country Southwest of Fort Smith," Geol. Surv., Can., Ann. Rept., new ser., vol. XV, 1902-03.

[5] McLeod, Sergt. R. W., "Vermilion to Hay River, Jan., 09," Royal Northwest Mounted Police Report, 1909, p. 178.

the Caribou escarpment to be a gently rolling, well-wooded plain dotted with numerous small lakes. Near the salt springs near Fort Smith, there are many open prairie sections interspersed with areas supporting a light growth of spruce and poplar; and much open prairie country is said to occur in the region between Little Buffalo and Buffalo rivers. Slave river in this part of the area flows through a broad alluvial plain of its own making, the western boundary of which is approximately Little Buffalo river. South of Pine point on Great Slave lake, the land rises with relative rapidity until, in a distance of 3 miles, it has an elevation of about 200 feet above the lake-level. A narrow strip of swampy muskeg country lying at about water-level along the lake shore appears to have been formed in lagoons cut off from the lake by barrier beaches of gravel and sand and subsequently partly filled and reclaimed by vegetation. The absence of any large tributaries east of Buffalo river indicates that the height of land between this river and Little Buffalo river lies very close to the former stream and that, consequently, the large area between these two streams and south to Caribou mountains drains chiefly to the east into Little Buffalo river.

The country west of Hay river is little known. Akins[1] reports that the country for 35 miles north of Hay river, adjacent to the 6th meridian, is gently rolling and well watered by numerous streams flowing east to Hay river. Then there is an abrupt rise at the escarpment of Cutknife hills to an elevation of 2,700 feet. Cutknife hills appear to be a broad, gently rolling plateau dotted with numerous small lakes which apparently drain westward to the headwaters of Kakisa river. Near Grumbler rapids on Hay river the escarpment of Swede mountains, 2,500 feet in elevation, shows to the west at a distance of about 15 miles. The escarpment is apparently a continuation of that of Cutknife hills to the southwest and, probably, connects with the Eagle Mountain escarpment to be seen to the south from Great Slave lake and Mackenzie river. From Eagle Mountain escarpment northward to the lake shore, and between Hay and Kakisa rivers, extends a low, flat, swampy country scarcely higher than Great Slave lake. It is reported by the Indians to be dotted with small, shallow lakes separated by stretches of muskeg. An old Indian canoe route connects Hay and Kakisa rivers through these lakes and swampy areas.

The country to the north of Great Slave lake and west of the North arm, Preble[2] reports to be "a low, broad plateau dotted with many lakes and muskegs. It contains no rivers of importance and is mainly rather thinly wooded, though a number of large prairies occur in the western part north of the outlet of the lake." Seen from the shore of the lake it appears to be a gently rolling plain with ridges of glacial drift separating low-lying muskeg areas which stand only slightly higher than the lake.

The region north of Great Slave lake is underlain by the Precambrian formations and is rocky and rolling, having been heavily eroded by the Keewatin continental glacier. Vegetation is scant, and confined to the low ground between the rocky ridges, where stunted spruce and poplar grow in a mossy muskeg soil.

HAY RIVER

Hay river, rising in the foothills of the Rocky mountains to the north of Fort St. John, B.C., and fed by numerous small streams, is one of the largest tributaries of Great Slave lake. It crosses the 6th meridian a few hundred yards south of section corner 25-114-1. From this point, though of a meander-

[1] Akins, J. R., "6th Meridian—27th Base-line to 60th Parallel," Ann. Rept., Dept. of Interior, Topographical Surveys Branch, 1916.

[2] Preble, E. A., "North American Fauna," No. 27, U.S. Dept. of Agriculture, Bureau of Biological Survey, 1908.

ing character, it holds remarkably well its direction of magnetic north (north 35° 30′ east astronomical) throughout the distance of 225 miles to Great Slave lake.

Throughout the 26 miles from the 6th meridian to the mouth of Meander river at Hay River outpost, the river has an average width of 200 feet, and is very swift and broken by a succession of rapids. The valley is less than half a mile wide and the adjacent country is gently rolling, drift-covered, and wooded with scrubby spruce and poplar, much of which has been burnt over in recent times.

North of Hay River outpost the valley widens and shallows and the river, straightening its course, widens to 400 to 600 feet and flows smoothly and sluggishly for 116 miles through a flat muskeg and brûlé country, which is in places relieved by low hills of glacial drift.

Devonian limestones come to the surface 116 miles below the mouth of Meander river and form low ramparts in the river valley that cause the river to narrow and the current to increase. For the next 33 miles, rapids occur in quick succession wherever the channel has been cut down to the limestones, until finally, 149 miles below Hay River outpost, the river plunges 106 feet, forming Alexandra fall. From the fall the river flows rapidly for a mile through a narrow gorge and then makes a second leap of 46 feet, forming Louise fall. The portage trail leaves the river on the left bank above Alexandra fall, leads for 2½ miles through a flat marshy plain forested with white spruce and jack-pine, and returns to the river where the limestone cliffs have been broken down to a slope.

The falls are due to a band of soft shale 47 feet thick interstratified with massive bedded limestones which overlie a thick series of soft clay shales. McConnell[1] shows that the rate of recession of the falls has been almost identical with that of Niagara falls. He says: "Niagara falls are generally regarded to have receded 6 miles since they were brought into existence by the elevation of the country at the end of the Glacial period and on Hay river the distance between the point at which the limestone band makes its first appearance and the lower falls is almost exactly 5 miles and between the same point and the upper falls 6 miles."

Below Louise fall the river has cut a narrow gorge about 250 feet deep in the limestone, through which it rushes for a distance of 6 miles before it clears the escarpment. For the succeeding 40 miles it flows with steadily diminishing velocity until about 4 miles from the lake it loses itself in a maze of channels amongst the delta deposits. Only one of these channels, however, finds its way to the lake separately, the others all coming together and issuing as one stream into the lake.

BUFFALO LAKE

Buffalo lake covers approximately 200 square miles. It is very shallow, its depth scarcely exceeding 10 feet in any place. Confined on the north by a low range of hills of glacial drift, the lake acts as a collecting basin for the waters draining the northern slopes of Caribou mountain. Three comparatively large streams flow into the southern end of the lake. Each of these is building a delta which is gradually encroaching on and slowly filling in this part of the lake. The whole shoreline is low and swampy, particularly on the south side, where in places willow and alder bushes are growing in 2 feet of water. A few islands, composed of glacial boulders of Precambrian granites and metamorphics, occur along the northern shore. The smaller of these resemble cairns and are bare of

[1] McConnell, R. G., "Explorations in the Yukon and Mackenzie River Basins," Geol. Surv., Can., Ann. Rept., new ser., pt. D, vol. IV, 1889.

vegetation, but upon the larger ones, scrubby spruce, poplar, and willow have found a foothold. These islands represent outliers of the low, east and west glacial morainal ridge that forms the north shore of the lake. The lake is evidently the remnant of a much larger morainal lake of early postglacial times.

BUFFALO RIVER

Buffalo river, which discharges from the northeast corner of Buffalo lake into Great Slave lake, flows northwest 5 miles, cutting through the low range of hills that bound the lake on the north. It then makes a wide swing to the right and after following a general course of magnetic north (north 36 degrees east astronomical) for 25 miles, swings in another wide curve, known as the Big Bend, after which it resumes a true north course for 25 miles to Great Slave lake. From Buffalo lake to the Big Bend the river valley is cut through a series of morainal ridges separated by flat muskegs and brûlé. The outside of each curve has a bank cut into glacial clays and gravels. Boulder rapids separated by stretches of smooth, though swift-running, water, are numerous. Below the Big Bend the ridges become more numerous and of greater height and the cut banks frequently show sections of glacial clays and drift 80 to 100 feet high. Here the current increases and the river runs turbulently in a succession of rapids amongst and over the large boulders washed from the drift. At a few places along its course it has cut into the underlying Devonian limestones, forming low ramparts similar to those on Hay river. About 3 miles above its mouth it suddenly expands and, diverging into numerous channels, loses itself in a braided channel amongst limestone gravel bars. These divergent streams reunite in a single stream which forces its way through a low barrier of glacial drift to Great Slave lake.

The volume of water carried by the river is subject to rapid fluctuation due to the shallow nature of Buffalo lake in which it has its source. Even comparatively light winds cause waves that quickly raise the level of the lake on the windward side. During strong winds a rise of 2 feet or more in the level of the lake was noticed and when the wind blows in the direction of the outlet the discharge down the river is greatly increased.

LITTLE BUFFALO RIVER

Little Buffalo river rises in Caribou mountains and follows an easterly course towards Slave river. It then swings north and closely parallels Slave river to Great Slave lake. It crosses the 60th parallel of latitude 28 miles west of Fort Smith and a portage 7 miles long connects it with Salt river near Fort Smith.

Little Buffalo river from the end of this portage to near its headwaters at the base of the Caribou plateau was examined by C. Camsell[1] in 1902. He reports a series of three falls occurring about 6 miles above the portage, giving a total drop of 71 feet. The falls are probably caused by an outcrop of limestone overlying gypsum beds similar to the Salt River escarpment. Camsell mentions no fossils from these limestones, but they probably represent a Middle Devonian horizon.

A traverse of Little Buffalo river from Salt River portage to Great Slave lake was made in 1920. The river averages 60 to 70 feet in width throughout the distance, has an exceedingly meandering course, but presents no hindrance to canoe navigation.

[1] Camsell, C., "Region Southwest of Fort Smith," Geol. Surv., Can., Ann. Rept., new ser., vol. XV, 1902-03, pt. A.

For the upper 35 miles it borders an east-facing escarpment varying from 40 to 150 feet in height. This escarpment is a continuation of the Salt River escarpment and in all exposures Devonian dolomite limestones overlie the gypsum series. Gypsum creek, a small stream fed by springs in a sink-hole on the edge of the escarpment, enters from the left about 25 miles below Salt River portage, and slightly above this creek a portage 7 miles long connects the river with Slave river at Le Grand Detour. Below Gypsum creek the escarpment is not so high and swings west, and no rock outcrops are met with until the mouth of Log-jam creek is reached, 40 miles above the mouth of Little Buffalo river. At the mouth of Log-jam creek a bed of flat-lying limestones causes a small rapid, the only one between Salt River portage and Great Slave lake. The limestones, which are just below water-level, carry a fauna closely allied to that found in the limestones about Resolution. Log-jam creek was ascended about 16 miles. It flows through a flat muskeg country that has no pronounced relief; and it exposes no bedrock except just at its mouth. Below the creek the valley walls of Little Buffalo river are low and the adjacent country is a flat muskeg. An escarpment about 200 feet high shows to the west for the last 15 miles, but no rock outcrops in the valley.

MACKENZIE RIVER

Mackenzie river, where it leaves Great Slave lake, is divided by Big island into two channels. The southern one has a width of 7 miles at the lake, but in 5 miles narrows to 4 miles and becomes choked with islands. It carries the main flow of water and is used by the steamers, yet is shallow and navigation in low water is difficult. The current here has a velocity of at least 3 miles an hour. The north channel has a width of about a mile and a half where it leaves the lake, in only a few places exceeds 2 feet in depth, and shows very little current until close to its junction with the main channel at the lower end of Big island. Below Big island, Mackenzie river keeps an average width of about 4 miles for a distance of 20 miles and shows only a very slight current. This part of the river is known locally as Beaver (Kakisa) lake and is reported to be rarely more than 12 feet deep.

KAKISA RIVER

Kakisa river, which enters the Mackenzie from the south about 25 miles below Great Slave lake, was ascended for 8 miles, to Lady Evelyn falls. It is swift and shallow and almost unnavigable. The adjacent country is a low muskeg with occasional ridges of glacial drift which, where crossed by the river, form typical boulder rapids. About 6 miles above its mouth, Devonian limestones make their first appearance in the valley, forming low cascades where the river cuts across the beds. The valley here is from 60 to 80 feet deep and shows heavy deposits of glacial material overlying the limestones. Two miles farther upstream is Lady Evelyn fall where the river drops 48 feet over a limestone cliff. This fall is caused in the same way as Alexandra fall on Hay river. The limestones exposed are the same as those that form Louise fall; but the overlying shales seen on Hay river have thinned out; consequently Alexandra fall on Hay river is here represented by a long series of low cascades from 3 to 15 feet high. No gorge is developed below the fall, though the valley walls are steep and show occasional cliffs of limestones.

GREAT SLAVE LAKE

R. G. McConnell,[1] in 1887, accorded to Great Slave lake a superficial area, including islands, of approximately 10,400 square miles and ranks it fifth

[1] McConnell, R. G., "An Exploration in the Yukon and Mackenzie Basins, N.W.T.," Geol. Surv., Can., Ann. Rept., pt. D, new ser., vol. III, 1888-89.

among the great lakes of the continent, being exceeded by Superior—31,500, Huron—23,800, Michigan—22,300, and Great Bear—11,400 square miles. Calculations based on the Dominion of Canada Railway map, issued 1914, slightly increase the areas of Great Bear and Great Slave, giving them 11,900 and 10,700 square miles respectively. Great Slave is divided into three arms as follows: West arm—5,430 square miles, East arm—4,120 square miles, and North arm—1,150 square miles. The writer's survey of the north shore of the West arm supplies more accurate data for calculating the area of this part of the lake; it indicates an area of 7,830 square miles, thus increasing previous estimates by 2,400 square miles. This increase gives Great Slave lake a total area of 13,100 square miles, or an excess of 1,700 square miles over Great Bear lake, and places it fourth among the great lakes of the continent.

Great Slave lake is about 300 miles long and in one place is over 60 miles wide. It had originally the form of a great cross with one arm penetrating the Precambrian crystalline schists and two others stretching north and south along the edge of the protaxis; the fourth extended over the flat-lying Palæozoic sediments to the west. The southern arm has been completely silted up and obliterated by Slave river.

The East arm, stretching about 200 miles to the east of Slave river, has an irregular outline and is dotted with many rocky islands. The water is said to be very deep and clear and to abound in fish of various kinds. The country north and east of this arm is described by Back[1] as one of bare, round-backed hills and ridges that rise gradually from the water's edge to a height of 1,000 to 1,200 feet.

The North arm, situated opposite the mouth of Slave river, has a width at its mouth of nearly 40 miles. Its eastern shore is a rugged, rocky country with many low, rocky islands offshore; whereas the western shore is flat, with sandy beaches and occasional wave-cut cliffs. The eastern shore was surveyed and examined in 1899 by J. M. Bell[2]; the western shore has been surveyed and geologically mapped by G. S. Hume, of the Geological Survey, since the time of the writer's visit to the lake.[3]

Exploration and examination of the western part of the lake—here referred to for convenience as the West arm—formed the major part of the writer's field work in 1916. Although a very large expanse of open water, and free from islands beyond 10 miles from shore, it is everywhere shallow, and sand-bars and reefs are reported to occur many miles out. It is slowly being filled by material brought down by Slave river, and the water, especially along the southern shore, is seldom entirely free from suspended matter. Towards the north shore the water is clearer, but even there a distinct cloudiness is noticeable and it is not until the northeastern shore is reached in the vicinity of the mouth of the north arm, that the water becomes clear. Sediment-laden waters are again observable in the vicinity of île les Bassée and île du Large, though they are more than 30 miles from the mouth of Slave river. The prevailing northeast winds cause an accumulation along the south shore of immense quantities of driftwood which sometimes takes fire and is often the starting point of destructive forest conflagrations. Piles of this wood 100 and more feet wide and several feet high are frequently to be found extending for miles along the shore.

The lake abounds in fish of many kinds, which should furnish a profitable industry when the country to the south becomes more settled and freight rates are reduced. Whitefish, jackfish, and trout are abundant, individual trout fre-

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[1] Back, Captain George, "Narrative of an Arctic Land Expedition to the Mouth of Great Fish River and Along the Shores of the Arctic Ocean in the Years 1833-34-35."

[2] Explorations in Mackenzie District: Geol. Surv., Can., Ann. Rept., new ser., vol. XII, 1899, p. 103 A; vol. XIII, 1890, p. 53 A; vol. XII, pt. C.

[3] Geol. Surv., Can., Sum. Rept., 1920, pt. B.

quently exceeding 50 pounds in weight. There is also taken from the lake the inconnu, or "conie," the edible qualities of which all but equal that of the northern whitefish. The inconnu is exclusively a northern species and is never found south of Fort Smith.

Description of the Shores of Great Slave Lake

The south shore from Stoney island west to Little Buffalo river is formed of delta deposits from Slave river that mark approximately the mouth of the pre-existing south arm. These fluvial deposits of crossbedded sands and silts are intimately associated with lacustrine deposits of a somewhat earlier period which extend as far south as Fort Smith. In places they are well covered with an abundant growth of excellent spruce. At Resolution a low range of hills rises above the silts and extends west into the lake, forming Mission and Moose islands and, still farther west, Burnt islands.

From the mouth of Little Buffalo river, which marks the western limit of the delta deposits, the shoreline is characterized by wide, shallow bays separated by low, gravelly or rocky points. Usually each bay has a gravelly or sandy beach behind which lies a narrow stretch of low, swampy muskeg or shallow, open lagoon. South of Pine point the ground rises gently inland until at a distance of some 10 miles it reaches an elevation of 300 feet above the present lake-level. This slope is well wooded with spruce, jackpine, and poplar and carries numerous well-developed old lake beaches which, extending in long, gentle curves, tend to follow the outline of the present lake shore. West of the mouth of Buffalo river the shoreline is generally low-lying and swampy with few pronounced points.

West of a line drawn from Hay river to Slave point on the north shore, the shores of the lake are formed presumably of soft shales, and the adjacent land is low-lying and swampy. Long stretches of spruce and tamarack muskegs reach inland from the lake. These are bounded on the south by Eagle mountains but the northern limit is not visible from the lake. Along this part of the shore, Precambrian erratics are abundant and frequently occur far enough offshore to endanger navigation. This part of the lake is very shallow and the shoreline in most places is formed of boulder pavements embedded in a soft blue-to-grey clay. Short, narrow points formed of boulders derived from the Precambrian rocks east of the lake are very numerous, particularly in the deep bay north of the outlet, and boulder reefs occur at long distances from the shore. All the points have a tendency to parallel the direction of glacial movement.

From Slave point the shore runs north for about 40 miles, then east for 25 miles, and then swings in a wide circle to the north arm. The entire shoreline shows clearly the effects of excessive glacial action. Many deep, narrow bays stretch inland approximately parallel to one another in a direction about south 60 degrees west magnetic, or north 85 degrees west (astronomical). That this direction is parallel to the glacial movement is shown by well-marked striæ on Nintsi point.

The heads of the bays are in most cases low and swampy, like those on the south shore, and show a well-developed boulder pavement of material derived from the Precambrian rocks to the east. Wide marshes, in many cases containing large open sloughs, stretch inland from the bays. On the broader points low, wave-cut cliffs in the limestone occur, though frequently the cliffs are situated some distance inland from the present lake shore. The narrow points show boulder pavements embedded in limestone gravels derived from the underlying sediments. A certain percentage of the boulders are probably glacial erratics, but undoubtedly the large majority have been derived from the glacial drift near the lake shore and from the lake bottom, and have been ice-rafted to their present position.

Distinct barrier beaches of limestone shingle are developed wherever the bedrock outcrops at water-level. Many of these extending in long, gentle curves enclose shallow, partly filled lagoons.

The inland country north of the lake is a low spruce and tamarack muskeg slightly higher than the lake, with numerous long, narrow hills rising 100 to 150 feet above lake-level. The hills, in many cases, show low, wave-cut cliffs, facing lakewards, at elevations above the present lake-level. Above and below these cliffs are numerous old lake beaches formed of limestone gravels washed out of the cliffs and clearly indicating changes in the level of the lake during early post-Glacial times.

One of the pronounced features of this region is the absence of drainage towards the lake. Throughout the entire 136 miles of shoreline between Mackenzie river and the North arm, only one small stream was found entering the lake.

The North arm marks the contact of the Precambrian rocks on the east with the Palæozoic sediments on the west; consequently the northeast shore, which is formed of Precambrian rocks, has a character entirely different from the others. It is rocky throughout and for the most part sparsely wooded except in the hollows. Boldly-carved and rounded hills of igneous and metamorphic rocks break off abruptly at the lake, and offshore are numerous irregularly-shaped, rocky islands. The shore is indented with many narrow bays and inlets which are mostly deep and afford excellent harbourage for small craft.

GENERAL GEOLOGY

DISTRIBUTION OF FORMATIONS

Except where the Precambrian rocks reach the surface, almost the whole of the vast district under consideration is mantled with a heavy covering of glacial drift, lacustrine, and fluvial deposits. Consequently, the underlying sediments outcrop infrequently, mostly in the river valleys where the erosive power of the rivers has cut through the superficial beds, or on the shores of the lake where ice and wave action have played a similar part.

The section of the region under consideration, which lies north of the 60th parallel of latitude, is underlain by flat-lying Palæozoic sediments of Silurian, Middle Devonian, and Upper Devonian age. No distinctly Lower Devonian sediments were observed and probably are not represented in the area. The stratigraphy as a whole resembles that of Manitoba, except that the Ordovician and much of the Silurian are absent. There also Tyrrell[1] was unable to locate outcrops carrying a definite Lower Devonian fauna.

At Little rapids on Peace river, soft shales carrying Upper Devonian fossils were found by Kindle unconformably overlying the massive gypsum beds. Exposures of the Gypsum series elsewhere in the district, however, as on Slave river and at the salt springs near Fort Smith, show these beds to be overlain by limestones carrying Middle Devonian fossils and this seems to be the correct sequence of the strata.

South of the 60th parallel the area between Caribou mountains and Slave river, and the Peace River valley as far west as Vermilion chutes, are also

[1] Tyrrell, J. B., "Report on North West Manitoba," Geol. Surv., Can., Ann. Rept., new ser., vol. V, 1890.

underlain by Devonian and Silurian sediments. At the chutes, Upper Devonian limestones equivalent to the limestones on Hay river and the Chemung limestones of New York, are exposed. At Little rapids on Peace river and at several points on Slave river in the vicinity of Fort Smith, limestones carrying gypsum beds are exposed, which, on fossil evidence, are equivalent to the Gypsum and Upper dolomitic limestones of Upper Silurian age found east of lakes Manitoba and Winnipegosis, in Manitoba.

In the valley of Hay river above Grumbler rapids and on Peace river above Vermilion chutes, soft Cretaceous shales are exposed. On Peace river these have been called by McConnell[1] the Loon River shales and are, probably, equivalent to the Clearwater shales and tar sands of the Athabaska River section. The Cretaceous shales on Hay river are lithologically similar to the Loon River shales, but lack of definite palæontological evidence makes it seem advisable to give them a separate nomenclature and simply suggest the correlation.

The plateau areas shown on the map (No. 1585), so far as is known, show no rock in situ, but their topographical forms indicate them to be outliers of the Cretaceous sediments found on Peace river to the west and south. They probably contain representatives of the Peace River sandstones, Fort St. John shales, and Dunvegan sandstones of McConnell's Peace River section. They appear to be plateaus of circumdenudation carved out of horizontal beds of the Cretaceous, like Birch mountains and Buffalo Head hills to the south of Peace river.

Three unconformities break the continuity of sedimentation during the Palæozoic period in this region. It, therefore, follows that any given geological boundary may involve widely different formations in different parts of the region. The greatest of these unconformities is that at the top of the Precambrian. The hiatus here includes the late Precambrian, the Cambrian, Ordovician, and part of the Silurian. The incursion of the Silurian sea into this region engulfed an old land surface of well-developed hills and valleys. Some of these hills were at least 100 feet high and it is most probable that many of them had not been entirely buried under sediments when the Silurian sea withdrew. In Middle Devonian time the sea re-invaded a region of old Silurian sediments which were doubtless broken here and there by low knobs of Precambrian rocks. The warping and surface inequalities developed during the lower Devonian erosion interval left a highly uneven surface, parts of which were submerged and covered by Middle Devonian sediments, and other parts remained uncovered until Upper Devonian time. The third great unconformity of the section cuts out all the intervening formations between the Upper Devonian and the Cretaceous. A further unconformity, representing the long Tertiary time interval immediately preceding the Glacial period, marks the contact of the Quaternary and Cretaceous beds.

The several formations are indicated in the following table, together with a probable correlation with a composite Peace River, Manitoba, and New York section. From this table it is evident that lithological evidence alone is not sufficient to deduce the stratigraphical succession in the map-area. The order in which the strata were laid down and the suggested correlations with the composite section are based upon collections of fossils made by the writer from type localities and identified by E. M. Kindle.

[1] McConnell, R. G., "District of Athabaska," Geol. Surv., Can., Ann. Rept., new ser., pt. D, vol. V, 1890-91.

Table of Formations

Period	Formation	Description	Thickness	Correlation
			Feet	
Quaternary.......	River and lake deposits	Sands, silts, and gravel beaches	....	Agassiz silts, gravels, and deposits of present rivers
	Glacial deposits....	Till and boulder clays.....	....	Glacial till
Contact unconformable				
Cretaceous........	Meander shales.....	Soft, greenish shales with sandstone beds and concretions	....	Loon River shales
Contact not exposed, probably unconformable				
Upper Devonian	Hay River limestones	Hard dolomitic limestones, shaly limestones, limy shales	300	Chemung
	Hay River shales...	Shaly limestones, soft clay shales with limestone, sandstone and ironstone bands	400	
	Simpson shales......	Greenish grey clay shales, weathering to fissile shale	250	Portage
Middle Devonian	Slave Point limestones	Grey shaly limestones...	200	Manitoba limestones
	Presqu'ile dolomites	Hard crystalline dolomites, dolomitic limestones, thin beds grey shaly limestone	375	Winnipegosan dolomites
	Pine Point limestones	Soft, grey, shaly limestones, blue to black thin-bedded hard limestones, grey to brown shaly limestones	595	Elm Point limestones
Contact unconformable				
Silurian	Fitzgerald dolomites	Grey dolomitic limestones with gypsum and anhydrite	275	Gypsum and Upper limestone of Manitoba
	Red beds...........	Red calcareous shale, red gypsum, salt, and red arenaceous shale	595	
Contact unconformable				
Precambrian...	....	Hard red sandstones, granite		

The following is a summary of Kindle's report on these collections:

Silurian. The Silurian fauna is represented by a single specimen of limestone showing a coral closely allied to if not identical with the well-known Guelph species *Pycnostylus guelphensis.* This specimen was collected from a point on the north shore of the lake about 5 miles west of Gypsum point. The same fossil has been found by Kindle in dolomitic limestones overlying gypsum beds on Peace river and at outcrops of Palæozoic sediments on Slave river above Fort Fitzgerald. The beds which furnish this coral fauna have been named the Fitzgerald dolomites.

Middle Devonian. The faunules from the south shore of Great Slave lake may be grouped in three lots.

The first group was collected from exposures in the vicinity of Pine point and furnished the following species:

Favosites sp. nr *limitaris*	*Liorhynchus* sp.
Cyathophyllum richardsoni	*Productella* sp.
Zaphrentis mcfarlani	*Stropheodonta* sp.
Sponge spicules (*Hyalostelia*)	*Atrypa reticularis*
Styliolina fissurella	*Martinia sublineata*
Chonetes pusilla?	*Proetus* sp.

This fauna suggests a palæontological correlation with the Elm Point formation of the Manitoba section. The beds containing this fauna have been called the Pine Point limestones. They represent the oldest Devonian formation in the region.

The second group was collected from exposures on Presqu'ile point and furnished the following species:

Actinostroma cf. *nodulatum* Nicholson	*Martinia* sp.
Favosites cf. *limitaris*	*Stringocephalus burtini*
Atrypa spinosa	

The presence in the faunule of *S. burtini,* first found at Presqu'ile point by Mr. Kindle, indicates the equivalence of this horizon to the limestone at the Ramparts on lower Mackenzie river and to the Winnipegosan dolomites of the Manitoba section. The beds containing this fauna have been called the Presqu'ile dolomites. They immediately overlie the Pine Point limestones.

Kindle[1] has recently discussed the significance of *S. burtini* and the associated fauna in Devonian correlation. It has been shown to occur throughout most of the length of the Mackenzie basin. This important guide fossil of the Middle Devonian is widely known in Europe, but curiously enough has never been found south of Canada. The *S. burtini* fauna of the Mackenzie Middle Devonian is thus closely related faunally to the Middle Devonian of Europe and the British Isles and rather sharply contrasted with the faunas of the same general horizon in the United States.

The Upper Devonian fauna of this section is on the other hand most closely related to the Upper Devonian of the United States as the list of fossils in a later paragraph shows.

The third group, collected from Sulphur point, contains only a few fossils and these are poorly preserved. Species identified included:

Cyathophyllum richardsoni	*Reticularia* sp.
Martinia sp.	

On the north shore of the lake similar limestones are exposed about Slave point and are to be found overlying Presqu'ile dolomites in the hills north of Sulphur bay. From this last locality the following fossils were collected:

Atrypa reticularis	*Cyrtina hamiltonensis*
Atrypa spinosa	*Schizophoria striatula*
Rhynchonella cuboides	*Murchisonia* sp.

[1] "The Distribution of *Stringocephalus burtini* in Canada," Trans. Roy. Soc. Can., vol. 15, 3d ser., 1921, pp. 21-24.

This is the most representative collection from these beds and the presence of *C. hamiltonensis* indicates that these beds are probably equivalent to the Manitoba formation of the Manitoba section. The beds containing this fauna have been named the Slave Point formation.

Upper Devonian. Upper Devonian sediments are exposed in the valley of Hay river and on Peace river at Vermilion chutes. Fossils collected represent the same general fauna which is listed below:

Phillipsastrea hennahi	*Schizophoria striatula*
Heliophyllum parvulum	*Cyrtina hamiltonensis*
Cladopora sp.	*Cranæna* cf. *iowensis*
Stromatopora sp.	*Spirifer whitneyi*
Hederella canadensis	*Spirifer* cf. *subattenuatus*
Spirorbis omphaloides	*Atrypa reticularis*
Productella sp.	*Atrypa spinosa*
Stropheodonta sp.	*Paracyclas* sp.
Camarotoechia sp.	*Bellerophon* sp.

This fauna correlates with the upper part of the Iowa Devonian and with the Chemung of New York.

Thickness of the Section. With the exception of the section exposed on Hay river no exposures of the sediments show a complete section through even one formation. Hay river gives a fairly complete and measurable section through the Upper Devonian, at least to the bottom of the Hay River shales, and shows a total thickness of about 700 feet. No exposures of Simpson shales occur in the map-area but they are assumed to underlie the Hay River shales. An estimate based on Kindle's report of the sections exposed at Simpson[1] would indicate 250 feet as a maximum thickness for these beds. The Slave Point limestones are exposed only locally and their thickness can at present only be assumed. About 200 feet of recrystallized dolomites of the Presqu'ile formation are exposed above water-level at Nintsi point. The remainder of this formation and the thickness of the underlying formations down to the Precambrian are shown in the log of the Imperial Oil Company's oil well drilled at Nintsi point during the summers of 1920 and 1921, given on page 16.

[1] Kindle, E. M., Geol. Surv., Can., Sum. Rept., 1920, pt. B.

Well Log

—	—	—	Thickness	Depth
			Feet	Feet
Middle Devonian	Presqu'ile dolomites	Sand and broken rock	6	0– 6
		Light grey dolomite	15	6– 21
		Dark brown dolomitic limestone	15	21– 36
		Light brown dolomitic limestone	50	36– 86
		Soft, grey, shaly limestone	15	86– 101
		Mottled, partly recrystallized dolomitic limestone	25	101– 126
		Soft, grey, shaly limestone	5	126– 131
		Mottled, partly recrystallized dolomitic limestone	25	131– 156
		Soft, grey, shaly limestone	5	156– 161
		Mottled, partly recrystallized dolomitic limestone	14	161– 175
	Pine Point limestones	Grey, shaly limestone	165	175– 340
		Hrad grey limestone	157	340– 497
		Brown, shaly limestone	33	497– 530
		Hard, black limestone	20	530– 550
		Brown, shaly limestone	30	550– 580
		Hard, grey limestone	20	580– 600
		Dark grey limestone	30	600– 630
		Grey, shaly limestone	50	630– 680
		Dark grey limestone	50	680– 730
		Light grey, shaly limestone	40	730– 770
Silurian	Fitzgerald dolomites	Light brown dolomitic limestone	20	770– 790
		Grey dolomitic limestone with gypsum	110	790– 900
		Gypsum	10	900– 910
		Grey dolomitic limestone with gypsum	70	910– 980
		Gypsum and anhydrite	65	960–1,045
	Red beds	Red shale with gypsum and salt	25	1,045–1,070
		Reddish stained salt	20	1,070–1,090
		Salt	30	1,090–1,120
		Red shale with salt and gypsum	20	1,120–1,140
		Gypsum	40	1,140–1,180
		Dark shale with gypsum and salt	20	1,180–1,200
		Salt	20	1,200–1,220
		Red shale with gypsum	40	1,220–1,260
		Red shale with gypsum and salt	120	1,260–1,380
		Reddish stained salt	10	1,380–1,390
		Gypsum and anhydrite	10	1,390–1,400
		Red shale with gypsum and salt	240	1,400–1,640
Precambrian		Red sandstone	20	1,640–1,660
		Brownish red sandstone	90	1,660–1,750
		Granite	56	1,750–1,806

The well was started in Presqu'ile dolomites at an elevation of about 15 feet above lake-level.

DESCRIPTION OF FORMATIONS

Precambrian

Rocks of Precambrian age are exposed on the northeastern shores of Great Slave lake and the islands lying to the south of them. Where examined, they were found to be granites and gneisses overlain by greenstone schists and metamorphics. On some of the îles du Large, coarse, white quartzites are abundant and occasional deposits of ferruginous limestones and some siderite were noted.

Robert Bell[1] reported sediments of probably Animikie or Lower Cambrian age on the eastern arm of the lake, but none were seen by the present writer.

Silurian Sediments

Slave river marks approximately the western boundary of the Precambrian shield and exposes at several places the contact between the Precambrian and the Palæozoic. The Precambrian floor is gently undulating and the Palæozoic sediments follow the undulations. The thicker sections expose gypsum beds under limestones and dolomites which carry a Middle Devonian fauna. The gypsum beds—best exposed on Peace river near Little rapids and in the escarpment at the salt springs west of Fort Smith—are interbedded with shaly limestones carrying Upper Silurian fossils.

In all the exposures on Peace and Slave rivers, Middle or Upper Devonian sediments immediately overlie the Gypsum series of Upper Silurian age and Kindle has proved that at Little rapids an erosional unconformity exists between these two series.

The following notes have been compiled from Camsell's report[2] upon the sections exposed on Peace and Slave rivers:

"The section exposed on Peace river shows as follows:

	Feet
Boulder clay and gravels of glacial origin..	5 to 20
Limestone—argillaceous and sometimes sandy—fossils.	
Dolomites, fractured and broken..	10 to 30
Gypsum beds..	up to 50

The section is exposed on the banks of Peace river for about 18 miles in cliffs which rise 20 to 60 feet above the level of the river. The fossils from the limestones yielded the following species:

Spirorbis sp.
Atrypa reticularis
Schizophoria striatula
Cyrtinia curvilineata

These indicate an horizon of Middle Devonian age."

Kindle, working on the section in 1917, found a well-developed fauna of Silurian age in the Gypsum series and has proved that an erosional unconformity exists between these beds and the limestone series from which Camsell obtained his fossils. Kindle reports shaly members carrying fossils equivalent to the Ithaca phase of the Portage of New York lying "in situ" in erosional and solution cavities in the Gypsum series, and suggests that during Lower Devonian times land areas existed here which were subjected to erosion, and large sink-holes were formed in the Silurian sediments similar to those now found in the Palæozoic series near the salt springs west of Fort Smith.

On the west bank of Slave river opposite La Butte, Camsell obtained two sections. The northern one shows 10 feet of gypsum, thin-bedded and impure, overlain by 20 feet of a fractured and broken limestone similar to that on Peace river.

The other section shows as follows:

	Feet
Massive limestone—fossils..	5
Pebbly limestone..	10
Brecciated limestone, bituminous..	6
Grey limestone, thin-bedded..	10

[1] "Mackenzie District," Geol. Surv., Can., Sum. Rept., pt. H, Ann. Rept., new ser., vol. XII, 1899, p. 103 A.

[2] Camsell, C, "Salt and Gypsum Deposits in the District between Peace and Slave Rivers, Northern Alberta," Geol. Surv., Can., Sum. Rept., 1916.

The beds undulate with dips up to 15 degrees and this, together with the fact that one of the beds has been fractured and brecciated, suggests the presence of a bed of gypsum beneath. Precambrian granites are exposed to the southeast within a few hundred yards.

The fossils collected from the upper bed of this section yielded the following species:

Atrypa reticularis
Martinia sublineata
Orthoceras—2 sp.

These indicate a Middle Devonian age, but the presence of gypsum in the northern section and the evidence suggesting its presence in the other imply that parts of the section at least are of Silurian age.

A number of good exposures occur on the banks of Slave river between Stoney and Caribou islands, 12 to 20 miles above Fitzgerald, and most of these sections show the contact betwen the Precambrian and the Palæozoic.

The Stoney Island section shows the following series:

	Feet
Limetone, light-coloured, massive, grading down into a dark grey, dolomitic limestone..	6+
Sandstones and conglomerates, arkose, granite. Coarse-grained, porphyritic..	8

The upper limestone contains a seam—one-half inch thick—of black, bituminous shale.

The Caribou Island section shows at the base a siliceous hornblende granite, jointed, fractured, and decomposed. Over this is an arkose about 10 feet thick of angular granite fragments becoming finer-grained at the top and passing gradually upwards into a dark grey dolomitic limestone which is exposed only beneath the drift for a thickness of 6 feet.

Camsell obtained no fossils from these sections, but Kindle found a Silurian fauna in both the Caribou and Stoney Island sections and refers the dolomitic limestones of both sections to a late Silurian horizon (verbal statement).

The escarpment at the salt plains on Salt river west of Fort Smith is from 150 to 200 feet high, but shows no complete section anywhere through its length. From fragmentary sections it is evident that the lower part of the escarpment is occupied by gypsum, whereas the top consists of a bed of dark grey, dolomitic limestone in which no fossils were noted. Both the gypsum beds and the dolomitic limestones are believed to be of Silurian age and to correspond in horizon to the gypsum cliffs at Peace point.

The Salt River escarpment extends northward down the west side of Little Buffalo river for a distance of about 35 miles and then appears to swing westward towards Buffalo river. Along Little Buffalo river it varies in elevation from 50 to 150 feet above the valley. Light to dark grey dolomitic limestones overlie the gypsum series. No fossils were collected from the gypsum beds, but the limestones yielded a fauna indicating a Middle Devonian horizon.

Below Fort Smith Palæozoic rocks are exposed at two points, but the outcrops are small. At Bell rock, a square, massive-looking cliff 7 miles below Fort Smith, a yellowish, brecciated dolomitic limestone is underlain by gypsum. A second exposure—on the point on the east side of the river just below pointe Ennuyeuse—shows 4 feet of thin-bedded, impure, grey gypsum underlying a fossiliferous, grey, shaly limestone, from which the following fossils, indicating a Middle Devonian horizon, were collected.

Favosites cf. *hamiltonæ*
Atrypa spinosa
Martinia cf. *meristoides*
Martinia cf. *sublineata*

The occurrence of gypsum indicates that Silurian sediments immediately underlie the Middle Devonian.

Near Gypsum point on Great Slave lake, most of the outcrops are poor, though, at the point itself, a cliff about 20 feet high gave one section. On the south shore of the first point west of Gypsum point, angular blocks of dolomitic limestone 4 feet to 8 feet square are strewn along the beach, and though not actually in place can have come only from the immediate vicinity. The limestones, which are dark grey, very porous, and weather easily, are medium to fine-grained and highly fossiliferous, but the fossils are poorly preserved. The presence of *Pycnostylus guelphensis* places these limestones in the Upper Silurian, and suggests the correlation with the dolomite gypsum series, outcropping west of Fitzgerald.

At Gypsum point the following section was obtained:

	Feet
Thin-bedded, badly fractured, fine-grained, soft limestone quite arenaceous and brick red in colour. It is quite porous, contains no fossils, but has vugs filled with soft crystal faunules and weathers to a pebbly material..	4
Bed of a brick red gypsum with some sandy, brick red shales interbedded..	1½
Fissile, sandy shales, brick red in colour, and thin stringers of more or less pure gypsum. Shaly material shows ripple-marks, mud-cracks, and rain-pitting..	2
Massive, bedded, brick red, fine-grained sandstone, hard, and flaggy, containing angular clear quartz fragments. Bottom not exposed..	10

The lake beaches in the vicinity of the point and along the west shore of the north arm of the lake show the characteristic red colour of these beds.

The contact between these beds and the overlying grey dolomite limestone series mentioned above is not exposed on the lake shore. The log of the Imperial Oil Company's oil well at Nintsi point, previously given, shows a thickness of 275 feet of dolomitic limestones interbedded with gypsum and anhydrite, lying between the lower shaly limestones of the Pine Point formation and the Red beds.

In view of Kindle's determination of the Silurian age of the Gypsum series at Little rapids on Peace river and in the exposed sections along Slave river above Fitzgerald, and the apparent continuity of this series northward it is assumed in this report that gypsum horizons elsewhere noted indicate Silurian sediments, and they have been so mapped.

Middle Devonian

Middle Devonian sediments found in the area under discussion have been subdivided on lithological and palæontological evidence into three formations: in descending order, the Slave Point limestones, Presqu'ile dolomites, and Pine Point limestones. The palæontological evidence, as already shown, tends to correlate these respectively with the Manitoba limestones, Winnipegosan dolomites, and Elm Point limestones of the Manitoba section of Tyrrell and Kindle.[1]

Pine Point Limestones. Sediments of this formation outcrop in the neighbourhood of Resolution and Pine point on the south shore and on the north shore to the north and west of Kolon island and probably as far west as House point.

Near Resolution and on Mission island the sediments are thin-bedded, grey limestones, medium to fine-textured. In some beds the light grey, fine-

[1] Kindle, E. M., "The Silurian and Devonian Section of Manitoba," Geol. Surv., Can., Sum. Rept., 1912, p. 248.

textured limestone is mottled with blotches of a darker grey, coarser-grained material. Some beds are very fine-grained, darker, and slightly bituminous. Small fissures and veinlets of pure white calcite are numerous. Fossils collected from this locality in 1920 yielded the following fauna:

Atrypa reticularis, var. *a*
Atrypa spinosa
Martinia sublineata
Cyrtina sp.
Productella spinulicosta
Paracyclas cf. *elliptica*
Pleurotomaria sp.
Euomphalus sp.
Proetus cf. *mundulus*

The abundance of *A. reticularis* var. *a* is conspicuous and the horizon may be conveniently termed the *Atrypa reticularis* zone.

In the vicinity of Pine point, thin-bedded bituminous limestones, grey to black in colour and in places very shaly, outcrop on a slight anticlinal structure. These beds though lithologically dissimilar belong on palæontological evidence to the same series as the soft grey limestones at Resolution, though somewhat higher in the series. Reference has already been made to the fossil collections made at this point in 1916. A further collection made in 1920 yielded:

Atrypa reticularis, var. *a*
Atrypa spinosa
Productella spinulicosta
Chonetes sp.
Liorhynchus sp.
Martinia richardsoni
Martinia sublineata
Stropheodonta sp.
Orthoceras sp.
Proetus cf. *mundulus*

An abundance of *Martinia richardsoni* is characteristic of this horizon and it may be conveniently called the *Martinia richardsoni* zone of the Pine Point formation.

The beds are mostly thin-bedded limestones, in some cases black and made up almost entirely of small brachiopods *(M. richardsoni and M. sublineata)*, and in others grey to blue-black in colour, containing numerous nodules which weather out characteristically, giving an uneven surface to the beds.

Near the crest of the hills south of Pine point and underlying massive dolomitic limestones carrying *Stringocephalus burtini* occur thin-bedded, shaly grey limestones carrying *Martinia richardsoni*, *Proetus* cf. *mundulus*, and other Pine Point fossils. These beds are assumed to represent the top of the Pine Point formation.

No exposures showing a measureable thickness of the Pine Point formation were seen either at Resolution or about Pine point. The estimated thickness given in the table of formations is based, therefore, on the log of the Nintsi (Windy) Point well.

In the valley of Little Buffalo river exposures north of the gypsum escarpment are few. At one point about 28 to 30 miles above the mouth, and just at the junction of Log-jam creek, the river cuts down into a highly fossiliferous limestone bed. The limestones are light grey in colour, thin bedded and interbedded with limy grey shale. Fossils collected included:

Favosites cf. *hamiltonæ*
Atrypa reticularis, var. *a*
Atrypa spinosa
Martinia sublineata
Paracyclas cf. *elliptica*
Pleurotomaria sp.
Euomphalus sp.
Proetus cf. *mundulus*

This horizon is undoubtedly referable to the *Atrypa reticularis* zone of the Pine Point formation.

Limestones directly overlying gypsum beds on Gypsum creek, tributary to Little Buffalo river 30 miles north of the portage between Salt river and Little Buffalo river, yielded the following fauna:

Favosites cf. *hamiltonæ*
Cyrtina sp.
Productella sp.
Paracyclas sp.
Euomphalus sp.
Pleurotomaria sp.

This horizon also shows affiliations with the Pine Point formation.

On the north shore of the lake on a projection between Jones and House points, a low, wave-cut cliff situated about 75 feet above lake-level exposed the following section:

	Feet
Thin-bedded, light grey shaly limestones carrying between the bedding planes a fissile shale. Limestones are fine-grained, even textured, and weather to semi-round fragments.. ..	12
Blue-grey weathering limestones, thin-bedded and argillaceous. Some beds hard and flaggy and characterized by worm tracks, mud-cracks, and an abundance of crinoid fragments	4
Bottom not exposed.	

This section is closely comparable with some of the beds forming the top of the Pine Point formation exposed in the high land south of Pine point on the south shore.

Along House point and in the bay to the north no outcrops occur on the shores, but the lake beaches, in places forming distinct barrier beaches, show angular fragments of limestone very similar to that seen in the above section.

In the low hills to the west of Moraine point a steep escarpment facing east exposes thin-bedded shaly limestones interbedded with fissile shaly layers. The limestones are light grey in colour and weather to nodular and semi-round fragments. They appear to be the same as those exposed near House point.

No fossils were obtained from any of these exposures and correlation with exposures on the south shore is of necessity based upon lithological similarity.

On the mainland north of Kolon island and about House point occur a few outcrops of a thin-bedded, dark brown limestone. About one-quarter of a mile inland from the lake shore a low, wave-cut cliff 30 feet above water-level exposes the following section:

	Feet
Irregularly jointed, thin-bedded, grey limestone..	3
Even-bedded, fine-grained, hard, grey limestone..	3
Fossiliferous, irregularly jointed limestone interbedded with grey, shaly layers..	3½
Even-bedded, more massive, fine-grained light grey limestone..	2
Bottom not exposed.	

Fossils collected from this exposure yielded:

Martinia sublineata
Martinia richardsoni
Paracyclas lirata

They suggest correlation with the Pine Point formation of the south shore section.

Presqu'ile Dolomites. The Presqu'ile formation consists of hard, fine-grained bituminous dolomites and dolomitic limestones interbedded with softer, thin-bedded, grey limestones. Some beds are completely recrystallized dolomites. They are exposed capping the escarpment south of Pine point and about Presqu'ile point on the south shore, and abundantly about Nintsi

(Windy) point and in the hills north of Sulphur bay on the north shore. In most exposures they are characterized by the presence of *Stringocephalus burtini* and may be conveniently termed the *S. burtini* zone.

The beds capping the escarpment south of Pine point are light brown, coarse-grained dolomitic limestones. They weather to a sandy-looking surface. Fossils collected included:

Favosites limitaris
Cyathophyllum sp.
Atrypa reticularis
Martinia sp.
Stringocephalus burtini

Farther south in the vicinity of the lead-zinc deposits the country rock is a coarsely crystalline, cavernous, and massive-bedded, white dolomite. The cavities are frequently lined with characteristic curved rhombohedral crystals of dolomite. Bitumen is entirely absent and no fossils were observed. Large sink-holes are numerous and expose a few feet of section in most cases. On lithological grounds these beds may be correlated with similar dolomites exposed about Nintsi point and there shown to be of the Presqu'ile formation.

On the middle islands of the Burnt Island group east of Pine point there are outcrops of a dolomitic limestone similar to those found about Presqu'ile point and carrying the following fauna:

Favosites limitaris
Cyathophyllum sp.
Atrypa reticularis
Atrypa spinosa
Martinia sp.
Stringocephalus burtini

The dolomitic limestones which outcrop just at water level about Presqu'ile point expose no great thickness of section. They are grey to white weathering porous dolomitic limestones. On fresh fracture they show a dark to grey-black colour and have considerable bitumen in the cavities. They are characterized by an abundance of fossils and are the type locality for the Presqu'ile series. The fossil collection made in 1916 has already been given. A further collection made in 1920 yielded the following species:

Aulopora sp.
Cyathophyllum cf. *cæspitosum*
Cyathophyllum sp.
Favosites limitaris
Cladopora sp.
Actinostroma cf. *nodulatum* Nicholson
Stromatopora sp.
Atrypa reticularis
Atrypa spinosa
Chonetes sp.
Gypidula cf. *comis*
Spirifer sp.
Stringocephalus burtini

On the north shore of the lake at Brûlé point a low, wave-cut cliff exposes the following section:

	Feet
Thin band of wormy-looking, somewhat bituminous limestone.	½
White weathering, almost white, compact dolomitic limestone, composed largely of stromatoporoids..	5½
Light cream weathering limestone composed largely of fossils embedded in a soft grey limestone..	4
Massive-bedded, grey weathering, light grey, soft limestone.. ..	3
Thin-bedded, compact, hard, fine-grained dolomitic limestone, red brown to grey in colour, somewhat bituminous..	2
Bottom not exposed.	

Fossils collected from the above section included:

Cyathophyllum sp.
Favosites limitaris
Cladopora sp.
Actinostroma cf. *nodulatum* Nicholson
Atrypa reticularis
Martinia cf. *meristoides*
Pleurotomaria sp.
Callonema sp.

Mr. Kindle has stated that the presence of *Actinostroma* cf. *nodulatum* suggests the correlation of these beds with the Presqu'ile dolomites exposed on the south shore at Presqu'ile point. The discovery of *Stringocephalus burtini* or some other diagnostic fossils is needed, however, to strengthen the present available evidence of the correlation.

Similar beds are exposed all along the shores of Nintsi point and abandoned lake beaches of angular fragments of the limestones are found inland for some distance, many of them at elevations up to 150 feet above the present lake level. A low barrier beach of limestone shingle extends around the east shore of Nintsi point, enclosing a shallow, partly filled lagoon.

Where exposed near Nintsi point and Sulphur bay they are massive-bedded, generally coarsely crystalline, porous, and cavernous dolomites. The weathered surface is white to light grey and, the rock being hard and resistant to erosion, glacial action has well scoured the surface, leaving but little detrital covering. Well-developed glacial gouging and striæ indicate a general movement of the ice in a direction south 60 degrees west magnetic or north 85 degrees west astronomical. Fresh fractures frequently show a mottling of fine-grained, dark brown, bituminous, dolomitic limestone against a background of white, coarse-grained, partly crystalline dolomite. Large caverns and pores are numerous and are frequently lined with dolomite crystals and filled with semi-liquid bituminous matter.

The rocks are badly fractured in two general directions, north 75 degrees east and north 25 degrees east magnetic. The fissures are sometimes filled with a pure, clear, crystalline calcite, but more frequently are open and from them and from between the bedding planes of the dolomites issues a heavy petroleum which collects into oil and tar pools. Strong flowing, cold water sulphur springs frequently accompany the tar seepages, leaving deposits of sulphur and sulphur salts and occasionally carbonaceous salts of lime and magnesia.

Slave Point Limestones. Sediments of the Slave Point series outcrop on the south shore at Sulphur point and on Buffalo river near Mellor rapids. On the north shore they show on Slave point and on the tops of the hills north of Sulphur bay.

Buffalo river near Mellor rapids has cut through the overlying glacial drift and exposed low ramparts of grey weathering, light grey, fine-grained, and thin-bedded limestones that are slightly bituminous and carry numerous but poorly preserved fossils. Exposed surfaces of the beds are rough weathering and nodular owing to the more resistant qualities of the fossil material. Some beds show as distinctly bituminous lime shales weathering to light colours.

East of Sulphur point a low, wave-cut cliff exposes the following section:

	Feet
Old lake beach of angular fragments of white weathering limestone..	3
Grey-weathering, thin-bedded limestones and limy shales. Light grey, medium-grained, and hard. Shaly bands, weather pebbly and are argillaceous. Little or no bitumen..	4¾
Grey weathering, fine-grained, slightly more massive-bedded, light grey limestone. Contains some fossils and is slightly bituminous. Carries one thin band of fissile dark shale about the centre of section..	2
Highly fossiliferous, porous, bituminous limestone, dark grey to brown in colour, medium-grained and hard..	1½
Smooth-weathering, blue-grey to grey shales. Bituminous, and somewhat fossiliferous. Is quite limy and grades to thin-bedded limestones below water-level..	½

No outcrops of sediments were noted between Sulphur point and High point, but the lake beaches are composed largely of small, angular fragments of slightly bituminous limestone similar to those found on Sulphur point and up Buffalo river. Strong-flowing, cold water sulphur springs occur on Sulphur point, on the shore east of High point, and in the banks of Buffalo river near the limestone outcrops.

On the north shore of Slave point thin-bedded, grey, fine to medium-grained limestones outcrop just at water-level but expose no thickness of strata. Weathered surfaces of the beds show a rough nodular appearance due to weathering out of the fossils.

On the crest of the hills lying to the north of Sulphur bay and overlying partly recrystallized dolomites a thin band of shaly limestones supplied the following fossils:

Atrypa reticularis
Atrypa spinosa
Rhynchonella cuboides
Cyrtina hamiltonensis
Schizophoria striatula
Murchisonia sp.

This is the most representative collection from the Slave Point series and the presence of *Cyrtina hamiltonensis* indicates that these sediments are probably equivalent to the Manitoba formation of the Manitoba section.

The limestones are exposed only as a capping and are mostly on the west slopes of the hills slightly below the crest, where they have been protected from glacial erosion by the more resistant qualities of the underlying dolomites. Dips as high as 12 degrees have been noticed in these beds, but they are believed to be only local and the average inclination probably does not exceed 40 feet to the mile.

Upper Devonian

Sediments of Upper Devonian age have been subdivided on lithological and palæontological evidence into the following formations, in descending order: Hay River limestones, Hay River shales, Simpson shales. On palæontological evidence Hay River limestones and shales appear to be equivalent to the Chemung formation, and Simpson shales to the Portage formation, of the New York section.

Simpson Shales. These shales, lying between the Hay River shales above and the Slave Point limestones below do not outcrop in the area under consideration. They are exposed, however, in the Mackenzie valley near Simpson and are considered to lie directly and conformably below the Hay River shales. They carry fossils analogous to those found in the Portage formation of New York.

The shores of Great Slave lake west of a line drawn from High point to Slave point are characterized by low, sandy or muddy, marshy flats and appear to have been gouged out of the soft Simpson and Hay River shales by glacial action. It is assumed that most of this part of the lake is underlain by these Simpson shales and it has been mapped accordingly, the boundaries being approximate. The major portion of Buffalo River valley must also lie in these shales, but no outcrop of any sediments overlying the limestones near Mellor rapid was noted, the neighbourhood being heavily mantled with glacial drift.

E. M. Kindle[1] gives the following description of the Simpson shales near Simpson.

"On the northeastern bank of the Mackenzie river opposite Simpson, greenish grey clay shale outcrops in horizontal beds exposing a thickness of about 140 feet. This shale is without limestone bands and is almost or quite free from thin sandstone bands. It weathers to small flakes of fissile shale. Excellent exposures of this shale occur on both sides of the Mackenzie about 20 miles above Simpson. Along this portion of the river the banks expose a section from 50 to 150 feet thick. Fossils are scarce except in certain narrow bands of the shale which are not likely to be located without considerable searching. In the east bank of the river, about 5 miles above Rabbitskin river, fossils were found in a section exposing about 65 feet of greenish to bluish grey shales. These include the following species:

Cyrtina sp.
Buchiola retriostriata
Paracardium doris?
Entomis serratostriata
Entomis variostriata

This is a Portage fauna and indicates that the beds which it characterizes should be correlated with the Portage of New York.

"Neither the top nor the bottom of this formation has been observed, but the beds which immediately follow are well exposed in the Hay River section and carry the *Spirifer disjunctus* fauna. The latest beds preceding it which have been observed in the Great Slave Lake section are those outcropping at Sulphur point."

Hay River Series. Hay river, from near Grumbler rapids to its delta, has cut through a thick deposit of Upper Devonian sediments which on palæontological evidence may be correlated with the Chemung formation of New York state. Lithologically, the series may be divided into two members, the upper one being largely limestone strata and the lower one mainly made up of shale beds. Actually the two members grade into one another, the limestones at their base being interbedded with shaly layers and the shales showing frequent limy strata in their upper parts. For the purposes of this report the line of separation has been drawn at the base of the massive-bedded limestone member which causes Louise fall on Hay river. The upper member is called the Hay River limestones, and the beds below, the Hay River shales. The predominant weathering colour of the limestones is a light cream to buff; that of the shales is a dull blue grey.

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[1] Kindle, E. M., "The Discovery of a Portage Fauna in the Mackenzie River Valley," Geol. Surv., Can., Mus. Bull. 29.

Hay River Shales. The following section of the shales has been compiled from several sections taken at intervals along the valley of Hay river below Louise falls:

	Feet
Bluish green, soft, fissile shales weathering to a grey, soft clay containing thin layers of highly fossiliferous limestone.. ..	42
Thin-bedded, light grey weathering, grey, soft limestones, shaly layers between beds. Limestone composed largely of fossils.	20
Blue green, soft shales, weathering to clay..	15
Flaggy sandstone, with shaly partings. Sandstones show ripple-marks, crossbedding, and worm trails. Light yellow in colour..	14
Fossiliferous, soft, grey, thin-bedded limestone..	8
Blue grey, soft shales weathering to clay..	28
Thin-bedded, fossiliferous, grey, argillaceous limestone. Thin beds of shaly material between limestone beds..	8
Blue green, soft, clay weathering shales, carrying thin limestone bands which are highly fossiliferous..	105
Thin-bedded, soft, greyish limestones carrying numerous fossils	8
Blue green, soft shales weathering to grey calcareous clays.. ..	10
Soft, shaly, rough weathering sandstone, argillaceous, and shows ripple-marks and worm trails..	12
Blue green, soft clay weathering shales with thin bands of limestone carrying numerous fossils..	90 (aneroid)
Thin-bedded, grey, shaly, argillaceous limestone, soft and no fossils..	25
Blue-green, soft clay weathering, calcareous shales..	15+
Bottom not exposed.	

Hay river has cut a deep gorge-like valley through these shales for 45 miles from Louise fall to within a few miles of Great Slave lake. The shales being soft and easily weathered, the cut banks show steep talus slopes of soft, very plastic, grey, calcareous clays through which the more resistant limestone bands project to form limestone bluffs where the beds are of any great thickness. The shales carry no fossils, but the interbedded layers of limestone are highly fossiliferous and the clay talus slopes show abundant well-preserved specimens derived from them.

No other outcrops of the shales were seen, but on stratigraphic grounds it is assumed that similar sediments underlie the basin of Buffalo lake and parts of Mackenzie and Kakisa valleys. On Kakisa river at Lady Evelyn fall thin-bedded, light-coloured limestones can be correlated with the lower beds of the Hay River limestones that directly overlie the shales in the gorge below Louise fall on Hay river. It is probable, therefore, that Kakisa valley below the falls is underlain by shales that have been eroded by glacial action and are now covered by drift.

The massive-bedded Hay River limestones are not exposed on Buffalo river or about Buffalo lake, but probably occur from the base of Caribou Mountain plateau southward and it is, therefore, likely that shales now covered by glacial drift underlie Buffalo lake and probably the upper part of Buffalo valley.

Hay River Limestone. Limestones of the Hay River series are exposed in Hay valley for about 40 miles from near Grumbler rapids to the gorge below Alexandra and Louise falls. Limestones representing the same formation and containing a fauna similar to that of the Hay River series are also exposed on Peace river at Vermilion rapids.

At the gorge on Hay river the following section is exposed:

	Feet
Massive, arenaceous, yellow to cream weathering, dark grey limestone..	30
Thick and thin-bedded, light yellow to buff weathering, light grey, fine-grained limestone with shaly layers between beds.	62
Massive, light-coloured limestone containing numerous corals and some bitumen..	16
Reddish brown, medium-grained, light weathering, thin-bedded limestones..	12
Soft, thin-bedded, shaly, grey limestones and blue grey shales..	5
Reddish brown, soft sandstone, calcareous and ripple-marked..	7
Soft, blue grey, fissile shales, arenaceous at top, but generally very argillaceous giving clay talus slopes..	47
Red brown, thin-bedded limestone..	8
Thin-bedded, soft limestones and calcareous shales with limestone nodules, grey colours, and rough pebbly weathering..	12
Thin-bedded, yellowish to cream weathering, red brown to grey, soft limestones..	21
Bluish grey Hay River shales below.	

Between Grumbler rapids and Alexandra fall, limestones outcrop frequently in the valley, forming low ramparts and rapids but giving no continuous section of any thickness. The limestones are mostly light grey, thin-bedded, and frequently have shaly partings. Some beds, distinctly purplish or flesh-coloured, are mostly more compact and show no shaly partings. The uppermost beds, exposed just above Grumbler rapids, are grey-weathering, thin-bedded, shaly limestones consisting of limestone nodules embedded in soft calcareous clay shales. These nodules—principally fossil coral—weather out, giving a conglomeratic appearance to the outcrops. The thickness of the limestones between the upper beds of the section at the gorge and the outcrops of Grumbler rapids, estimated from the fall of the river between these two points and the observed general dip of the beds, is about 100 feet.

Limestones, lithologically similar to those at the bottom of the section in the gorge at Hay river, outcrop in the valley of Kakisa river causing a fall of 48 feet. They show here the following section:

	Feet
Grey to white-weathering, soft, thin-bedded, limestones with layers of soft, grey, calcareous shales between beds. Weathers to a rough nodular or pebbly appearance..	15
Blue grey, soft, fissile shales..	4
Thin-bedded, grey to brown, medium-grained limestones with shaly partings..	22
Interbedded, grey, soft, thin-bedded limestones and blue grey, fissile, calcareous shales..	26

The upper three members of this section seem to correspond to the bottom members of the Hay River section of the limestone, and the lowest member probably represents the gradation into the underlying Hay River shales.

During the summer of 1920 the Provincial Government of the province of Alberta drilled a well for salt at McMurray, Alberta. Professor J. A. Allan, of the University of Alberta, who was the geologist in charge of these operations,[1] gives the following section encountered in drilling.

[1] Allan, J. A., Second Annual Report of the Mineral Resources of Alberta, 1920, p. 104.

Core Record of Salt Well No. 1

McMurray, Alberta

Strata	Thickness	Depth
Soil	15	0– 15
Quicksand	3	15– 18
Blue alluvial mud	24	18– 42
White sand and boulders	18	42– 60
Shaly limestone, crevices filled with sand and boulders	35	60– 95
Grey, fossiliferous limestone	12	95–107
Shale and limestone interbedded	5	107–112
Massive and shaly limestone interbedded	32	112–144
Calcareous shale and shaly limestone	7	144–151
Shaly, fossiliferous limestone	9	151–160
Shaly limestone	19	160–179
Calcareous shale including 7 feet soapy shale near top	44	179–223
Mottled limestone	13	223–236
Massive, fossiliferous limestone	54	236–290
Fragile shale	5	290–295
Fossiliferous limestone	18	295–313
Soft blue and grey shale	51	313–364
Mottled limestone	3	364–367
Calcareous shale with 3 feet talcose shale on top	17	367–384
Dark grey limestone	28	384–412
Talcose shale	6	412–418
Grey limestone	12	418–430
Soft shale	7	430–437
Fossiliferous limestone	3	437–440
Green shale	17—	440–457
Grey, calcareous shale	33	457–490
Grey, massive limestone	10	490–500
Hard anhydrite and gypsum	14	500–514
Limestone	2	514–516
Shale and gypsum	21	516–537
Blue shale	8	537–545
Gypsum and shale	9	545–554
Green and brown shale	8	554–562
White and bluish anhydrite, gypsum near top	55	562–617
Anhydrite and gypsum	14	617–631
Rock salt and saline mud	10	631–641
Salt and anhydrite	7	641–648
Transparent rock salt	14	648-662
Anhydrite, gypsum, and salt	12	662–674
Limestone and rock salt	5	674–679
Compact hard anhydrite	6½	679–685½

Allan[1] gives a report on the fossils obtained from the upper 500 feet of this core by Mr. P. S. Warren, of the University of Alberta.

Mr. Warren's lists show one general fauna, including:

Bryozoa sp.
Spirorbis omphaloides
Crinoid stems
Schizophoria striatula
Atrypa reticularis
Atrypa spinosa
Productella sp.
Spirifer sp.
Eatonia variabilis
Stropheodonta demissa
Cyrtina sp.
Euomphalus sp.
Aviculopecten sp.
Leptodesma sp.
Lingula spatulata

Warren states: "There were no fossils below this point (500 feet).

"It is difficult to determine the age of this fauna on account of the species being new and the lack of good horizon markers. I would place it in the Upper Devonian for the following reasons:

"(1) The presence of *Lingula spatulata.*

[1] Allan, J. A., ibid, p. 113.

"(2) The resemblance of this fauna to that obtained in the Upper Devonian as developed on Hay river, some of the fossiliferous bands being almost identical."

Warren also notes "the entire absence of the typical Middle Devonian fauna as developed on Great Slave lake."

Cretaceous

It is probable that Cretaceous sediments underlie most of the southern section of the area under discussion, but the known exposures are confined to the valleys of Peace and Hay rivers.

On Peace river above Vermilion rapids, soft, dark, fissile, marine shales of Cretaceous age outcrop in the banks of the river and represent parts of the Loon River shales of McConnell.[1] These have been well described by McConnell and McLearn[2] and no further mention need be made of them here.

On Hay river from the 6th meridian crossing to within a few miles of the first limestone outcrops near Grumbler rapid, shales, generally analogous to the Loon River series of McConnell's Peace River section, outcrop in numerous places where the river has cut banks in the valley walls. They are soft, dark, fissile, marine shales carrying numerous large spheroidal concretions and occasional hard, thin, ironstone bands. Selenite crystals are of frequent occurrence on talus slopes of the shale. Above Hay River outpost at the mouth of Meander river the shales are interbedded with thin, soft sandstones that may represent the Peace River sandstones of McConnell's section[3] on Peace river. Overlying the sandstones are soft shales, somewhat darker than the lower series and lacking concretions, which probably represent the basal member of the Fort St. John shales. But no fossil evidence was noted in any of the series and it is best not to attempt their subdivision or correlation, but to classify them as Cretaceous in age and probably for the most part representing the Loon River series of the Peace River valley.

The large area between Hay and Peace rivers, so far as is known, shows no rock outcrops. The plain between Peace river and Caribou mountains and on the west towards Hay river has the general appearance of an old lake basin of probably post-Glacial age. Caribou Mountain plateau and the small plateau of Watt mountains appear, by their elevation and stratigraphical relations, to represent outliers of the Cretaceous rocks of the Upper Peace River section farther southwest and probably contain representatives of the Peace River sandstone, Fort St. John shales, and Dunvegan sandstones of that section, overlain by glacial drift.

Pleistocene and Recent

Almost all the area shows marked effects of Pleistocene glaciation. The eastern part, underlain by Precambrian rocks, has little drift-covering and in many places exhibits unweathered rock surfaces that have been ground down and smoothed by the ice-sheet. The part underlain by limestones and shales is mostly covered by drift deposits such as boulder clays and contains numerous boulders of Precambrian rocks derived from the east. Sand and gravels of fluvioglacial origin occur only in small amounts. The surface of the boulder clay (ground moraine) is somewhat uneven, but is for the most part of low relief. In places, there are low, rounded hills, usually elongated somewhat in

[1] McConnell, R. G., "District of Athabaska," Geol. Surv., Can., Ann. Rept., new ser., vol. V, 1890, pt. D.

[2] McLearn, F. H., "Peace River section," Geol. Surv., Can., Sum. Rept., 1917.

[3] McConnell, R. G., "District of Athabaska," Geol. Surv., Can., Ann. Rept., new ser., vol. V, 1890, pt. D.

the direction of ice movement, irregularly spaced and separated by swampy depressions. The rivers, wherever they cut across these hills, show banks frequently up to 100 feet high on the outside of the curve, and the boulders washed out of the drift collect in the river bed forming typical boulder rapids.

Glacial striæ are frequent and are specially well developed on limestone surfaces exposed by river or wave action. In the Precambrian rocks east of the lake, the striæ have a general trend south 22 degrees west, magnetic, or south 57 degrees west astronomical. On Buffalo river, they point south 16 degrees to 18 degrees west magnetic (south 52 degrees to 54 degrees west astronomical), and on Hay river above the falls south 25 degrees west magnetic (south 61 degrees west astronomical). Near Nintsi point striæ are well shown on the Presqu'ile dolomite and have a direction south 60 degrees west magnetic (north 85 degrees west astronomical). That this direction of ice movement was constant over a considerable part of the north shore is well shown by the character of the shoreline. In the deep bay to the west of Slave point and near the outlet of the lake all the points are approximately parallel to the direction of the striæ. Low boulder points are numerous in this bay and on Big island and have great accumulations of boulders derived from the Precambrian rocks. The same general conditions exist from Nintsi point north to Takgatea point. Unmistakable roches moutonnées are seen at several places, especially in the islands offshore between Resolution and Pine point, and in the Precambrian rocks to the east.

Striæ and the distribution of the drift show that the region was glaciated by an ice-sheet advancing from the Keewatin centre of glaciation and moving in a general west-southwest direction across the region. As the ice approached the upland known as Eagle mountains, west of Hay river, part of the sheet flowed down Mackenzie valley and part through the Buffalo and Hay valleys.

Terminal moraines occur in the Buffalo and Hay valleys and consist of low ranges of irregularly-shaped hills—200 to 300 feet high—that trend at about right angles to the striæ and cause—in the Buffalo valley—a dam behind which the waters from the north slopes of Caribou mountains form Buffalo lake. This moraine extends north to within a short distance of Great Slave lake. Two moraines were noted in the valley of Hay river, one between Watt mountain and Cutknife hills, the other between Caribou mountains and the hills west of Grumbler rapid. The low ridge of glacial drift between Watt and Caribou mountains, which forms the watershed between Peace and Hay rivers, appears to be an interlobate moraine formed between two lobes of the ice-sheet, one of which occupied Hay valley and the other the Peace valley.

During the retreat of the ice-sheet the northward drainage in Hay and Buffalo valleys was ponded between the retreating ice margin and the high land to the south, forming large, glacially-dammed lakes. Wide lacustrine flats, representing former lake bottoms, occur south of Buffalo lake. The wide plain near Vermilion was probably also a lake bottom. On both sides of Great Slave lake abandoned beaches as much as 200 feet above the present lake-level prove the existence of a once much larger lake. It is probable, as pointed out by McConnell,[1] that this lake owed its origin to depression of the land and has been partly drained in post-Glacial time by differential elevation of the land towards the east and northeast. The general direction of ice retreat was eastward, and it is improbable that the outlet of the lake basin down the Mackenzie valley could have been blocked by the ice at a time when the greater part of the basin was unoccupied by the ice-sheet.

[1] Geol. Surv., Can., Ann. Rept., vol. IV, 1888-89, p. 25 D.

Recent Deposits

Alluvial (flood-plain) and delta deposits of Recent age occur in the valleys and at the mouths of most of the rivers. The rivers, though they are generally swift, are always widely meandering and are subject to great fluctuation in volume. Hence they are bordered in many places by alluvial flats or flood-plains underlain by crossbedded sands and silts. The rivers transport large quantities of sediment and at their mouths are forming deltas, the largest of which is at the mouth of Slave river. The sediment-laden waters of this river have gradually extended the delta out into Great Slave lake, filling a former embayment of the lake, and are now depositing their sediments into the west arm of the lake and gradually building land areas in it. This steadily growing delta is composed of crossbedded sands and silts. A fringe of excellent spruce borders the river banks and the interior is reported to be somewhat open prairie country with bluffs and copses of a light growth of spruce and poplar. Smaller deltas occur at the mouths of Hay and Buffalo rivers. The Buffalo delta is developed in an embayment which is cut off from the lake proper by a long series of old lake beaches through which the river has cut a single channel.

About 20 miles below Red river, Peace river on its south shore cuts for 3 miles into a bed of water-laid sand the top of which is mostly about 10 to 50 feet above high water.

Section opposite lower end of Long island:

	Feet	Inches
1. Forest bed and soil	1	
2. Brown sand	6	
3. Forest bed, etc.		6 to 0
4. Grey sand with pebble band in middle	1	
5. Hard sand within limy bands	1	
6. White marl		8 to 0
7. Grey sand with calcined roots	2½	
8. Marly sand		2
9. Grey, even-bedded sand partly covered	30	

No. 7 of above section shows roots that have extended through the marl of No. 6 and been covered by a thick tube of lime in No. 7.

About 125 miles above the mouth of Slave river cut banks of yellow sand 14 feet to 18 feet high are common for long stretches. They terminate abruptly against the ordinary alluvial banks and evidently represent a different and earlier set of deposits that are probably of lacustrine origin. Immediately below "Le Grand Detour" cut banks of this yellowish sand and gravel 40 feet high are exposed.

STRUCTURAL GEOLOGY

Bedrock in the region is gently monoclinal with dips of 1 or 2 degrees to the west or southwest. Except in the vicinity of Little rapids on Peace river where very abrupt anticlinal forms are developed, no dips exceeding 6 degrees were observed. The eastern edge of the area shows the margin of the Precambrian protaxis and the Palæozoic sediments laid down on this floor follow the irregular relief of the protaxis and thicken to the westward as the distance from the Precambrian rocks increases.

The tendency of the Palæozoic sediments to conform to the underlying Precambrian floor is particularly well shown on Slave river a few miles above Fitzgerald, where the stream has cut through a projecting arm of the Precambrian, exposing a gently rolling erosion surface. Coarse-grained, arkose material, derived by weathering of the Precambrian floor, overlies these rocks, and is covered by Silurian or Devonian limestones that gently dip away from the sides of steeply rising knobs of Precambrian rocks, thus conforming to their rolling and irregular surface.

The sedimentary rocks range in age from Upper Silurian to Lower Cretaceous. On Peace river, Kindle finds an erosional unconformity between Upper Silurian and Upper Devonian beds, but on Great Slave lake a thick series of Middle Devonian sediments is found under the Upper Devonian, indicating variations in the extent of the early Palæozoic seas. At no point in the area were distinct Lower Devonian beds found and it is probable that they are not represented.

On Hay river above the falls, and on Peace river above Vermilion chute, Cretaceous shales overlie the Upper Devonian limestones. The contact is not exposed in the area examined, but where seen in the Athabaska valley shows as an erosional unconformity.

Throughout the district, the drift interferes with an accurate study of the structural features. Outcrops are mostly small and far apart, being confined, as already stated, to the valleys and lake shores.

On Hay river above Alexandra falls and on Buffalo river at Mellors rapid the limestones show local anticlinal folding with gentle dips, but the surface is uncovered only in the immediate valley bottom and the superficial extent of the folds was not determinable.

On the shores of Great Slave lake structural features are obscured largely by the limestone gravels formed by ice and wave action on the exposed surfaces of the sediments. Here again local inclinations are often greater than the general dip. They appear to be very local, however, and seldom exceed 6 or 8 degrees from the horizontal. They often show dips in all directions within a radius of a few hundred feet.

The eastern edge of the district lies close to an eastern shore-line of the Palæozoic epicontinental seas. Epirogenic movements were gently oscillatory and the sea invasions seem to have come largely from the north and west. The seas were frequently shallow as shown by the brecciation of much of the limestones, particularly where they immediately overlie the Gypsum series as at Bell rock below Fort Smith. The absence of coarse detrital material in any of the sediments indicates a low-lying shore-line to the east, from which little or no rock-forming material was being derived except that in solution. This is shown in the exposures on Slave river above Fitzgerald where the arkose material overlying the Precambrian granites and gneisses is made up of residual decomposed granitic and gneissic fragments embedded in a calcareous matrix.

LOCAL DOMING

On the lake shores wherever outcrops occur at or near water-level a warping of the strata into small local domes is evident. These have diameters of from 100 to 200 feet and have dips seldom exceeding 8 degrees. In a few cases where shelving outcrops occur, soundings were taken at some distance from the shore and it was found that the shelves break off into deeper water forming cliffs similar to those above water-level on the north shore. It was also found that wherever the thin-bedded limestones outcrop at water-level the dip of the strata is apparently towards the lake.

The domes may be due to the transformation of anhydrite beds at depth into gypsum, with consequent increase in volume. This theory is supported in several cases, particularly at Sulphur and Nintsi points, by the presence of large sulphur springs in the vicinity, though no springs were found on any of the domes. Moreover, the massive-bedded dolomites exposed in spite of heavy glaciation at the tar springs on Nintsi point distinctly show doming which could not have been formed by the action of lake ice.

SLAVE AND PEACE RIVERS SECTIONS

On Slave river between Stoney and Caribou islands 12 to 20 miles above Fitzgerald, sections are exposed showing the contact between Palæozoic sediments and the underlying Precambrian floor.[1] The sections show coarse-grained, porphyritic, and siliceous hornblende granites, jointed, fractured, and decomposed, overlain by conglomerates and arkose about 10 feet thick and these in turn by dark grey, dolomitic limestones. The beds have a slight dip and occupy depressions in the old granite surface, depressions which have a depth of as much as 50 feet, suggesting that the relief when these beds were deposited was not very different from the present relief in the adjacent Precambrian area.

On Peace river near Little rapids and Peace point, cliffs 20 to 60 feet high rise above the level of the river. As reported by Camsell[2] the lowest bed exposed is of gypsum of variable thickness but not over 50 feet. The next overlying bed is a fractured and broken dolomite from 10 to 30 feet thick above which is an argillaceous, sometimes sandy, limestone containing fossils.

"The beds undulate in both sharp and gentle folds and in one place are bent into a sharp anticline with dips on either limb of 60 degrees. The strike of the folds is not constant but varies widely.

"In seeking for the cause of such a disturbed and irregular structure it was evident that the disturbance of the beds could not possibly be connected with any orogenic movement of great magnitude, but was local in its effect and apparently confined to these particular beds. Certainly there is no evidence elsewhere throughout the region of the great plains, of the operation of mountain-building forces producing such sharp folds as those indicated by dips of 60 degrees. The solution of this problem was found in the gypsum itself. At certain of the outcrops of gypsum, rounded cores of anhydrite were noted in the gypsum. These cores showed a scaly rim of gypsum where the anhydrite by the absorption of water was altering to gypsum. At other localities, thin beds of anhydrite are interbedded with the gypsum. These facts suggest that some of the layers of gypsum, if not all of them, were originally anhydrite which by the accession of two molecules of water became altered into gypsum. In process of this alteration there would be an increase in the volume of the beds by 33 per cent. This increase causes horizontal as well as vertical expansion. The horizontal expansion results in folding of the beds and both together would probably cause the fracturing and brecciation of the overlying beds of limestone, for almost everywhere that the gypsum and the overlying limestone beds were exposed, the limestone was found to be so fractured and brecciated, in places for only a vertical distance of 10 feet, but in other localities for as much as 40 feet."

GREAT SLAVE LAKE SECTION

The Palæozoic sediments are frequently exposed from Resolution west towards Presqu'ile point. From Presqu'ile point to High point exposures are confined to the points and are mostly situated from 8 to 12 miles apart. West

[1] Camsell, C., "Salt and Gypsum Deposits in the District between Peace and Slave Rivers, Northern Alberta," Geol. Surv., Can., Sum. Rept., 1916.

[2] Camsell, C., "Salt and Gypsum Deposits in the District between Peace and Slave Rivers, Northern Alberta," Geol. Surv., Can., Sum. Rept., 1916.

of High point the lack of exposures suggests that the lake basin is here gouged out of the soft, easily weathering clay shales of the Hay River series. The bedrock is essentially flat-lying with a westerly dip not exceeding 50 feet to the mile, and this condition appears to be uniform throughout the whole of the western part of the lake basin.

At Pine point and in Resolution bay the exposures indicate a gentle anticlinal tendency, the apex of the anticline being in the vicinity of the point itself. The limbs of the fold do not show except by fossil evidence and the lithological similarity of the rocks found on Burnt islands to the east and at Presqu'ile point. About Resolution and Mission island the *Atrypa reticularis* zone of the Pine Point series is well developed and the same horizon is shown on Little Buffalo river, about 30 miles above its mouth. The middle islands of the Burnt Islands group show Presqu'ile dolomites carrying *Stringocephalus burtini.* The remainder of the Burnt Island group and the shores of the mainland from near Twin islands to a point west of Deadman island show the Pine Point sediments. The escarpment south of Pine point is capped by Presqu'ile sediments overlying upper members of the Pine Point series and the Presqu'ile is again exposed at water-level about Presqu'ile point to the west. Sediments very similar to the Presqu'ile series occur on the mainland for about 2 miles west of Little Buffalo river.

West of Presqu'ile point no structure other than the gentle monoclinal conditions already referred to is observable along the south shore. From Sulphur point the Slave Point limestones appear to continue to west of High point where they disappear and are overlain by the soft Simpson or Hay River shales. The character of the shore west of High point suggests the presence of these soft, easily weathering shales and they apparently continue to Mackenzie river.

Middle Devonian limestones and dolomites are exposed about Slave and Nintsi points. Coarsely crystalline and porous dolomites of the Presqu'ile series, abundantly exposed about Nintsi point and north of Sulphur bay, are badly fractured and fissured and show seepages of a heavy petroleum. Strong flowing cold water sulphur springs are numerous and salt water accompanies the petroleum.

North and east from Nintsi point soft, shaly limestones, lithologically similar to the upper members of the Pine Point series, are exposed in places about Jones and House points and as far north as Moraine point, where the shore eastwards becomes low and swampy and shows no outcrops. This part of the lake basin has probably been eroded in these soft shaly members of the Pine Point series. At Ketsikta point, lower members of the Pine Point series, exposed at water-level, are followed to the east by underlying dolomites and gypsum beds of Silurian age.

The north shore section shows no evidence of structural conditions similar to those indicated about Pine point to the south, but the sediments appear to lie in normal sequence with a slight dip to the west or southwest.

ECONOMIC GEOLOGY

GENERAL STATEMENT

The Precambrian rocks to the east are largely granites and granite gneisses and are not likely to be rich in metalliferous deposits. In a few places there are patches of older metamorphic greenstones, quartzites, conglomerates, and occasional limestone sediments. Near the contact between these and the granites, fissures occur showing copper and iron stainings, but are usually small and show no evidence of larger deposits occurring at depth. Gold has been reported in fissures in the neighbourhood of Yellowknife river northeast of the map-area, and in 1916 copper with gold and silver was reported from Caribou island at the entrance of the east arm of the lake. A large body of iron ore has been reported from the îles du Large, but though the writer spent several days amongst these islands during the autumn of 1916, he found no evidence of this deposit nor was his compass in any way affected by local attraction.

The Palæozoic sediments contain deposits of possible economic importance of lead, zinc, petroleum, salt, gypsum and brick clay, sulphur, and potash. A deposit of galena and blende has long been known in the region south of Pine point. Claims have been staked, allowed to lapse, and been restaked since the deposit was first discovered by a party of prospectors on their way to the Klondike in the middle nineties. The salt deposits on Salt river and the salt plains west of Fort Smith have been known ever since the white man first visited the country and have supplied the demand from all the northern part of Mackenzie basin. Gypsum occurs with the salt at the salt springs and outcrops at various places along Slave river and particularly on Peace river near Little rapid. At Nintsi point seepages of a heavy petroleum occur in numerous places and on evaporation of the volatile constituents leave tar pools which supply pitch for local needs. The thick beds of Hay River shales on Hay river weather to a plastic clay which is used as a wall-wash for the Indian houses at Hay river and has been proved to burn to a good grade of building brick. Strong-flowing sulphur springs occur at numerous places; these by depositing sulphur may be of economic importance. Potash is to be looked for in the vicinity of the gypsum and salt beds. Analyses of spring waters from near these beds show a potassium content insufficient to be profitably exploited. Better results are reported of waters from between Fort Smith and Peace point.

LEAD-ZINC DEPOSITS

About 10 miles south of Pine point and about 250 feet above the lake a flat-lying, crystalline dolomite outcrops in places over an area of several square miles. The dolomite is grey, weathering white, and quite coarsely crystalline. Fresh fracture shows a porous structure and many cavities in which typical curved rhombohedral crystals of dolomite occur. The general lithological character of the rock is identical with that of the Presqu'ile dolomites on Nintsi point, but bituminous matter and sulphur springs are here absent and no fossils were obtained by which correlation could be confirmed. Large sink-holes 10 to 20 feet deep and as much as 200 feet in length are numerous.

At one place a slight folding of the strata into a monocline or broad anticline is developed. The western limb only is exposed and has a dip of 5 degrees to the north and a strike of north 20 degrees east magnetic or north 55 degrees east astronomical. This fold strikes transverse to the axis of the Pine Point anticline. Its crest is badly fractured and fissured and there the dolomites are impregnated with considerable quantities of galena and some sphalerite. Exceptionally large sink-holes occur just east of the crest of the fold and expose shallow sections of the impregnated dolomites.

The general structure shows a massive bedded dolomite. Mineralizing solutions have percolated along the bedding planes and impregnated the overlying beds. In some cases galena is evenly disseminated throughout a bed, but usually is more abundant in the lower 18 or 20 inches. Some of the beds are more highly impregnated than others. Sphalerite always acompanies the galena and in places is the predominant ore mineral. In the limited exposures examined, sphalerite appears to increase with depth. Small amounts of pyrite or marcasite are sometimes present, usually encrusting poorly defined and undeterminable fossils.

The origin of the ores was not evident. The ore-body appears to be a replacement of the dolomite by mineralized solutions which entered along fissures. At one point situated a few hundred feet southeast of the crest of the fold, a thin fissure was traced for a few feet and then lost under the surface till. It shows as a vein a few inches across, in some places completely filled with a coarsely crystalline galena and in others showing a banded structure of calcite, zinc blende, and galena deposited in the order shown. Pyrite was absent in the vein-filling where seen, but shows in small quantities in the impregnated dolomites.

The calcite forming the gangue of the vein is white to grey-white and very fine-grained, almost lithographic in character. It is frequently impregnated with fine, hair-like lines of galena spreading from a common point into a fan-like structure. This point is the end of a thin fissure in the calcite which though not metalliferous connects with the more massive galena filling in the interior of the vein. The sphalerite is usually dark brown and has a botryoidal structure at its contact with the galena. It, also, is somewhat mixed with coarse galena. The galena fills the central parts of the vein, is massive, usually coarsely crystalline, and carries but little sphalerite.

The dolomite forming the country rock is very coarse and porous, carrying numerous vugs and cavities which in places have been filled by the mineralizing solutions. These show concentric structures and a deposition of the minerals in the order, calcite, zinc blende, galena. Galena usually occupies the centres of the cavities or shows thin fissures connecting the centre with the cavities.

On exposed surfaces secondary oxides of zinc and lead are common, and in places secondary sulphides occur in stalactitic and botryoidal forms.

Claims have been staked and some prospecting work has been done, but very little in recent years. The prospect pits are all badly caved now and no data were obtainable from them.

The mineralized area appears to be confined to the anticline where fissuring has allowed the mineralizing solutions access to the dolomite. Since the ores are non-argentiferous the value of the deposit does not seem very great.

BITUMEN AND PETROLEUM

The determination of the possibilities of an oil field near Great Slave lake was one of the main objects of the exploration. The Athabaska and Peace River districts to the south have been prospected for oil and several wells sunk, though with little success. Small flows of oil and strong flows of gas have been struck in several places, the most promising to date being near the town of Peace River. Here in 1917 the McArthur well No. 2 struck strong gas flows and obtained a production of about nine barrels of heavy oil a day.

The oil appears to come from an horizon in the Cretaceous not far above the Devonian and it was hoped that a study of the Devonian sediments exposed to the north would determine whether this oil originates in the Devonian sediments or in the overlying Cretaceous.

A well was sunk at Vermilion chutes in Devonian sediments and reached a depth of 850 feet when drilling difficulties caused the hole to be abandoned. No oil or gas was encountered.

On the shores of Great Slave lake practically all the outcropping limestones are more or less bituminous and some on fracture give a distinct seepage of heavy petroleum.

At Nintsi point the massive-bedded Presqu'ile dolomite is highly impregnated with oil. Several tar pools are formed where this oil, on reaching the surface, has lost its more volatile constituents, partly by evaporation and partly by absorption by the mosses and soil. Where seepages occur on bare rock, oil pools collect in the hollows and crevices. The dolomite is white or grey weathering and coarsely crystalline. Fresh fracture shows a cavernous and porous structure, the cavities mostly holding considerable quantities of bituminous material. In places it has the appearance of a mixture of a dark brown bituminous crystalline magnesian limestone and a more coarsely crystalline white dolomite. The rocks are badly fractured and fissured and show distinct evidence of local doming. The tar and oil pools occur along these fissures and along the bedding planes. Cold water sulphur springs are numerous in the vicinity of the oil seepages.

At Presqu'ile point and on the islands east of Pine point, cavernous and porous dolomitic limestones of the Presqu'ile series also show bituminous and oily matter in the pores and cavities, and the Pine Point series of shales and shaly limestones outcropping at Pine point and known to underlie the Presqu'ile series are highly charged with bituminous matter.

The Presqu'ile dolomites appear to be the principal oil-bearing horizon and as these are exposed at the surface on the limb of the anticline the possibilities of an oil field of great value near the lake are slight.

For a productive oil field four particular geological features are necessary.

(1) A supply of liquid oil of sufficiently low viscosity to flow through the pores and cracks of the oil sand at the temperature obtaining where the oil is found.

(2) A container porous in itself, as in the case of a sandstone, or made so by fracturing or other changes as in the case of a shale, limestone, chert, or dolomite.

(3) An impervious capping, usually a shale, over the container, for imprisoning the oil until it is released by the drill.

(4) A rock structure favourable for the accumulation of the oil in reservoirs from which it may be obtained when tapped by the drill.

Two, and possibly three of the conditions are fulfilled in the area about Great Slave lake. The structure sections, at least at Pine point, show proper anticlinal conditions, though of a gentle order, the Presqu'ile dolomites are sufficiently porous to act as a container, and the oil pools on Nintsi point show that some petroleum is present in the dolomites. The container is, however, exposed at the surface and the oil content of this structure has probably long ago escaped.

Underlying the dolomites are the Pine Point series of limestones and limy shales, which, where exposed on Pine point, appear to be sufficiently compact to act as a capping over any possible oil-bearing horizon existing below these sediments. But the sediments underlying the Pine Point series on the north shore do not look to be suitable for containing oil, although the immediately underlying Fitzgerald dolomitic limestones are somewhat porous.

Undoubtedly the Presqu'ile dolomites are the best container for oil and if an impervious capping can be found overlying these in a district structurally suitable, the conditions would at least warrant exploration with the drill.

Hay river gives an excellent section through the sediments overlying the dolomites. This section shows 340 feet of a soft, fissile clay shale overlain by 200 feet of rather massive limestones. Between the shales and the dolomites are 250 feet more of soft shales and 200 feet of a thin-bedded shaly limestone. This 790 feet of shaly material would prove an ideal capping for an oil field.

The well drilled at Vermilion chutes by the Peace River Development Corporation is the only one which has penetrated the Devonian sediments. The log of the well is given below and for purposes of comparison a summary of the Hay River-Great Slave Lake section is given with it. It is to be noted that the fossil evidence shows the limestones outcropping in the vicinity of Vermilion chutes to be analogous to the upper limestones found on Hay river.

Hay River–Great Slave Lake section		Well log at Vermilion chutes, Peace river	
Upper Devonian:			
Hay River limestone series	Feet		Feet
Limestone	200+ –	Limestones	129
Clay shale	49	Clay shales	40
Limestones	51	Limestones	131
Hay River shale series			
Clay shales with limestones	400		
Simpson shales	250+ –	Clay shales	550
Middle Devonian:		Depth of well	850
Slave Point limestone	200+ –	Flooded by salt water and abandoned.	
Presqu'ile dolomites	375		
Pine Point limestones	595		
Upper Silurian:			
Fitzgerald dolomite limestones	275		
Red beds	595		
Precambrian:			
Granites and metamorphics			

The well driller reports oily or bituminous matter in the limestone strata in sufficient quantity to cause stickiness and somewhat hinder drilling operations, though not in sufficient quantity or fluid enough to give a flow. It is to be regretted that it was found impossible to continue the well to greater depths. Another 200 feet or 300 feet might have penetrated the dolomites and proved the value of that horizon as an oil container at this locality.

Kindle's section on Peace river near Little rapids, however, shows that, there, the Upper Silurian gypsum beds are unconformably beneath the shale series and the porous Presqu'ile dolomites are absent. Whether or not similar conditions hold at Vermilion chutes, 100 miles farther west, cannot be stated until another well is drilled in the vicinity.

The oil occurrences at Nintsi point appear as seepages on the exposed surfaces of the oil-bearing horizon and, therefore, if an oil field is to be located in this horizon it should be looked for to the west of the outcrops where it will be under the suitable cover of Hay River or Simpson shales.

A possible explanation of the oil seepages at Nintsi point is worthy of notice. The sulphur-bearing waters rising from below, carrying considerable quantities of calcium and magnesium salts and percolating through the overlying thin-bedded, dolomitic limestones change them to crystalline magnesium limestones and dolomites. In the process bitumen is set free and forced into the cavities in the dolomites or through the fissures developed during dolomitization, to the surface, to form the tar and oil pools.

The field facts upholding this explanation are:

Certain parts of the beds are not yet completely changed to dolomite, but are made up of a coarsely crystalline white dolomite mixed with a more finely crystallized, dark brown, bituminous, dolomitic limestone. No distinct line of separation exists between the two phases and there is a gradation of one into the other.

In places the outlines of fossil remnants are distinctly visible. In the neighbourhood of Sulphur bay to the north of Nintsi point similar dolomites occur and, there, distinct fossils are numerous, though they show a partial recrystallization into curved rhombohedral crystals of dolomite.

No natural gas accompanies the oil seepages.

If the above is the true explanation of the conditions at Nintsi point, it would tend to show that the oil seepage there represents only local conditions and the possibility of a commercially economic oil horizon in the Presqu'ile dolomite is small. On the other hand, the oily matter in the cavities in the Presqu'ile dolomites exposed at Presqu'ile point and Burnt islands indicates much more extensive oil-bearing conditions and tends to prove that the structural conditions are the deciding factor in the concentration of the oil. Which explanation is the correct one will only be proved when a well is drilled into the dolomites through the overlying impervious capping. It is the writer's opinion that the oil seepages at Nintsi point are probably the product of the joint action of both conditions.

Regarding the character of the oil, the following table gives analysis of a sample collected at the seepages and for comparative purposes an analysis of a sample from one of the wells on Peace river near Peace River crossing.

Comparative Analyses of Oils from Great Slave Lake and Peace River

—	Great Slave lake	Peace river
Sp. gr. crude at 15·5° C	0·957	0·984
Sulphur in crude	1%	4·9%
Cal. value (B.T.U.) crude	18070	17520
Oil distillate by vol	64·5%	73·9%
First drop	178° C.	140° C.
Gasoline and kerosene (to 150° C.)	—	2%
Illuminants (150° to 300° C.)	23% of distillate	32·5% of distillate
Lubricants and residue	77% "	64·5% "

It has already been noted that nearly all the limestones outcropping on the lake shore are bituminous. At Nintsi (Windy) point, thin-bedded, dolomitic limestones, porous and cavernous and highly fossiliferous, apparently overlie the massive, crystalline dolomites that may be the product of secondary alteration of the dolomitic limestones. Cold sulphate water springs occur in the crystalline dolomites and though unfortunately no sample of the waters was taken for analysis, a partial analysis of salt encrustations from near one of the springs showed abundant sulphates and carbonates of calcium with appreciable amounts of magnesium. An analysis of sulphur water from Sulphur point[1] gave the following:

Ions	Parts per million	
Chlorine	213	
Sulphuric acid (SO_4)	1,500	
Bicarbonic acid (HCO_3)	370	
Calcium	480	
Magnesium	130	
Sodium	200	
Potassium	trace	
Total	2,892	
Hydrogen sulphide	42	
Hypothetical combination	Parts per million	Percentage
Potassium chloride	–	–
Sodium chloride	351	12·14
Magnesium chloride	191	6·60
Calcium chloride	–	–
Magnesium sulphate	644	22·27
Calcium sulphate	1,220	42·18
Calcium bicarbonate	486	16·80
	2,892	100·00

Probably the sulphate waters at Nintsi point are similar to these.

CLAYS

The soft, fissile, bluish green shales of the Hay River series weather to a plastic, blue-grey clay that mixes well and has been used locally as building material.

Mr. Keele of the Ceramic Division, Department of Mines, reports as follows on a sample of the shales submitted to him by the writer.

"This material is a hard, light grey, highly calcareous shale. When ground to pass a 16-mesh screen it has good plasticity and is very smooth in working. It burns to a hard pinkish body at low temperatures with very little shrinkage. When burned to a temperature of Cone 1 (1150° C.) it turns to a strong buff colour, but the body is still porous.

"The shale softens at a temperature of 1230° C., so that it is not a fine clay.

"The material is a typical clay shale of high lime content, being similar to some of the shales beds in the Paskapoo formation in southern Alberta, where the shale is used for the manufacture of face brick or hollow blocks."

GYPSUM

Bedded gypsum deposits occur at a number of places in the area under consideration, and in other places where no outcrops occur their presence is suggested by the pitted and broken nature of the surface. At Little rapids, Peace river, a maximum thickness of 50 feet is exposed and fossils collected

[1] Camsell, C., "Salt and Gypsum Deposits in the District between Peace and Slave Rivers, Northern Alberta," Geol. Surv., Can., Sum. Rept., 1916.

from shaly or limy beds in the series indicate an Upper Silurian age. At Gypsum point, limestones carrying Upper Silurian fauna overlie a series of red arenaceous limestones carrying gypsum and it is assumed that the gypsum is characteristic of the Silurian in the area and that the fauna is indicative of Silurian sediments.

Reporting on the gypsum deposits between Peace and Slave rivers, Camsell[1] says, in part:

"At almost all the outcrops of Palæozoic rocks in the area an important deposit of gypsum occurs. How much of the region is actually underlain by gypsum it is difficult to say, but the area must be very great and can probably be measured in hundreds of square miles.

"On Peace river gypsum is exposed on both banks of the river almost continuously for a distance of 15 miles, or from Little rapids at a point 5 miles below Peace point. The exposed thickness varies from a few feet up to a maximum of 50 feet, the latter occurring on the south side of the river at the foot of the rapids. The gypsum is usually white and massive, but in places it is earthy and thin bedded or holds narrow bands of dolomitic limestone. Selenite is rare, but thin veins and beds of satin spar are common. Anhydrite is occasionally present in rounded nodules or thin beds. Overlying the gypsum is a fractured and broken bed of limestone, but frequently this has been removed by erosion and glacial drift 5 to 15 feet thick forms the only capping."

Camsell estimates at least 217,000,000 tons of gypsum in the vicinity of these Peace River outcrops. Much of this tonnage is favourably situated for mining on account both of its location and the thin overburden of drift. No attempts have been made to work the gypseum and no claims have as yet been taken up.

Camsell's section at La Butte on Slave river shows a 10-foot bed of a somewhat earthy gypsum, thin-bedded and white, grey or bluish in colour. Seams of selenite and satin spar traverse the beds, which are overlain by some 20 feet of brecciated limestone.

Gypsum is said to underlie the brecciated limestones at Bell rock near Fort Smith, and outcrops on Slave river immediately below pointe Ennuyeuse where a thickness of about 4 feet of thin-bedded, impure gypsum is exposed near water-level.

In the escarpment at the salt plains west of Fort Smith gypsum exposures up to 40 and 50 feet are reported by Camsell. The gypsum is thin bedded, white or greyish, and disposed in horizontal beds. Occasional narrow beds of anhydrite or dolomite are interbedded with the gypsum. Northward the gypsum appears to thin and is overlain by beds of grey crystalline dolomite.

Regarding the extent of these deposits, Camsell says:

"The escarpment is known to extend more or less continuously from a point some 8 miles southwest of Fitzgerald in a sinuous line northwestward for about 40 miles, or beyond Little Buffalo river. Since the escarpment is probably caused by erosion where hard resistant beds overlie softer and more soluble strata, it is reasonable to suppose that as the strata of the escarpment are horizontal, gypsum will be found to occupy the base of the escarpment throughout the greater part of its length. This suspicion is borne out by the character of the surface on the top of the escarpment, which is broken and pitted with sink-holes in a way characteristic of a gypsum region."

At Gypsum point, on Great Slave lake, thin beds of flesh-coloured, impure gypsum are interbedded with brick-red, arenaceous, thin-bedded limestones.

[1] Camsell, C., "Salt and Gypsum Deposits of the District between Peace and Slave Rivers, Northern Alberta," Geol. Surv., Can., Sum. Rept., 1916.

Thin seams and stringers of pink satin spar traverse the gypsum beds and in the arenaceous limestones casts of large salt crystal "funnels" are numerous. The gypsum as exposed is too thin-bedded and impure to be valuable, but its presence here indicates the extent of gypsum deposits in the Silurian sediments.

The well of the Imperial Oil Company drilled at Nintsi point passed through 65 feet of gypsum and anhydrite in one bed and 10 feet in another, and the grey dolomitic limestones associated with these deposits appear to carry other numerous stringers or thin beds. The red beds directly following these dolomitic limestones are also highly gypsiferous and carry several deposits of appreciable thickness as well as considerable quantities of salt.

SALT

Rock salt is to be looked for associated with gypsum, and is reported in the logs of most of the wells drilled in the region. The reported occurrence of thick beds of salt encountered in wells drilled for oil in the vicinity of McMurray led the Provincial Government of Alberta to sink a well for salt at McMurray during the summer of 1920. The log of this well has already been given.

Allan gives the following analyses of samples of salt from the core of this well:

Analyses of Rock Salt from Drill Core

—	1	2	3	4
Water, soluble	53·78	–	–	–
Insoluble	46·32	0·24	0·46	0·30
Analyses of water, soluble				
Calcium sulphate	1·94	4·74	0·90	2·78
Sodium chloride	97·28	94·78	98·46	96·53
Ignition loss	0·40	0·	–	0·18
Magnesia	0·00	0·00	0·00	0·00
Potash	0·00	0·00	0·00	0·00

1. Transparent rock salt from 660 feet.
2. Rock salt from the 14-foot bed.
3. Transparent rock salt from 650 feet.
4. Rock salt with anhydrite lenses from 645 feet.

Saline springs, depositing salt in naturally formed evaporating basins, occur in several places along the foot of an east-facing escarpment on the banks of Salt river west of Fort Smith. Camsell[1] reports the salt deposited in shallow basins about or near the brine springs issuing from the base of the escarpment. There is evidence that the salt probably did not come from bedded deposits but from crystals of the mineral disseminated through the gypsum beds in the base of the escarpment. The occurrence of bedded deposits of rock salt found by drilling near McMurray to the south and at Nintsi point to the north, however, suggests the possibility of bedded salt deposits at this point, at depth. Four groups of springs occur, the three important ones being: Snake Mountain springs, Hudson's Bay Company springs, and Roman Catholic Mission springs. Altogether about 4 tons of salt are annually collected from these springs for the trading posts and missions of the Mackenzie basin.

[1] Camsell, C., "Salt and Gypsum Deposits in the District between Peace and Slave Rivers, Northern Alberta." Geol. Surv., Can., Sum. Rep., 1916.

No. 1. From Hudson's Bay springs, sample taken August 21, 1916
Contains in 1,000 parts by weight

Ions		Hypothetical combination	
Potassium	0·5	Potassium chloride	0·9
Sodium	101·5	Sodium chloride	258·0
Calcium	1·2	Calcium sulphate	4·1
Magnesium	0·2	Sodium sulphate	0·4
Chlorine	157·7	Magnesium chloride	0·8
SO_4	3·1		
	264·2		264·2

Temperature of air on collection	62° F.
Temperature of brine	42° F.
Sp. gr. at 65° F.	1·204

Flow about 1½ gals. per min. from each of eight springs.

No. 2. Roman Catholic Mission springs, August 26, 1916
Contains in 1,000 parts by weight

Ions		Hypothetical combination	
Potassium	0·4	Potassium chloride	0·8
Sodium	100·8	Sodium chloride	256·3
Calcium	1·2	Calcium sulphate	4·2
Magnesium	0·2	Sodium sulphate	0·2
Chlorine	156·6	Magnesium chloride	0·8
SO_4	3·1		
	262·3		262·3

Temperature of air on collection	70° F.
Temperature of brine	35° F.
Sp. gr. at 65° F.	1·204

Flow about 3 gals. per min.

No. 3. Snake Mountain springs, August 29, 1916
Contains in 1,000 parts by weight

Ions		Hypothetical combination	
Potassium	0·4	Potassium chloride	0·8
Sodium	100·7	Sodium chloride	256·0
Calcium	1·2	Calcium sulphate	4·2
Magnesium	0·2	Sodium sulphate	0·2
Chlorine	156·4	Magnesium chloride	0·8
SO_4	3·1		
	262·0		262·0

Temperature of air on collection	58° F.
Temperature of brine	40° F.
Sp. gr. at 65° F.	1·202
Flow in gals. per min.	4 to 5

These analyses show that sodium chloride constitutes in each sample over 97·6 per cent of the total solids. The percentage of 26 per cent dissolved matter indicates a saturated solution of salt at the brine temperature.

The Imperial Oil Company's oil well at Nintsi point on Great Slave lake penetrated salt beds at 1,070 feet, 1,090 feet, 1,200 feet, and 1,380 feet, as shown by the log of the well previously given. All these salt beds occur in the Red beds underlying the gypsiferous dolomitic limestone of the Fitzgerald series. Samples obtained from the drilling operations on washing show a remarkably clear almost colourless rock salt carrying well over 90 per cent sodium chloride. Some samples are stained the characteristic brick red colour of the interbedded shales, whereas others are almost clear white. A total estimated thickness of 60 feet of salt is shown in the four beds mentioned above. The majority of the cuttings from the interbedded red shales show a considerable quantity of salt and gypsum intermixed with the shale.

POTASH

Potassium salts are to be looked for in association with gypsum and salt beds and prospecting for them has been done near the gypsum beds on Peace and Slave rivers, but without success. The humidity of the region would not allow outcrops of the soluble chloride and sulphate salts to remain exposed. Until extensive drilling operations are carried on, the existence of potash deposits at depth can be determined only by analysis of underground waters that reach the surface.

The analyses already quoted of mineral-bearing waters show that the proportion of potassium is too low to be extracted on a commercial scale; and there is nothing to indicate that the water of these springs has passed through rocks containing an unusual proportion of potash.

MACKENZIE RIVER DISTRICT BETWEEN GREAT SLAVE LAKE AND SIMPSON

By E. J. Whittaker[1]

CONTENTS

Illustrations

INTRODUCTION

The season of 1921 was spent in making a geological examination of the country along Mackenzie river between Great Slave lake and Simpson (Map 1956). Micrometer surveys by canoe were carried up Horn river for 125 miles, up Trout river for nearly 100 miles, and up Kakisa (Beaver) river to and around lake Kakisa. This lake has a shoreline of over 60 miles and is much larger than sketched on existing maps. Geological traverses back from the rivers and lakes were made, the longest being into Horn mountains from a point on Horn river about 25 miles above Fawn lake.

The writer wishes to acknowledge the many acts of courtesy accorded him by the various people whom he met. In particular he wishes to mention Mr.

[1] *Itinerary of Parties under E. J. Whittaker, G. S. Hume, and M. Y. Williams.* Owing to the anticipated rush into the oil fields and the consequently uncertain nature of transport conditions it was deemed advisable for the Geological Survey parties to be as independent as possible of outside aid. A scow was, therefore, built at Peace River, Alberta, in which the combined parties of thirteen men with the summer's equipment and supplies journeyed to their destinations. Two Evinrude motors gave steerageway to the 50-foot scow and helped its progress downstream.

The journey was commenced on May 19. Aided by the swift current of the Peace the trip of 350 miles to Vermilion chutes was made in five and a half days, during one of which the scow was tied up owing to heavy wind. After a short delay the scow with all cargo aboard was safely run through the rapids by a skilful pilot, Joe LaFleur of Fort Vermilion, and was lined, empty, over the lower chutes. The complete operation, including portaging and reloading of the scow, occupied only half a day and by noon of May 27 the second stage of the journey to Fitzgerald began. This was accomplished without incident and the parties reached Fitzgerald on May 31 almost exactly twelve days from the time of departure from Peace River.

The whole outfit was taken across the portage at Smith rapids by the tractor of the Alberta and Arctic Transportation Company, to avoid the risk of taking the scow through the rapids.

At Fort Smith the Geological Survey parties joined forces with those of the Topographical Survey under Messrs. Seibert, Bowman, and Norrish, and all journeyed together as far as Providence. Fort Smith was left at noon June 7 and the mouth of Sawmill channel, Slave river, was reached on the morning of the 10th. The worst weather of the trip was encountered on this stretch causing some delay. A fifth party, under Mr. Blanchet, joined the flotilla a short distance above the mouth of the river, so that the complete parties now included about sixty men with five scows.

Canada
Department of Mines
Hon. Charles Stewart, Minister; Charles Camsell, Deputy Minister
Geological Survey
W.H. Collins, Director
Issued 1922

C.O. Senécal, Geographer and Chief Draughtsman.
A. Joanes, Draughtsman.

Publication No. 1956

MACKENZIE RIVER BETWEEN GREAT SLAVE LAKE AND SIMPSON, DISTRICT OF MACKENZIE.

Scale of Miles

To accompany report by E.J. Whittaker in Summary Report, Part B, 1921

SOURCES OF INFORMATION
Geology by E.J. Whittaker, 1919, 1921.
Base map from surveys by E.J. Whittaker, 1921, R.G. McConnell, 1887, and the Topographical Surveys Branch, Department of the Interior, 1921.
Map compilation by J.O. Fortin.

Ballsillie, the Hudson's Bay Company's representative at Providence; the members of the mission at Providence; and Mr. Vale of Hay River. He wishes also to record the assistance and hearty co-operation of the Topographical Survey parties. Mr. A. K. McGill acted very capably as assistant.

GENERAL CHARACTER OF THE COUNTRY

MACKENZIE LOWLANDS

The area between the north arm of Great Slave lake and Mackenzie river is part of the Mackenzie lowlands. It is heavily drift-covered. This part in general is a flat plain with many lakes and muskegs and, except for very narrow strips along the banks of the rivers, is poorly drained. Although parts of the area are fairly well wooded there is a large amount of muskeg, either quite treeless, or else covered with sparse and stunted spruce trees. Belts of forest and treeless areas alternate irregularly. Almost the whole area drains towards the Mackenzie, except a narrow fringe on the west side of the north arm of Great Slave lake and south of lake la Martre. The drainage is effected by many small creeks and three rivers—the Horn, Spence, and Rabbitskin. All three are sluggish at their mouths, but soon contract and become swift and broken streams.

Horn river, which is much the most important, drains into Little lake near its upper end, but also connects by one large and many small intersecting channels with Mackenzie river. It averages 200 yards in width for the first 5 miles above its mouth and has a gentle current; then narrows to 200 feet and the current increases to 4 or 5 miles an hour. Its banks are low, seldom above 25 feet except for a short distance in the upper reaches where there are shale cliffs 60 feet high. With the exception of short stretches of lake-clays and the above-mentioned shale, the banks are composed of till from which came the many boulders that now occupy the bed of the river. Boulder pavements are common. Up to Fawn lake the country has been largely burnt over, and is now covered with a dense growth of young poplar as far back from the river as good drainage permits.

Mink, Birch, and Fawn lakes, also called First, Second, and Third lakes, occupy shallow depressions in the valley and have, except as hereafter noted, uniformly low willow-lined shores. The river is an almost continuous rapid except for the short distance between Birch and Fawn lakes. In that stretch it flows sluggishly in a wider, deep channel carved through lake clays, and it

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Great Slave lake had become free of ice about a month earlier than usual. A gasoline-power boat was chartered from Alex. Loutit of Resolution, and the journey was continued on the day of arrival. The scows were separately taken through the intricate channels off the delta of Slave river and assembled near Mission island where they were taken in tow at midnight by the motor boat. Favourable weather continuing, Hay river was reached on the afternoon of June 11 and after a short stay the last stage of the journey was undertaken and all the scows brought safely to Wrigley at the head of the Mackenzie, early Sunday morning June 12. The distance from Resolution to Wrigley by way of Hay river is nearly 110 miles. For many days and nights travel had been almost continuous and the day after arrival was devoted to rest and relaxation.

On June 13, at the upper end of Beaver lake, Mr. Blanchet commenced work on the survey of Mackenzie river. Providence was reached shortly after midday and here the Geological Survey party under Mr. Whittaker, and Mr. Seibert of the Topographical Survey, disembarked. Providence was the headquarters of Mr. Whittaker who, during the summer, examined the country between Great Slave lake and Simpson.

The other geological parties under Dr. Williams and Mr. Hume, continued together as far as Two-island Indian village, 31 miles below Simpson. The country between Simpson and Wrigley was geologically mapped, Dr. Williams working on the east side of the Mackenzie and Mr. Hume on the west. Although these parties acted independently, a common base of supplies was maintained on the scow which was moved slowly down the river for that purpose. By August 8 the work had been completed as far north as Wrigley and it was deemed advisable to visit the oil field at Norman. The journey was continued by scow as far as Norman, the outcrops along the banks of the Mackenzie being seems probable that these lakes were once united. The general course of Horn river from the Mackenzie to Birch lake is north 30 degrees east, but its course changes abruptly as it swings around the southeastern end of Horn mountains and as far as the survey was carried, continues north 50 degrees west. At this point the stream was 75 feet wide. Its principal tributary, Laferté creek, flows into Mink lake a short distance west of its outlet and drains the southern slopes of Horn mountains just as the main river above Fawn lake drains the northern, eastern slope.

Rising to a height of 2,000 feet from the monotonous plain of muskeg and lake, Horn Mountain range roughly parallels the Mackenzie and disappears opposite Simpson. These hills rise gradually to a height of about 1,200 feet above the plain in a distance of about 6 miles. At this height the slope is truncated by a level strip averaging 1½ miles wide, and then follows an abrupt rise of 400 to 500 feet to the top of the range, which is a plateau (Plate I A), almost treeless, covered with caribou moss, and dotted with small ponds. One of these ponds is worthy of being called a lake, being about 1½ miles long by ¾ mile wide.

Only the southeastern end of the range was explored. It averages 8 miles in width at this end, but apparently widens out farther to the northwest.

The trees on the bare plateau of the range show plainly the effect of the prevailing winds. The limbs all point to the southeast, and the northwest sides of the trees are scarred and limbless. Mink, Birch, and Fawn lakes have willowy and marshy shores on the northwest sides, but the southeast sides are covered with boulders and an occasional sand or gravel beach. This is evidently due to the prevailing winds, the heavy wave action on the southeast sides forming a beach in each case.

ALBERTA PLATEAU

The area lying to the south and west of Mackenzie and Liard rivers, excluding a narrow strip of low land along the Mackenzie from Great Slave lake to a point opposite Rabbitskin river, belongs to the physiographic province known as Alberta plateau. Its north and east boundaries are sharply defined by a prominent escarpment which extends from Hay river south of Great Slave lake, around the western end of the lake, and, after roughly paralleling the Mackenzie, disappears a short distance above Simpson. This escarpment can be first seen from the river just below Little lake. The plateau at the escarpment in this area averages 300 to 400 feet above the Mackenzie and gradually

studied at various places. The trip from Norman to the oil well of the Imperial Oil Company was made in a canoe fitted with an Evinrude motor, the return to Norman being made on August 16. While waiting there for the Hudson's Bay Company's steamer *Mackenzie River* the strata on Bear mountain and near Norman were examined. From the Tertiary beds a collection was made of plant material, a report on which by W. A. Bell accompanies the report of G. S. Hume.

The return trip commenced August 26. A very fast run was made without any delays and Edmonton was reached seventeen days later. At Providence Mr. Whittaker and party, who had returned only the day before from their last trip up Kakisa river, boarded the steamer, thus uniting the three geological parties after a separation of two and a half months. At Resolution Mr. Hume and one canoeman disembarked to visit Caribou Island at the east end of Great Slave lake where the Aurous Gold Mining Company claim is located. The remainder of the parties continued up Slave river to Fort Smith which was reached on September 4. By the evening of the following day all the freight and passengers had been transported over the 16-mile portage. The trip up Slave and Athabaska rivers, on the steamer *McMurray*, was accomplished without delay and McMurray was reached Friday morning September 9. Passengers and freight were taken 18 miles up Clearwater river and across to the end of steel on The Alberta and Great Waterways railway in time to catch the weekly train reaching Edmonton Sunday evening September 11. Mr. Hume, who on his return from Caribou island, was not able to secure such prompt connexions, was delayed along with the Topographical Survey parties which did not leave Fitzgerald until September 25. The same route was followed and Edmonton was reached on October 2.

but slowly rises to the eastern range of Rocky mountains. The drainage is poor and the country is covered with muskegs and lakes, though not so much so as the Mackenzie lowlands. Between Great Slave lake and Simpson the area is drained by Kakisa, Bouvier,[1] Redknife, Trout, and Liard rivers. These rivers are all very much alike. They are turbulent, broken, and swift in their upper reaches and pass over the escarpment to the lowlands by a series of falls and rapids, where the river has cut down to the underlying rock. Elsewhere a heavy mantle of drift has prevented the streams from cutting down to bedrock.

Trout river is nearly half a mile wide at its mouth, but rapidly contracts to 150 feet and flows between gravel bars in a low valley about 2,000 feet wide cut in the boulder clay. Upstream the river becomes swifter and narrower and is broken by rapids much greater than those on Horn or Hay rivers. Seventeen miles above the mouth the valley contracts and the river flows at the bottom of a deep gorge with perpendicular cliffs rising 125 feet. The current runs in this gorge from 6 to 8 miles per hour, but is so smooth that it is only when seen foaming around some obstruction that a proper conception can be formed of its speed. Three miles above the lower end of the gorge are two heavy unnavigable rapids. Just above this point the river makes an S bend and in quick succession passes over three falls, a cascade of 10 feet, a fall of 47 feet passed by a portage one-third mile long, and, half a mile above the latter, another fall of 17 feet passed by a portage of a few yards.

Above the falls the river, which has pursued a generally southerly course since leaving the Mackenzie, turns to about 20 degrees south of west, and maintains this course as far as the survey was carried. The valley widens to over a third of a mile, with vertical cliffs on the outer sides of the bends. The current is easier, and, eighteen miles above the falls, the river leaves the cut banks behind and flows through a flat plain which averages only 6 feet above the river. One low dome of limestone projects 20 feet above this plain for a distance of three-quarters of a mile. The river in this section widens to 200 feet with long straight reaches in which the channel is studded with alluvial islands. Here were discovered the first traces of Indian habitation since leaving the Mackenzie, for the natives avoid the lower river. The current averages 4 miles per hour. Forty miles above the falls this low, level plain which represents the bed of an old lake gives way to higher land underlain by boulder clay, which continues as far as the survey was carried. Through this country the long, straight stretches of river are replaced by short bends carved in the boulder clay, and the river is an almost continuous boulder rapid. Trout lake was not reached before shallow water compelled abandonment of the survey. At this point the country is about 1,000 feet above the Mackenzie. Trout lake is apparently a little west of its sketched position on the maps. In the last 30 miles surveyed the river drops 350 feet and its current averages 7 miles an hour. In its entire course Trout river receives only three very small tributaries, each about 12 feet wide, and so retains its volume of water throughout. It cannot be considered in any sense a navigable stream.

The falls are produced in the same manner in each case. A hard, resistant bed of limestone forms the top of the falls and is underlain by softer, shaly limestones or sandstones, which wear back more rapidly than the limestones.

Redknife river was not explored, but from an examination just above its mouth it seems to be less than half the size of the Trout and probably is less than 100 miles long.

[1] The name Bouvier has been applied to this river by G. H. Blanchet of the Topographical Survey Branch, Dept. of the Interior. It refers to M. Bouvier, a pioneer of this country, now living at Providence.

Bouvier river, which is nearly equal in volume to Redknife river, flows in from the south side about 25 miles below Little lake. It discharges muddy water instead of the brown water characteristic of these streams.

There are no streams of importance on the south side of the Mackenzie between Bouvier river and Kakisa river.

Kakisa river heads in the highlands of the Cretaceous plateau to the southwest and pursues a general northeasterly direction to join the Mackenzie 30 miles above Providence. It averages 200 feet in width. In its course it flows through two large lakes, Tathlina and Kakisa. It enters the Mackenzie by two main and several small channels. About 2 miles above its mouth the river is dotted with islands and very much resembles a former delta, when the Mackenzie stood at a higher level than now. This river is cutting down its bed very slowly, for cut banks are rare. Even in the short gorge below Lady Evelyn falls—9 miles above its mouth—the river bank is forest-covered, and, owing to overhanging bush, is bad for tracking. The river cascades at intervals over ledges of limestone along a 4-mile stretch in the middle of which is Lady Evelyn falls. These are passed by a lift-over at the lower cascade, 6 feet high, a portage of $\frac{3}{8}$ of a mile past the big falls and cascades, and a short portage of 200 yards past the upper cascade, 4 feet high. Lady Evelyn falls is a beautiful vertical cataract 47 feet high. From the upper cascade the river is smooth but swift to lake Kakisa.

Lake Kakisa is nearly 25 miles long, and its long axis lies 25 degrees north. It is about 8 miles wide at its eastern end and gradually narrows to less than 3 miles at its western end. It is quite shallow, seldom being over 12 feet deep. Its shores present abrupt contrasts in topography. The northern shore is low and uniform, seldom rising more than 6 feet above the water and, back of that, the country is largely muskeg. The southern shore is more rugged, showing large boulder beaches and wave-cut rock cliffs, and back from the shore 200 feet above the lake is an abrupt escarpment, apparently the one seen farther down the Mackenzie. It continues southeast of Kakisa river as a broken line of grass-covered hills which reach Eagle mountains. South of this escarpment the country is flat and the rock lies close to the surface. This has been deeply cut by many small streams and by Kakisa river between lakes Tathlina and Kakisa. The western end of lake Kakisa is very marshy. The north side has the typical muskeg drainage of many small streams 2 or 3 feet wide. On the southern side are four small streams, apart from Kakisa river. This river becomes swift and broken about 2 miles above its mouth and remains so to lake Tathlina, two portages being necessary to pass the worst chutes. According to Mr. Seibert of the Topographical Survey the river is swifter than below lake Kakisa, but tracking is easier. The first portage is on the west bank of the river and is three-quarters of a mile long. Above this, for about a mile, the river passes through a shallow gorge flanked by ledges of limestone 15 to 20 feet high. By taking advantage of slack water, first on the west and then on the east side, a canoe may be paddled through this stretch of the river, except for a chute at its upper end necessitating a short portage. For 5 miles above this point the stream widens out, the banks become lower, and the current is easier. Above this wider part and up to lake Tathlina the river narrows between high limestone banks and flows at 8 miles an hour in a series of rapids. Tracking is good at ordinary stages of water.

Lake Tathlina is much larger than indicated on existing maps. Thirty miles of the north shore was traversed by Mr. Seibert and the eastern end of the lake was not visible. It is very shallow and its shores are low and swampy. Kakisa river flows in at its western end. It is much reduced in size and navigable for canoes for about 15 miles only. South of the lake, the land rises rapidly for several hundred feet to form what are known locally as the Cutknife hills. A deep valley is cut in these hills by a large river which enters the lake 12 miles east of its western end.

South of Cutknife hills the land continues to rise slowly and at the junction of the sixth meridian and the Alberta-Northwest Territories boundary (latitude 60 degrees, longitude 118 degrees) its elevation is about 2,500 feet above sea-level. The same monotonous succession of muskeg and pond characterizes the country here as elsewhere. From the above position lake Batcho can be plainly seen away to the southwest.

Mackenzie river has been so fully described elsewhere that the writer need only state that from Great Slave lake to 10 miles above Providence the banks are low and unimpressive. From this point to Little lake (also called Mills lake) the river is narrower and swifter, and passes through a boulder-clay area. From the above lake to the Head-of-the-Line, the river is once more broad with gentle current and low banks. From this point to Simpson it is narrow and swift, and has carved its bed deeply into the boulder clay.

TIMBER

The timber of this area is not of a very high quality, the majority being suitable only for pulpwood and the stand per square mile averages low. Spruce and birch of good size are found on the lower, well-drained slopes of Horn mountains, but are not easily accessible. Elsewhere the forest has been largely reduced by fire. Birch suitable for canoes is obtained at a few favoured localities only. All the Indians at Providence obtain their birch bark from Birch lake on the route from that fort to Rae. Tamarack is very common along the lower ground, but no large living trees were observed.

FISH AND GAME

The area cannot be said to be a good big-game country. During the whole summer only three moose, one bear, one fox, and one beaver were observed by the party. In the rivers jackfish or pike are abundant. Bluefish are found in Trout river above the falls, and at the head of several islands opposite Providence. The inconnu and whitefish are found in Little lake, more rarely at Providence, and abundantly at Wrigley. Whitefish of large size occur also in lakes Kakisa and Tathlina. The lake trout is found rarely below Little lake. Suckers are everywhere abundant in the river eddies. In the muddy water of Liard river fish are very scarce.

The area about Little lake and the lakes on Horn river and in Horn mountains teem with ducks and geese, and geese are very common up Trout river, 20 miles above the falls, and also on lakes Kakisa and Tathlina. The snow-goose or wavy is less common. Waterfowl are abundant along the Mackenzie between Great Slave lake and Kakisa river, but as this section is well-travelled they are shy. Spruce partridge are abundant in the wooded slopes of Horn mountains. In the winter the Indians shoot and trap the common fur animals, but the returns are poor compared, for instance, with parts of northern Ontario.

TABLE OF DISTANCES ALONG RIVERS

Kakisa River

	Miles
From outlet to Lady Evelyn falls	9
" " " outlet of lake Kakisa	14
" " " point where upper Kakisa river enters lake Kakisa	25
" " " lake Tathlina approximately	45[1]

[1] Information on the upper Kakisa river kindly supplied by Mr. F. H. Seibert of the Topographical Survey Branch, Dept. of the Interior.

Horn River

From outlet to outlet Mink lakes	36
" " " " Birch lakes	56
" " " " Fawn lakes	65
" " " Sulphur creek	78
" " " Horseshoe rapid	94
" " " end of micrometer survey	123

Trout River

From outlet to Table Rock rapid	14
" " " Second falls	20
" " " Big Bend	22
" " " foot of upper rapids	64
" " " end of micrometer survey	97

NATIVE INHABITANTS

The Indians in the area under discussion belong, with one exception, to the Slavi tribe. They are divided into several distinct bands. One band which hunts and traps up Horn river and in Horn mountains is referred to as the Horn River Indians. They come to Providence to trade in the spring and remain near the mouth of Horn river, supporting themselves by fishing until the autumn when they return up the river to their hunting grounds. On the headwaters of Horn river a band of Dog-Rib Indians, who come in from Rae, encroach upon their hunting grounds. This is common knowledge and is corroborated by the fact that the writer discovered in this locality a starving dog, which followed the party to the mouth of Horn river and was not claimed or recognized by any of the Horn River band, all of whom were assembled at this point at that time. Hence it seems probable that it belonged to the Indians from Rae.

Another band of Indians, known as the Trout Lake band, live on the shores of Trout lake. They do not descend Trout river to its mouth, but travel overland to Liard river to trade at either Simpson or Liard.

A third band lives at the west end of lake Tathlina and trades at Providence. This band seems to have had a composite ancestry which embraces Trout Lake Indians, Indians from Hay river and Providence. Confusion has arisen because this band also is referred to as the Trout Lake Indians. In general these Indians have kept themselves aloof from the Indians and white men along the Mackenzie, and are a superior type. They have the reputation of being more industrious, skilful in hunting, and reliable than other Indians of the district.

GENERAL GEOLOGY

In the area under discussion formations of Devonian, Cretaceous, and Pleistocene age are recognized. The general section is as follows:

Table of Formations

—	—	Thickness
		Feet
Pleistocene and Recent	Boulder clay, alluvial and lacustrine deposits	20–100
Cretaceous	Mountain shales	100–500
Upper Devonian	Hay River beds	700
Middle Devonian	Simpson shales	150
	Pine Point limestones	100
	Horn River shales	100

HORN RIVER SHALES

The shales to which the name Horn River is here applied are first seen on Horn river 11 miles above Fawn lake. They outcrop at frequent intervals along the river, at least as far as the survey was carried. They are brown-black, fissile, much jointed and fractured. One set of joint planes runs about east 10 degrees north, but others, less conspicuous, run about due north and south. These shales are either quite horizontal or dip very gently toward the southwest. Locally, small folds with maximum dip of about 3 degrees are observed. No fossils were observed, though minute markings at first thought to be *Styliolinas* were noted. Sixty feet of these shales were seen with the lower part covered. Owing to their position immediately below the Pine Point limestones, they are placed in the Middle Devonian.

These shales may be identical with the upper part of the red and reddish brown shales reported from the Nintsi Point well at a depth of 1,040 feet.

PINE POINT LIMESTONES

This formation was encountered at only two localities, both up Horn river about 30 miles above Fawn lake. Fifteen feet of flat-lying limestone were observed immediately above the Horn River shales. The upper surface has been smoothed and gouged by glacial action. These limestones are dark grey and certain layers are quite fossiliferous. The fauna is similar to that seen at Resolution, being characterized by a large flared *Atrypa, Paracyclas, Martinia,* cf. *meristoides,* and a small *Schizophoria.* The nearest exposure of this formation previously observed is on the north shore of Great Slave lake just west of Hardisty island, 120 miles distant.

On the east side of the Mackenzie no rocks were found between these beds and the Cretaceous. All the Upper Devonian is covered. The lowest beds of the Cretaceous exposed are about 15 miles away and 1,200 feet above the Pine Point limestones.

SIMPSON SHALES

These shales are exposed on Mackenzie river 5 miles above Rabbitskin river in the first rock exposure on the river below Great Slave lake. They are also exposed at intervals down to Simpson and up Liard river for 20 miles. The fauna is very characteristic, but extremely restricted. The characteristic species are *Buchiola retriostriata* and *Entomis brookei.* This formation probably underlies a part of the low land bordering the Mackenzie.

HAY RIVER BEDS

A nearly complete section of limestones and shales of the Upper Devonian corresponding to the Hay River limestones is exposed along Trout river and to a lesser extent along Kakisa river and to the south of lake Kakisa. The section exposed along Trout river is as follows:

(Top)

	Feet
t. Rubbly-weathering, grey limestone, fossiliferous with *Leiorhynchus* sp. common	4
s. Thin-bedded, grey to buff limestone, rarely fossiliferous, with *Leiorhynchus* and *Productella*	$4\frac{3}{4}$
r. Decomposed shale band, unfossiliferous	$\frac{1}{2}$
q. Heavy-bedded, grey, rubbly limestone. Beds 2 feet thick, fossils common including *Leiorhynchus, Camarotoechia, Euomphalus, Bellerophon* cf. *maera*	16
Covered interval about	40
p. Pure, fine-grained, grey limestone. Fauna as above, but including also *Schizophoria.* Conspicuous joint planes east 20 degrees north	10

HAY RIVER BEDS—*Continued*

(*Top*)—Continued

o. Fine-grained, buff weathering limestones. Cavities filled with pitch. Characteristic fossil *Athyris* cf. *angelica* ..	15
NOTE.—Above beds are exposed as low ramparts for a long distance along the river.	
n. Grey, impure, sandy limestones averaging 20 inches thick, interbedded with grey green sandstones and sandy shales. Characteristic fossil *Spirifer whitneyi*..	88
m. Porous, buff, dolomitic limestone with poorly preserved corals.	4
Top of Third falls	
l. Heavy-bedded, pure, fine-grained limestones, very irregular in thickness, abundant fauna including *Cryptonella* cf. *pinonensis*, *Diaphorostoma* and other gastropods, *Fenestella*, *Gypidula*..	14
k. Soft, greenish, impure limestone with shaly partings, with an abundant coral fauna and crinoids..	6
j. Limestone coral reef..	12
i. Thin-bedded, grey limestone with poorly preserved corals..	21½
Top of Second falls	
h. Irregularly-bedded coral reef with some large corals 4 feet in diameter..	6
g. Grey, sandy limestone with poorly preserved corals	8
f. Heavy-bedded coral reef. Conspicuous horizon, full of nodules of marcasite which weather rusty..	3
e. Grey, thin-bedded, shaly limestone with shale partings	30
Bottom of Second falls	
e. Same as above..	17
Top of First cascade	
d. Thin-bedded limestone with abundant fauna including *Spirifer disjunctus* and many corals..	36
Covered interval measured by aneroid..	45
c. Soft, blue-grey shales with thin bands of sandy limestone. Fossils include *Atrypa spinosa* and a large *Chonetes*..	30½
b. Compact, pure, grey, limestone weathering buff, with an abundant molluscan fauna, *Hypothyris cuboides* and a form resembling *Spirifer disjunctus* var. *occidentalis*..	8
a. Limestone as above, but with a large coral fauna including *Acervularia* and *Phillipsastræa*; *Spirifer disjunctus* and *Schizophoria striatula*..	35
Total thickness of section..	454

NOTE. The base of Zone *a*, the lowest beds seen on Trout river, is, according to aneroid, 90 feet above the level of Mackenzie river.

The above section lies entirely within the limits of the formation called by Cameron the Hay River limestones, but includes higher beds than those exposed on Hay river. The most restricted and conspicuous horizon, and the one most useful for correlation, is Zone *l*, which outcrops along the edge of the escarpment for a long distance. There is a submarine unconformity at the top of this zone. Zones *o* to *t* are characterized by an abundance of *Leiorhynchus* and may be referred to as the *Leiorhynchus* zone. Zones *m* and *n* may be called the *Spirifer whitneyi* zone, as they are characterized by that fossil. Zone *l* may be called the *Cryptonella* zone (Plate II A, B). Below this horizon the section is characterized by the widely disseminated form *Spirifer disjunctus* and is called by that name. Lithologically, however, the *Leiorhynchus* and the *Cryptonella* zones are the only ones readily distinguished.

The section on Kakisa river is similar, but not so thick. The *Cryptonella* zone, which here forms the top of the section, to the south of lake Kakisa is notable for the extreme abundance of *Hypothyris cuboides*, a form rare elsewhere. It also contains a new trilobite, and *Conocardium* in abundance. At Lady Evelyn falls the river drops over strata of the *Spirifer disjunctus* zone, but much lower down in the section than the beds at the falls on Trout river. The rocks exposed at the top of Lady Evelyn falls correspond to the lowest beds seen on Trout river, and 60 feet of strata in the section at Lady Evelyn falls are, consequently, not seen in the Trout River section. Although part of the section between the falls and the escarpment is covered, the upper and lower limits are well exposed.

The Liard River section at the rapids 30 miles above Simpson cannot be correlated so readily in detail with the Trout River section. About 150 feet of sandstones and sandy limestones undoubtedly belong to the *Spirifer disjunctus* zone. These are underlain by about 60 feet of dark grey shales with an occasional bed of limestone which probably belongs to the same zone, but may correspond to lower beds not seen on Trout or Kakisa rivers.

CRETACEOUS

The Mountain shales are exposed near the top of Horn mountain along many of the small streams (Plate I B) which drain the plateau and slopes. The very heavy deposit of drift including large boulders has acted as an effective check on the cutting down of their valleys. The upper 400 feet is entirely drift-covered, and not a single exposure of rock was found in any of the traverses. From the topography it might be concluded that a heavy bed of sandstone capped the formation, but not even a fresh boulder was found to substantiate such a supposition. The shales outcrop at the top of the wooded gentle slope which rises from the muskeg plain, 80 feet in all being exposed. They are thin, fissile, and brown-black and weather yellow.

Throughout these shales, bands, 1 to 2 inches thick, of a decomposed hydrous aluminum silicate, occur. The silicate is white except where stained by iron, and has the plastic consistency of brick clay. For 6 inches above and below these beds the shales also are much decomposed and jet black. More rarely and near the top of the section are bands, averaging 2 inches thick, of ironstone, many developing incipient concretionary structures. Yellow ochre from the decomposition of these ironstones is found in considerable quantities along the upper reaches of the creeks. Another decomposition product is sulphur, of which small quantities were observed coating crevices in the shales. Combustion of this sulphur accounts probably for many small irregular patches in the shales which are reddened and hard and seem to have been baked.

Fossil collecting produced nothing but some unrecognizable plants and some fish remains, no invertebrate remains being discovered. The collection has not yet been critically studied, but there appears to be no doubt the remains are Post Palæozoic and similar to undoubtedly Cretaceous remains discovered near Norman by Kindle in 1919.

But little structure was observed. The beds are horizontal, though local folds are occasionally formed by great masses slumping down into the ravines.

On Trout river, 67 miles above its mouth, for about 100 yards along the north bank of the stream, similar shales are exposed. They are more decomposed than those exposed on Horn mountains and fossils are very rare. The shales are impregnated by minute crystals of gypsum. Beds of ironstone and of white, hydrous, decomposed, clay material occur as in the Mountain shales. Many septarian concretions occur at the base of the section. Twenty feet only are exposed and its base is about 150 feet above the highest Palæozoic beds observed.

It is probable that the high land observed by Mr. Seibert south of lake Tathlina is also underlain by Cretaceous strata.

PLEISTOCENE—RECENT

A heavy mantle of boulder clay covers nearly the whole area, and—especially east of the Mackenzie—has prevented the streams from cutting down to the underlying rock. It is well exposed along the Mackenzie from above Providence to Little lake and from the Head-of-the-Line to Simpson, as well as along the subsidiary streams. The irregularities in its surface are occupied by shallow lakes and ponds. From one point in Horn mountains over sixty of these were observed, of which those on Horn river were among the largest. Glacial striæ were observed at one point only—on Trout river 18 miles above the Third falls. Two sets were observed running south 67 degrees west and south 50 degrees east. It was impossible to determine definitely their relative ages, but those running south 50 degrees east appeared to be the older. Lacustrine deposits of clay, and more rarely sand and alluvial sediments of clay, sand, and gravel, complete the recent deposits. A considerable deltal island has formed at the mouth of Horn river where it enters Fawn and Mink lakes. In passing through the very short distance between Fawn and Birch lakes, the river, not having much opportunity to erode its banks, does not carry any such burden of sediment, and hence no delta is formed.

OIL POSSIBILITIES

As noted above, very little structure is to be observed. The formations exposed along Horn river, even if the structure were suitable, are too low down in the section for any large oil accumulations to occur. Twelve hundred feet of strata lie between the highest Pine Point limestone and the lowest Cretaceous, but the bottom of the Cretaceous was not observed and it is impossible to calculate the thickness of Devonian sediments, though they probably thin out considerably to the east. With the known sediments above and below lying horizontal, it is improbable that there is any anticlinal structure in the potential oil-bearing formations.

Above the falls on Trout river, there is a low dome in the limestone, which, however, soon becomes horizontal again. This is the most prominent of several very gentle folds, whose dips are not over 2 or 3 degrees. Geological conditions are more favourable here for oil accumulation than elsewhere, though there is no evidence that the structure extends to the oil-bearing strata. As in the above case, however, the locality is not yet commercially accessible.

MINERAL SPRINGS

On Sulphur creek, a small tributary of Horn river, are several small sulphur springs, one of which is accompanied by a considerable flow of hydrogen sulphide. These springs apparently originate in the Horn River shales.

The waters of all the streams heading in the Cretaceous shales in Horn mountains are heavily impregnated with iron, which, however, is deposited before the plain is reached.

EXPLORATION EAST OF MACKENZIE RIVER BETWEEN SIMPSON AND WRIGLEY

By M. Y. Williams

CONTENTS

Illustrations

INTRODUCTION

The work undertaken by the writer during the field season of 1921 was an exploration of the country bordering Mackenzie river on the east, between Simpson, at the mouth of Liard river, and Wrigley. Towards the close of the season, a trip was made with G. S. Hume to the discovery well of the Imperial Oil Company, Ltd., 58 miles below Norman.

The writer was ably assisted by A. H. Bell. Valuable aid was rendered by officers of the Hudson's Bay, Northern Trading, and Alberta and Arctic Transportation Companies. The local information obtained from Mr. Fred Camsell, factor at Simpson, was especially useful and made it possible to carry on explorations back from the river with expedition and success. Hearty co-operation existed with the government officials, viz., the officers of the administrative parties, of the topographical and hydrographical surveys, and of the astronomic party. Officials of the Imperial Oil Companies were most kind and assisted the work in every way possible.

WORK ACCOMPLISHED

Work was started at Simpson on June 16. The shale outcrops opposite the Post were examined and from there downstream the right bank was followed, and it is believed no outcrops were overlooked. From Two-island Indian village, 31 miles below Simpson, an inland traverse was made over an Indian winter trail. This survey was run by pace and compass, the only feasible method where timber is prevalent. It was accomplished in ten days, a return being made to the scow or base of supplies by June 27. On June 30 the exploration of Willow Lake river was begun. The survey of this river with compass and Rochon micrometer for nearly 70 miles occupied about two weeks, after which a study was made of the south end of Franklin mountains. This was followed by another overland trip through the bush to the mountains, starting from just south of the point known on Ogilvie's map as the River-between-two-Mountains, where the mountains are about 6 miles distant from the Mackenzie.

After carefully examining the rocky island at the site of old Fort Wrigley, two traverses were made from near Smith creek,[1] on one of which a point

[1] Eleven miles above Wrigley.

in the Franklin range 8 miles distant from the Mackenzie was reached. On July 29 camp was moved to the east bank of the Mackenzie about 1 mile above Wrigley and the rocky island just above the Post and Roche-qui-trempe-à-l'Eau were studied. Eight days were occupied by a trip over an Indian winter trail to Cap mountain which lies about 14 miles east of Wrigley.

The remainder of the season's work was done in conjunction with G. S. Hume in an examination of the outcrops along the Mackenzie as far north as Norman; and on a visit to the Imperial Oil Company's well. While waiting for the steamer *Mackenzie River* at Norman, a study of Bear mountain was undertaken and the Tertiary in the vicinity was also examined.

GENERAL CHARACTER OF THE REGION

PHYSIOGRAPHY

The region between Simpson and Wrigley consists of the following physiographic subdivisions:

The Mackenzie River lowland which is adjacent to the river; the Mackenzie and Franklin mountains farther back from the river; and groups of hills—remnants of an older plateau—south of these mountains.

The present topography is a modification of a land surface that dates back to pre-Tertiary time, for undisturbed Eocene beds occupy a considerable part of the valley above Norman. In fact the highlands suffered erosion in Cretaceous time, the Cretaceous sediments being mainly clastics derived from the Devonian rocks.[1] That little earth movement has taken place since Cretaceous time is indicated by the gentle folding of the Cretaceous sediments, which contrasts strongly with more intense folding of the underlying Devonian strata.

Mackenzie Lowland

The Mackenzie lowland is mainly excavated in soft shales and sandstones of Upper Devonian age, but here and there a mountain spur or anticline of Middle Devonian limestone has been cut through. Side streams draining lakes to the eastward flow through Franklin mountains in narrow gorges suggestive of ancestral streams of greater importance. The extent of the lowlands is in fact suggestive of the valley of an ancestral river, which had reached a stage of advanced maturity. The lowland is now occupied by strata of Cretaceous, Eocene, and Pleistocene age, Mackenzie river flowing for the most part through the younger unconsolidated silts, sands, and gravels. Many lakes and ponds scattered over the floor of the lowland in the vicinity of the river, and terraces occurring commonly at different heights above the present river level, indicate that the river has meandered to a considerable extent since glacial time. The present incised channel has resulted probably from down-cutting at the ramparts, and consequent increase in grade.

Between Simpson and the mouth of North Nahanni river, the lowland is bordered by hills which are remnants of an older land surface. Ebbutt hills[2] are situated about 10 miles from the river at Two-island village, and rise about 1,500 feet above the river level. The underlying rock is soft Upper Devonian shale. The hilltops are plateau-like, and are covered with muskeg, black spruce, etc., as on the lowland. The side facing the river is steep, with escarpments at some places, and is being rapidly eroded by brooks that descend by steep and narrow channels. From the hills the land surface slopes more and

[1] Kindle, E. M., and Bosworth, T. O., Geol. Surv., Can., Sum. Rept., 1920, pt. B, p. 53.
[2] Named after E. Ebbutt of the writer's party.

more gently toward the river. It is covered by muskeg, and tundra, with here and there a meandering stream or small river finding its way across the glacial deposits, and around local sandhills.

At the mouth of North Nahanni river, the Mackenzie lowland is deflected northward by Mackenzie mountains, and north of the mouth of Willow Lake river is shut in on the east by Franklin mountains.

Franklin Mountains

The southern part of Franklin mountains included in the area extending north of Willow Lake river to near Wrigley consists of sharp, but open, southerly plunging folds, the axes of which control the trend of the river. Just north of Willow Lake river, two ranges, about 10 miles apart, appear to represent the east and west limbs of an eroded anticline, although it has not been established that there are no intervening folds. The easterly ranges die out 4 or 5 miles north of the latitude of Fish Lake river, the westerly range where traversed by this river containing an open anticlinal axis, with its eastern limb truncated. Farther north, due to the rising axis, older formations are exposed and the mountains are high and more complex, and cover a broader belt.

At Smith creek the western range has split into two, the eastern branch being subdivided into several irregular ridges, extending in different directions. Opposite Wrigley, the Roche-qui-trempe-à-l'Eau forms the westernmost ridge of the Franklin system. Four miles to the east the mountains rise as a somewhat dissected mass, which may be grouped into two main ranges, with another which there forms the easternmost part of the system, dying out to the north. The folded nature of the mountains is quite apparent, and shows especially well in the two eastern ranges, between which there is probably a strike fault. The lowland to the east is covered by almost innumerable lakes which drain westward to Mackenzie river. Farther east, however, is a low divide, beyond which large lakes of La Martre system could be faintly discerned. Cap mountain,[1] which in its southern extent is flanked by a ridge to the east, consists of a quartzite ridge dipping steeply to the west and rising in elevation at its northern end where it forms the highest mountain of the Wrigley region—its height being estimated at more than 5,000 feet above sea-level. As will be shown elsewhere, the eastern side of the mountain is probably a fault scarp. The limestone mountain resting upon its flank to the west has been named mount Kindle by the writer, in honour of the first geologist to visit this locality, and the highest mountain on the south side of Fish Lake river has been named mount Bell after A. H. Bell of the writer's party.

[1] This mountain was named by Kindle in the report cited above.

GENERAL GEOLOGY

Table of Formations

Quaternary	Recent		River silts, marls, and peat
	Glacial		Tillites, outwash gravels, sands, and clays
Palæozoic	Devonian	Upper	Simpson shale and overlying limestone
		Middle	Grey limestone veined with calcite, and some selenite, and containing numerous remains of gastropods, bivalves, and corals
	Silurian	Upper	Cavernous dolomite.
		Middle (Mount Kindle formation)	Halysites and other corals
		Lower (Franklin Mountain formation)	Red and green shales, in part sandy
	Ordovician?		Soft red and green shales
	Cambrian	Upper? (Mount Cap formation)	Sandy shales and thin-bedded sandstone above, and below thick-bedded, pink quartzite

CAMBRIAN: MOUNT CAP FORMATION

The oldest rock seen in the area occurs on Cap mountain, about 14 miles northwest of Wrigley. Here a westerly-dipping, truncated fold of heavy-bedded pink quartzite forms the elevated ridge called Cap mountain. At the top of the exposed section are 100 feet or more of grey and rusty shales or phyllites, overlying green and rusty, thin-bedded sandstones, which rest upon pink quartzite. The section of the sandstone and quartzite farther north is described by Kindle[1] thus:

	Feet
Red quartzite and sandstone (summit of mountain) dip 10 to 15 degrees west	500 plus
Red shale and ferruginous sandstone	50
Hematite	20
Red sandstone with high percentage of iron	50
Dark shales	150
Greyish to drab shale	225

This formation dips southwesterly at 10 to 15 degrees and passes under a mountain which carries at its summit Middle Silurian corals (*See* cross-section on Map 1957), as described below. There is also direct evidence of the age of the Mount Cap formation in the presence of free cheeks of a trilobite probably of genus *Saratogia* in the thin sandstones near the top of the section. This genus occurs in the Middle, but more commonly in the Upper, Cambrian. Even such generic characters establish the Cambrian age of the beds and point strongly to late Cambrian time. As will be seen, this conclusion does not agree with the tentative age described by Kindle. Dr. C. D. Walcott, to whom these specimens were referred, writes concerning them as follows: "The surface of the piece of quartzitic sandstone might have come from most any of the arenaceous shales of the Upper Cambrian formations of Montana and Idaho. There is very clear evidence of the presence of a Cambrian form of trilobite closely related to species that have been referred to *Saratogia*. There is also one impression that strongly suggests *Agnostus,* but it is too doubtful to mention it."

[1] Sum. Rept., 1919, pt. C, p. 2 C.

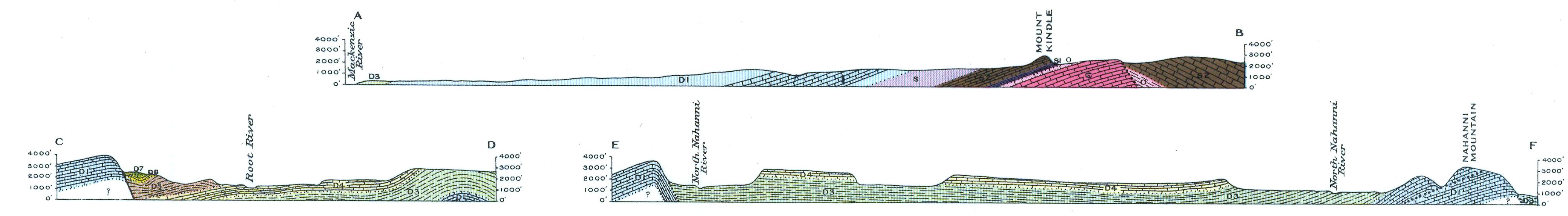
Canada
Department of Mines

Hon. Charles Stewart, Minister; Charles Camsell, Deputy Minister.

GEOLOGICAL SURVEY

W. H. Collins, Director.

Issued 1922



Structural sections along lines A B, C D, and E F.
Scale, horizontal and vertical 126720
Datum: Mackenzie River

LEGEND

UPPER DEVONIAN

- D7 — Third shale zone (dark fissile shale)
- D6 — Athyris angelica zone (yellow limestone with interstratified grey shale)
- D5 — Second shale zone (principally grey and reddish calcareous shale)
- D4 — Leiorhynchus zone (dark-grey limestone with some shale)
- D3 — First shale zone – Simpson shale (greenish-grey shale)

MIDDLE DEVONIAN

- D1 — Dark bituminous limestone overlying light-grey limestone

MIDDLE SILURIAN

- S2 — Mount Kindle formation (grey magnesian limestone with coral fauna)

LOWER SILURIAN

- S1 — Franklin formation (red and green sandstone and shale)

SILURIAN (UNSUBDIVIDED)

- S — Limestone and dolomite

ORDOVICIAN(?)

- O — Red clay shale

UPPER(?) CAMBRIAN

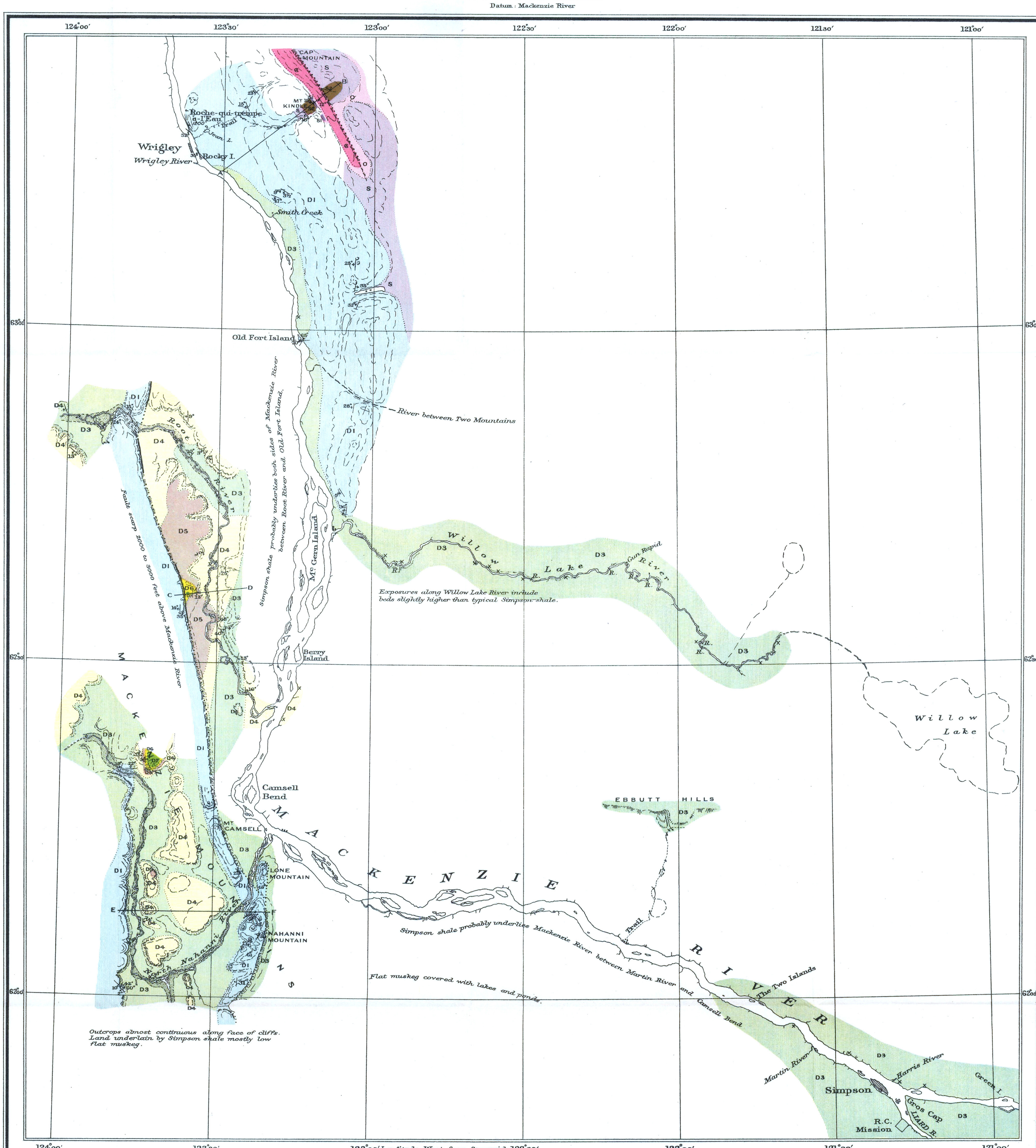
- Є — Mount Cap formation (red and sandy shale overlying pink quartzite)

Symbols

- Geological boundary (assumed)
- Fault (defined)
- Fault (assumed)
- Dip and strike
- Rock outcrop
- Horizontal strata
- Escarpment
- Rapid or fall
- Indian house

Note:—Rock outcrops are abundant in the mountainous areas, but in the low lands are mostly confined to the banks of streams. Elsewhere the bedrock is drift-covered.

Approximate magnetic variation 39°East.



C. O. Senécal, Geographer and Chief Draughtsman.
A. Joanes, Draughtsman.

Publication Nº 1957

MACKENZIE RIVER BETWEEN SIMPSON AND WRIGLEY, DISTRICT OF MACKENZIE.

Scale of Miles

10 5 0 10 20

To accompany reports by G.S. Hume and M.Y. Williams, in Summary Report, Part B, 1921.

SOURCES OF INFORMATION

Geology by G.S. Hume and M.Y. Williams, 1921.
Base-map from surveys by G.S. Hume and M.Y. Williams, 1921, and the Topographical Surveys Branch, Department of the Interior, 1921.
Map compilation by J.O. Fortin.

The limestone and underlying shales in knobs and ridges to the east, dip away from Cap mountain and are so close to the escarpment as to preclude the possibility that the quartzite may change its direction of dip and pass below them as the east limb of an anticline. Evidence points to the presence of a fault as indicated on the map and cross-section.

The base of Mount Cap formation[1] was not seen, nor was the top determined; it is probable, however, from the observed outcrops and structure that the thickness is between 1,000 and 1,500 feet.

SHALES OF PROBABLE ORDOVICIAN AGE

A cover of loose deposits obscures the bedrock to the west of Cap Mountain ridge (where examined by the writer) as far as the base of mount Kindle. The under phyllites of Mount Cap formation probably underlie a part of the intervening 4,000 feet, but soft red clay shale outcrops at the base of mount Kindle as though squeezed out by the overlying mass of rock. Although little is known of this formation, it lies between the Cambrian and Silurian formations, and is thought to be of Ordovician age.

SILURIAN FORMATIONS

On the eastern declivity of mount Kindle, pea-green shales and red, sandy shales litter the talus for hundreds of feet, and rocks are found in place between 420 and 480 feet below the outcrop of the Middle Silurian coral horizon. No fossils were found in these shales nor were the limits of the formation seen, but from stratigraphical position, and because of the general similarity to lower clastic Silurian sediments known elsewhere, this formation is provisionally classed as Lower Silurian, the name Franklin Mountain formation being applied to it from its occurrence in Franklin mountains. It is thought to be not less than 500 feet thick. Sections of the formation outcrop in the face of the mountain to the south of mount Kindle and also in the mountain to the east of the southern end of Cap Mountain ridge.

The upper 80 feet of mount Kindle and its western slope for a mile or more consist of grey magnesian limestone, composed in large measure of the fossilized remains of Silurian coral reefs. As will be seen from the following determinations, these corals are characteristic of Middle Silurian time, especially as represented by the life of Niagaran seas of eastern and central North America. The writer proposes to name this the Mount Kindle formation because of its splendid development on this mountain, near which Kindle first obtained specimens of the contained fauna. Judging from outcrops and structure the Mount Kindle formation may be 500 feet thick.

The following fossils have been recognized. In the creek to the south of mount Kindle: Cyathophylloid coral, probably new genus and new species, *Columnaria alveolata* Goldfuss?, *Diphyphyllum multicaule* (Hall), *Halysites catenularia microporus* (Whitfield), *Bumastis ioxus* (Hall)?.

At the top of mount Kindle: Stromatoporoids, *Zaphrentis stokesi* Edwards and Haime, *Diphyphyllum multicaule* (Hall), *Cladopora multipora* Hall, *Halysites catenularia microporus* (Whitfield).

About 100 feet higher in the section, but down the west slope of the mountain: *Zaphrentis stokesii* Edwards and Haime, and *Conchidium* sp. in a boulder probably not far out of place.

[1] The name "Cap mountain" is preferable, but is pre-empted, being used for a Cambrian formation in Texas.

The Mount Kindle formation appears to grade upward into rough cavernous dolomite which is much cut by calcite veins. Somewhat similar rock was seen on the crest of the anticline at the top of Roche-qui-trempe-à-l'Eau, and elsewhere at crests of anticlines in the Franklin range. The upper "brecciated" dolomite of Kindle's Bear Mountain formation is similar in many ways to this cavernous formation, but as metamorphism has had a marked effect on the limestones and dolomites of the Franklin mountains, it seems unwise to attempt to correlate formations of widely separated areas except on the basis of fossils, or impressive stratigraphic evidence. The cavernous dolomite is, probably, 500 feet thick. The exposures in the mountains in the vicinity of mount Kindle will probably make it possible, however, to work out a complete Silurian section. Until this be done, it will be uncertain whether the red clay shales and gypsum of the Bear Mountain formation are represented in the Mount Kindle region.

MIDDLE DEVONIAN LIMESTONES

The common limestones of the Franklin Mountain region are Middle Devonian in age according to their fossil content. From the southern tip of the range, near Willow Lake river, northward to Roche-qui-trempe-à-l'Eau, these limestones form the mountain exposures, excepting where axes of folds bring up older rocks, as described above. These limestones also outcrop near Wrigley on the east shore and in the small islands, and in the islands above old Fort Wrigley and along the east shore opposite them. Similar limestones form the western slopes of Bear mountain as already described by Kindle.

The limestones are generally dark grey, and at most localities are semicrystalline and are cut by stringers and veins of calcite, and, less commonly, of selenite. Fossils are widely distributed, but are rarely abundant, and are generally poorly preserved and difficult to collect. Consequently, many identifications are uncertain. The formations intervening between the Middle Silurian and the Middle Devonian strata have not yet been studied, and the inter-relationships are not known. The Mount Kindle region will probably yield this much-needed information to future investigators. The Middle Devonian limestones are overlain by the soft, clay shales of Upper Devonian age described below. The contact was nowhere seen, but the general relationships are well shown in the vicinity of Willow Lake river where the anticline of limestone to the north plunges beneath the shales which are well exposed along the river banks. The thickness of the Middle Devonian limestones is probably between 1,000 and 2,000 feet.

It is not easy to correlate the Middle Devonian limestones of the southern Franklin Mountain region with subdivisions made elsewhere, except that they apparently include Kindle's Beavertail limestone of Bear rock. *Stringocephalus burtini* has not been found by the writer, so that correlatives of the Rampart limestones are not recognized. In a broad way, the faunas closely resemble those of the Onondaga (Corniferous) seas of Ontario, Manitoba, New York state, and Kentucky.

The following identifications have been made from the fossils collected:

From southern end of Franklin mountain near mouth of Willow Lake river: *Phillipsastræa verneuili* Edwards and Haime, a few feet higher in the same section *Favosites nitella* Winchell, *Cladopora* sp., *Ambocoelia* cf. *nana* Grabau.

From a few hundred yards to the north on the mountain top, but probably 200 feet lower in the section, *Cyathophyllum* sp., *Syringopora nobilis* Billings, *S. perelegans* Billings, *Favosites emmonsi* Rominger?. The species here identified has corallites rather smaller and more regular than the descriptions of *F. emmonsi* indicate.

From the west side of Bell mountain (6 miles east of the river at the mouth of the River-between-Two-Mountains): *Productella spinulicosta* Hall, *Ambocoelia* sp., *Callonema sp.* From 30 feet higher in the same section: *Cladopora* sp., *Productella spinulicosta* Hall, *Cranæna* suggesting *romingeri* Hall and *Loxonema* sp.

Rock outcrops on the islands and on the shore of the river near the site of old Fort Wrigley represent a section of about 120 feet of limestone. The lower 50 feet are thick-bedded and from the upper 10 feet of these beds the following fossils were obtained: *Streptelasma prolificum* Billings, *Favosites emmonsi* Rominger?, *Leptaena rhomboidalis* (Wilckens), *Productella spinulicosta* Hall, *Cyrtina* sp., *Spirifer* sp. In thin-bedded limestone from 50 to 60 feet up in the section the following fossils were found: *Cyathophylloid* compound corals, *Syringopora* sp., *Favosites nitella* Winchell?, *Productella spinulicosta* Hall, *Spirifer davisi* Nettleroth, *Paracyclas elliptica* Hall, *Euomphalus decewi* Billings, *Callonema bellatula* Hall, *Proetus* sp. From the top of the section, the following were obtained: *Streptelasma prolificum* Billings?, *Favosites nitella* Winchell?, *Productella spinulicosta* Hall, *Callonema clarki* Nettleroth, and an undetermined lamellibranch.

The following fossils were collected from a 90-foot westerly facing escarpment of a low mountain 3 miles east of Mackenzie river at Smith creek: *Favosites nitella* Winchell, *Cladopora francisci* Davis?, *Productella spinulicosta* Hall, *Ambocoelia* cf. *nana* Grabau, *Paracyclas elliptica* Hall.

The rock exposed along the east shore of Mackenzie river opposite the lower end of the small island above Wrigley represents 90 feet or more of a section, and from it zonal collections of fossils were made. So little change is evident, however, in the faunal assemblages, that the list is given as one: *Favosites emmonsi* Rominger?, *Productella spinulicosta* Hall, *Paracyclas elliptica* Hall (the last two common throughout the section).

The small rocky islet about one mile above Wrigley contains a section of about 250 feet of blue-grey limestone in a low anticline pitching rather steeply to the south. Zonal collections have furnished the following lists:

Lowest 15 feet of the section: *Favosites alpenensis* Winchell?, *Cladopora dispansa* Davis. From 5-foot coral zone, 65 to 70 feet up in the section *Favosites emmonsi* Winchell?, *Cladopora labiosa* Billings. From 130 feet up in the section: *Favosites alpenensis*, Winchell?, *Atrypa* cf. *reticularis* Linnaeus, *Spirifer tullia* Hall?, *Clinopsitha subnasuta* Hall and Whitfield, cf. *Naticopsis manitobensis* Whiteaves, *Loxonema altivolvis* Whiteaves?

One hundred and sixty feet up and also at 80 feet *Productella spinulicosta* occurs along with *Atrypa aspera* Schlotheim. *Favosites emmonsi?* occurs 205 feet up and *Gypidula galeata* Dalman?, *Rhynchonella tethys* Billings?, and *Proetus* sp. occur in the upper 15 feet of the section.

Roche-qui-trempe-à-l'Eau along the east side of Mackenzie river about 1½ miles below Wrigley is a crushed anticline of grey limestone with axis extending about 10 degrees east of north. The westerly dips average about 42 degrees and the easterly dips 22 degrees. Faults and fractures have relieved the crushing stresses, and sheeted jointing in places obscures the bedding. The rock rises about 1,140 feet above the river and continues northward for about 2 miles as a low ridge, comprising the western limb of the anticline and ending in a knob which includes the east limb of the fold. The stratigraphy was studied along the river, where two sections start at a fault and extend, one upstream with a thickness of 300 feet, and the other downstream with a thickness of between 400 and 500 feet. At the fault, which is nearly vertical and strikes about 7 degrees east of north, secondary selenite occurs in fractures and between beds of limestone, cutting secondary vein calcite. Some of the selenite veins are 6 inches thick.

The core of Roche-qui-trempe-à-l'Eau consists of crystalline limestone (probably dolomitic) cut by calcite stringers and chert. No determinable fossils were found in it, and the lowest beds exposed are probably not more than 150 feet below the base of the section seen along the river. Still lower beds are probably exposed in the northern end of the range 2 or 3 miles away.

The main ranges of Franklin mountains rise about 8 miles east of Roche-qui-trempe-à-l'Eau, the following fossils being found in the western extension of their foothills: *Syringopora perelegans* Billings, *Cladopora* sp., *Schuchertella* sp., *Productella spinulicosta* Hall, *Bucania* sp.

The above fossil lists indicate a Middle Devonian age for the limestones. Many of the species are common in the Onondaga limestone and its correlatives of eastern and central North America, and some are common in the Manitoba Middle Devonian.

UPPER DEVONIAN SHALES AND LIMESTONES

The Simpson shales, named from the occurrences near Simpson, form the lowest of the Upper Devonian formations of this region. They consist of soft clay-shale of greenish grey or bluish grey colour, containing ironstone concretions. *Buchiola retriostriata* has been found by Kindle and Whittaker in calcareous beds in these shales.

The writer found these shales at a number of localities, viz., in the east bank of the river about 5 miles below Simpson; in Ebbutt hills about 10 miles north of Two-island village; at many localities along the 70 miles of Willow Lake river surveyed; in the east bank of Mackenzie river 2 miles below the site of old Fort Wrigley, and also in the east bank 9 miles below the old fort and opposite the lowest of four islands.[1]

The shale exposures of Ebbutt hills, as measured in a stream bed, represent strata about 650 feet thick, neither the top nor base being seen. No fossils were found at this locality, but ironstone concretions up to 3 feet in diameter are common. These are generally of the turtle-back type, due to shrinkage cracks which are filled with shaly material. The shales here are soft, and appear to lie nearly horizontal.

A number of exposures of soft blue or green shale were seen along Willow Lake river. These are generally much folded and contorted, the shale having been metamorphosd to a phyllite. Two sets of fissility are commonly developed, cutting the shale into small rhombs. At some localities, thin calcareous beds occur in the shales. A few fossils, mostly lamellibranchs, were found in the shales themselves, but they generally disintegrated on drying. Some fossil plants and other remains were found in calcareous beds and are described below. The other outcrops in the river banks gave no further information than that already described by previous writers.

An ironstone concretion found loose on the shore about 40 miles up the river, and evidently from the shales, contains the remains of two Schizopod crustaceans to be described elsewhere.

Two exposures of soft grey limestone occur near water-level in the east bank of Mackenzie river, one about 1 mile above, and one $2\frac{1}{2}$ miles below, the mouth of Root river. From fossil content, this limestone is determined as of Upper Devonian age, and appears to belong just above the Simpson shale formation. The fossils found in these beds are as follows:

[1] Most of the river exposures have already been described by Camsell and Malcolm, Geol. Surv., Can., Mem. 108 and revised edition, 1921, p. 65.

From locality above Root river: *Productella hirsuta,* Hall?, *Leiorhynchus* cf. *clarkei* Prosser, *Spirifer disjunctus* Sowerby, *Paracyclas elliptica* Hall? At the outcrop below, *Leiorhynchus* cf. *clarkei* is, as at the former locality, the most abundant fossil.

GLACIAL DEPOSITS

Unconsolidated tillite, gravel, sand, and clay occur everywhere over the area. The tillite occurs most commonly at the base of the sections and contains a variety of rock fragments, including granite and other igneous rock, along with limestone of local origin, and pink Cambrian quartzite. The gravel, sand, and clays are evidently glacio-fluviatile, or outwash deposits, frequently showing bedding or crossbedding. At some localities sand lies in channels cut into bedded clay deposits.

Back from the river, glacial ridges of gravel and till rise 100 to 300 feet above the river, and near Two-island village sand dunes covered with jackpine are evidently outwash sand modified by wind action. The sorting is usually poor, however, the frozen condition of the soil in this latitude probably preventing typical wind sorting. The direction of the axes of parallel ridges of till near Smith creek is 10 degrees west of north (astronomic) the direction of glacial action being, probably, at right angles to this direction or from north 80 degrees east.

Glacial erratics, mostly of granite or quartzite, are common on the tops of all the highest mountains visited, showing that the ice-sheet covered the highest peaks, leaving on them its Precambrian debris derived from the old land to the east.

RECENT DEPOSITS

Silt, marl, and moss-peat occur at various places on islands in the river or near the top of the river banks. In islands above the mouth of North Nahanni river, 15 feet of silt contains marl lenses with freshwater gastropods, and thin seams of peat composed of compressed moss and roots. A bed of marl about 1 foot thick extends along the river opposite Wrigley, about 60 feet up in the bank. Such deposits were formed probably in lakes and shallow river expansions before the Mackenzie entrenched its present channel. Small shallow lakes are exceedingly numerous at the present time on the flat land bordering the river.

MINERAL SPRINGS AND TUFA DEPOSITS

Near the fault in the Roche-qui-trempe-à-l'Eau, and at the probable fault location in the island above the site of old Fort Wrigley, mineral springs occur. At the old fort springs issue from the surface of the smaller island about 15 feet above river level, depositing lime over a considerable area. This commonly forms local pools by damming up the water. On the mainland opposite, just above the mouth of a small creek, and about 60 yards away from the shore, lime deposits cover about one-half acre of land, where no trees grow. Small ponds, dams, waterfalls, and brooks result from these tufaceous deposits which encrust moss that thrives in the limy water. The deposits are usually firm enough to walk upon.

At Roche-qui-trempe-à-l'Eau, warm mineral springs deposit considerable calcareous material in the fault zone where it is exposed along the river. One spring issues from a travertine cone about 50 feet above the river. The cone has been formed by the calcareous deposits, and by the talus cemented together by them. The rock on both sides crumbles and falls away, leaving the deposits standing by themselves. The mineral contents of the springs have not been investigated.

SOILS

Vegetable gardens are cultivated at all the posts and soils varying from clay to sand are found. It is, however, only on the river terraces and on the islands that drainage is sufficiently well developed to yield arable soil.

STRUCTURE

The nearly flat-lying Palæozoic sediments of the Simpson region abut against the foothills structure of Franklin mountains in the vicinity of Willow Lake river. Here the soft Simpson shales have been folded and compressed.

Franklin mountains consist of open-folded limestone and underlying shale, sandstone, and quartzite, with here and there closely folded blocks, relieved in part by strike and cross faulting. On the south, a wide anticline with broken arch appears to have formed the two ridges of the Franklins. Farther north, the deeper, somewhat more complicated structures are laid bare, but even here, simple though rather closely compressed folds are the rule.

METAMORPHISM

As already described, the Simpson shales of the Willow Lake region have been crushed and sheared to fissile phyllites, with two or more sets of highly inclined planes of cleavage. The thin interbeds of limestone are cut by veins and films of calcite. The Middle Devonian limestones are in general semi-crystalline, are almost everywhere seamed with calcite, and near fault planes are cut by veins of calcite and selenite, several inches in width. At the tops of anticlines, as seen at several localities, the limestone is so crystallized and cut by calcite as to be unfossiliferous.

The higher beds seen in the Silurian section are cavernous, evidently due to the solution of gypsum deposits. The coral horizons are semi-crystalline, and chert has developed locally, as a weathering product. The Cambrian quartzites, as their name implies, are sufficiently indurated to be classified as quartzites rather than sandstones.

ECONOMIC MINERAL RESOURCES

CLAY FOR BRICK MANUFACTURE

The Simpson shale, as well as the glacial outwash clays, would probably be useful for brick for local requirements.

LIMESTONE FOR LIME MANUFACTURE

The limestone of the Middle and Upper Devonian formations is suitable for the manufacture of quicklime, so much needed at the trading posts for chimneys and fireplaces.

OIL

As the chief interest in the area lies in its oil possibilities, the various conditions bearing upon its occurrence in commercial quantities will be summarized. No oil seepages were seen by the writer in the Simpson-Wrigley area, nor were the limestones notably bituminous. The Simpson shale is very impervious and would make an excellent cover rock for the retention of oil pools; the beds beneath it, however, are limestone which is not particularly porous and consequently not as favourable for oil accumulation as would be a sandstone formation. The structure of the Franklin Mountain region, though in itself rather too intense for oil retention, suggests suitable structure in the outlying areas. The degree of metamorphism, which is largely a measure of the extent of compression, is generally found to have a direct bearing upon oil retention or dissipation. Where extreme metamorphism exists, oils are apt to be fractionated and dispersed through fractures, rather than accumulated into commercial pools. The metamorphism characteristic of Franklin mountains appears, therefore, to be unfavourable for oil accumulation. However, from Simpson to the mouth of North Nahanni river and to the northward in the vicinity of Ebbutt hills, gentle structure or almost flat-lying beds and little metamorphism are the rule, and here favourable conditions may occur for oil accumulation. In this region, however, it is difficult to discover the low arches or anticlines which are most favourable for the occurrence of oil pools, and a number of test wells would be necessary before the possibilities could be definitely determined.

NORTH NAHANNI AND ROOT RIVERS AREA AND CARIBOU ISLAND, MACKENZIE RIVER DISTRICT

By G. S. Hume

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Illustrations

INTRODUCTION

During the summer of 1921, the writer investigated the country west of Mackenzie river between Simpson and Wrigley, N.W.T. Two rivers, the North Nahanni and Root, both flowing from Mackenzie mountains, were ascended for about 60 miles in each case and a micrometer survey was made. The stratigraphy was studied and data were collected for the preparation of a geological map.

In this work the writer was ably assisted by J. B. Mawdsley of McGill University.

GENERAL CHARACTER OF COUNTRY

MACKENZIE RIVER AND THE IMMEDIATE VICINITY

From Great Slave lake for 250 miles the Mackenzie valley is rather poorly defined. The river flows slightly north of west through a broad, flat plain where low hills on either side of the river, but at long distances inland, relieve an otherwise monotonous, densely wooded landscape. In such a country rock outcrops are few and on the Mackenzie itself the banks are mostly drift material· material. The river flows with a good current in a broad channel broken by many islands.

Two hundred and fifty miles below Great Slave lake there is a change in the character of the country, particularly on the west side. The course of the river is deflected abruptly from northwest to north, this "Great Bend" being caused by the proximity of Mackenzie mountains. The low, flat plain of muskeg, dotted with almost innumerable small lakes, continues up to the foot of the mountains where an abrupt escarpment extends for some miles along the river. The top of the escarpment is 2,000 to 3,000 feet above the plain and the easterly face is unscalable except at a number of gaps where rivers or streams have cut through. It is through such a gap or break in the mountains that the North Nahanni flows from the west and enters the Mackenzie about 10 miles above the Great Bend.

NORTH NAHANNI AND ROOT RIVERS

North Nahanni river (Maps 1585 and 1957), except for a short distance at its mouth, flows through a valley with mountains rising about 2,000 feet on each side. It enters the Mackenzie by two channels, one quite small, the other about half a mile wide at its mouth. Its discharge varies greatly with the seasons and when the mountain snow is melting even the daily fluctuation is considerable. During the period of flood there is much undercutting of banks with consequent slumping of material into the river. This furnishes an abundance of driftwood which soon becomes stripped of all limbs and is in places piled into heaps 10 to 15 feet high. When the flood period passes these great masses of driftwood are left stranded on sand and gravel bars or at the heads of islands. Their abundance is striking testimony to the erosive power of a large river in flood.

The great fluctuation in discharge greatly influences its character. During the period of flood the river is often a half mile to a mile wide. The bottom of the channel is everywhere sand and gravel with no rock outcrops except occasionally in the banks, the whole valley floor being made up of pebbles derived from the country rock, and material from a thick cover of glacial drift in the valley bottom. No falls were encountered in the 60 miles of river ascended. The current except at the mouth is everywhere swift, but, owing to the almost complete absence of large boulders in the channel, there are no dangerous rapids. The fall of the river for the 60 miles averages about 7 feet a mile, with over 8 feet for the upper 40 miles, and in many places near the upper end of the traverse 10 and 15 feet a mile were not uncommon. The water is milky-white in colour and cloudy due to fine material in suspension.

In low water the river spreads out in numerous channels which flow through the wide gravel flood-plain. In very few places are these streams concentrated into one channel. Consequently the river is a network of streams surrounding sand and gravel bars, and islands wooded with spruce, poplar, and willows are common in the flood-plain.

The North Nahanni has remarkably few permanent tributary streams. Its basin is simply the narrow valley into which in the spring numerous gorges from the sides carry the great rush of water from the melting snow on the mountain slopes. Later in the summer the gorges are almost invariably dry, or contain insignificant streams. About 20 miles above the mouth, the river divides into two nearly equal branches, one from the southeast, and the other from the northwest. The east branch was mapped and sections along it were studied. A small stream of clear water empties into the Nahanni from the east a short distance below the forks. This is the only tributary of any importance in the part of the Nahanni that was traversed. It derives its water in part from a lake 10 to 15 miles long, situated on the flat plain between the Mackenzie and the mountains to the west. The Nahanni valley through the mountains is scarcely more than a quarter of a mile wide and the mountains on either side rise precipitously to over 2,000 feet above the channel. Through this gap, less than a mile in length, the flow is very sluggish, but beyond, the current is rapid. The structure of the mountains is evidently the controlling factor.

Root river, like the North Nahanni, flows into the Mackenzie from the mountains to the west, but is somewhat different in character. It is smaller than the North Nahanni, being not more than a quarter of a mile wide at the mouth and continuing in one main channel for the greater part of the 60 miles which were traversed. Evidence of fluctuation of flow on the Root were even more marked than on the Nahanni, although the amount of stranded driftwood was much less. Driftwood at considerable heights above the stream is evidence that this river, where both banks had been cut, is subject to ice-jams, and that the water under such conditions may rise 20 to 30 feet above the dams. As on the Nahanni, there are no rock falls, but boulder rapids occur in various places between stretches of swiftly flowing water. The fall of the river in 60 miles averaged slightly over 5 feet a mile.

GENERAL GEOLOGY

Description of Formations

—		Thickness
		Feet
Upper Devonian	Shale, zone 3	100
	Athyris angelica zone	200
	Shale, zone 2	1,000–1,200
	Leiorhynchus zone	800–1,100
	Shale zone 1—equivalent of Simpson shale=Fort Creek shale of Norman area	1,000+
Middle Devonian	Bituminous limestone	2,500
Silurian	Non-bituminous dolomite=Lone Mountain dolomite	

SILURIAN

It is not certain that rocks of Silurian age are present in the North Nahanni and Root River areas. The rocks of this age seen elsewhere in the Mackenzie district and on Great Slave lake do not appear in these sections. However, Kindle[1] has reported fossils of possible Silurian age from the base of mount Camsell in the Lone Mountain dolomite. The rocks are very hard, massive, grey dolomites and fossils are extremely rare. No concrete confirmation that Silurian was present could be obtained and the examination of many sections elsewhere in the area did not reveal any evidence of a discordance such as would be expected to occur between the Silurian and Middle Devonian.

MIDDLE DEVONIAN

It was found impossible to subdivide the Middle Devonian in the Nahanni-Root sections. The rocks are a lithological unit and fossils when found are poorly preserved. There are no shale members such as occur farther down Mackenzie river, and divisions could not be made, nor was any sharp dividing line seen between fossiliferous Middle Devonian and the unfossiliferous part below that has been called the Lone Mountain dolomite. A limited number of specimens of *Martinia* sp., similar to those occurring in the Pine Point limestone of Great Slave lake, were found. No doubt this horizon is about the same wherever *Martinia* occurs in the Nahanni-Root sections, but this fossil was not very closely confined in its vertical distribution. Near the top of mount Camsell there is a small series of shales between heavy-bedded limestones and in these shales *Schuchertella chemungensis* occurs at the top of an exposed thickness of 1,550 feet of limestones. The same fossil also occurs on

[1] Kindle, E. M., Geol. Surv., Can., Sum. Rept., 1920, pt. B, p. 44.

Wrigley rock (Roche-qui-trempe-à-l'Eau) at Wrigley, and on the first mountain to the west of Wrigley. On mount Camsell there is a coral horizon about 20 feet higher stratigraphically than this shale zone. This coral zone contains *Cyathophyllum* cf. *quadrigemum, Favosites, Cladopora, Alveolites,* and *Stromatoporoids.* The same coral zone appears on the top of Lone mountain, an isolated mountain southeast of the junction of the North Nahanni-Mackenzie, and 1,900 feet above it. The thickness of strata represented here above the bottom of the talus is slightly over 2,000 feet. On other mountains to the south of this about 500 feet more strata lie on top of the coral zone so that the exposed thickness for the Middle Devonian and Lone Mountain dolomite is in the neighbourhood of 2,500 feet. The base was not seen.

To the south of Lone mountain there is one of the highest peaks of the Nahanni range which it is proposed to call Nahanni peak. It rises about 3,600 feet above the Mackenzie and the summit is composed of Middle Devonian rocks. The edge shows a well-pronounced thrust fault (Plate III A), and its elevation above the other peaks is believed to be due to this cause. Nahanni peak can be recognized for long distances and is one of the most striking mountain features that greets the view of the traveller down the Mackenzie.

Although there is no definite dividing line of lithological distinction between the Lone Mountain dolomite and the Middle Devonian rocks, there is an easily recognizable general difference between the top and bottom. The lower part consists of light grey dolomite, whereas the upper part is much darker, bituminous limestone. The first member of the Upper Devonian above the top of the Middle Devonian is a dark shale, equivalent to the Simpson shale or the Fort Creek shales of Norman. These shales are in places highly bituminous and in them the Imperial Oil Company sank the first oil well. The dark colour and bituminous odour of the Middle Devonian are no doubt due to bituminous materials that have migrated from the shales above. The rock of the Middle Devonian is much the same throughout the whole Nahanni-Root sections; and to the west of Wrigley, it is a very hard, compact dolomitic limestone that could scarcely be considered a very favourable oil reservoir in this region, because of the metamorphism to which it has been subjected. The porous dolomite of the Presqu'ile formation of Great Slave lake is lacking in the Nahanni-Root River area, although it is probably represented by much less porous dolomites or dolomitic limestones. No *Stringocephalus burtini*—the characteristic fossils of this horizon—were found, but since this fossil occurs on Great Slave lake and in the section north of Norman near Fort Good Hope in the Ramparts limestone, there are probably stratigraphic equivalents in the intermediate areas. In fact, the presence of the coral *Cyathophyllum* cf. *quadrigemum* may have some significance as it occurs elsewhere in the *Stringocephalus* zone.[1]

UPPER DEVONIAN

Shale Zone No. 1. These shales, from their position in the stratigraphic column and their fossil content, agree in age with the Simpson shale at Simpson and with the Fort Creek shales of Norman. They lie immediately above the hard Middle Devonian limestone, the contact between the two being very sharply defined (Plate III B). In the Nahanni-Root River area they are dark fissile shales that weather very readily, and consequently they are little exposed as extensive outcrops. Nahanni river flows over these shales for most of its course, except where it cuts through the mountains, and it is owing to the soft erosive character of the shales that the river is free from rapids and falls.

[1] Report of the second Norwegian Arctic Expedition in the *Fram*, 1898-1902, vol. iv, p. 9.

The shales are mostly clay shales, dark to black in colour and quite bituminous. Along with them are thin layers of limestone up to 3 inches thick and layers of calcareous and arenaceous shale. Ironstone concretions are abundant in some localities. The shales are mostly unfossiliferous and consequently it is impossible to identify the same horizons in them from place to place. Fossils do occur, however, and quite abundantly in one zone close to the top, where two species of very small *Chonetes* are the most common along with *Atrypa reticularis*.

Owing to the fact that correlation of strata within the formation is hazardous, the thickness is not absolutely known. It is thought, however, to be not less than 1,000 feet and may be as much as 2,000 feet. Where the best exposures occur and opportunity was afforded for measuring the thickness, folding within the shale itself was evident. It would seem that in the process of mountain-building, with the consequent upheaval of the hard, Middle Devonian rocks into anticlinal ridges, the soft shale took up much of the stress. The dips change very quickly in short distances and in a few places the shale itself has been metamorphosed almost to a phyllite.

Leiorhynchus Zone. Leiorhynchids being very widespread and abundant in strata overlying the Simpson shale equivalents, it is proposed to use the name Leiorhynchus zone instead of adopting a new formation name. Sedimentation was continuous upwards from the Simpson shale and, therefore, there is no sharply defined line between the Simpson shale and the Leiorhynchus zone. An arbitrary dividing line is drawn in a series of alternating thin beds of limestones and shales in which the shale becomes increasingly preponderant downwards and the limestone beds become thicker and more abundant upwards until the whole becomes a limestone phase of sedimentation. This limestone, wherever seen, is mixed with a small amount of shale so that the fossils break from the rock very readily and on talus slopes Leiorhynchids especially were easy to collect and free from the enclosing rock. These Leiorhynchids show a striking variation and have a long vertical range, but by their abundance together with the occurrence of other fossils this zone can be definitely identified. A list of fossils provisionally identified appears below:

Leiorhynchus sp.
Camarotoechia contracta. Abundant at certain horizons
Schizophoria iowensis
Spirifer disjunctus. Common at certain horizons and distributed through the whole zone
Athyris angelica. Rare
Rhynchonella duplicata. Rare
A few lamellibranchs, one species of which is quite abundant in shaly facies of this zone.

In this zone was found a coral reef in which a number of fine crinoid heads were discovered. The fauna of this coral reef differs somewhat from the rest of the fauna seen elsewhere and is, therefore, given separately.

Crinoids—25 crinoid heads in a fine state of preservation were obtained.
Cladopora
Cyathophyllum sp.
Diphyphyllum arundinaceum. Abundant
Phillipsastræa verneuili. Common
Phillipsastræa sp.
Aulopora sp.
Eatonia sp.
Atrypa reticularis. Particularly abundant
Atrypa spinosa. Particularly abundant
Hypothyris cuboides
Leiorhynchus sp.
Spirifer sp.

The fauna here described occurs above the shale which is known to be the equivalent of the Simpson shale. The Simpson shale fauna has been shown by

Mr. Kindle[1] to be the equivalent of the Portage fauna of New York, so that this horizon in which the crinoids occur is younger than the Portage formation. The outcrop of the coral-crinoid reef is about 58 miles up Root river and 2 miles south of the river. Dr. Springer has kindly consented to describe the crinoids found here. The thickness of the Leiorhynchus zone is between 800 and 1,100 feet.

Shale Zone No. 2. Above the Leiorhynchus zone there is another shale facies. Again the line of division is not sharply marked. It is a shaly phase of continuous sedimentation. The lower part is less than 500 feet thick and consists of grey, thin shales alternating with thin layers of limestone. This is followed by a heavy band of massive unfossiliferous limestone only a few feet thick, above which reddish shales occur. These shales have fossils of which the principal one is *Leiorhynchus*. These red shales change upwards to shaly red limestones interstratified with limy shales and in these fossils are quite abundant. The most abundant fossil is *Leiorhynchus* sp., but the specimens from this zone were nearly all very much larger than those found elsewhere. Rarely a *Spirifer disjunctus* was seen. The fossil here referred to *Spirifer disjunctus* may be *S. whitneyi*, because in this zone Spirifer with the fine lines on the striations do occur and are similar to those described as *S. whitneyi* elsewhere. Where the shell is somewhat exfoliated these lines cannot be seen and consequently distinction between *S. whitneyi* and *S. disjunctus* becomes difficult as there is considerable variation shown in specimens of both species. There is another Spirifer—apparently a new species—from this zone which is as far as known confined to these upper red shaly limestones. It has a peculiar shape, being very sinuate on the anterior margin, this giving it a great length in an anterior-posterior direction compared with its narrow width.

A complete list of fossils from this zone is as follows:

Leiorhynchus sp.
Spirifer disjunctus
Spirifer whitneyi
Spirifer sp.

Spirifer disjunctus occurs in the Hay River limestones and shales of Hay River-Great Slave area, and in the Bosworth sandstone of Norman. Until all the faunas are studied in more detail it will not be possible to say how much of the Nahanni Root section is the stratigraphic equivalent of these.

The thickness of the zone measured from the Root River area is not less than 1,000 to 1,200 feet.

Athyris Angelica Zone. This is a relatively thin zone of yellowish limestone with which some grey shaly material is interstratified. The thickness is not more than 200 feet and is probably a little less. Good exposures were found both in the North Nahanni area and in the Root River sections.

The fauna is as follows:

Leiorhynchus sp.
Athyris angelica. Abundant
Spirifer whitneyi
Spirifer disjunctus?
Eatonia sp.
Productella lachrymosa var. *lima*
Ambocoelia sp. Very small fossils—common
Hypothyris cuboides. Two small specimens only

The presence of *Athyris angelica* in abundance is sufficient to distinguish this limestone from the Leiorhynchus zone lower down. The Leiorhynchids that occur in the zone are small and flat and are decidedly different from those

[1] Kindle, E .M., Geol. Surv., Can., Mus. Bull. No 29.

in the Leiorhynchus zone. From a preliminary study it seems safe to say that the Spirifers most closely resembling *S. whitneyi* occur higher stratigraphically than *S. disjunctus*, although both occur together in intermediate zones.

Shale Zone No. 3. This is a thin shale series, the top of which does not occur in the area. It is a dark, fissile shale, much like shale from the lower part of shale zone No. 2. It was found on top of the *Athyris angelica* zone in the North Nahanni section, in the axis of the syncline, where it has been preserved. Its thickness did not exceed 100 feet and it is unfossiliferous.

STRUCTURE

For the major structure it is only necessary to consider the larger stratigraphic subdivisions, the Middle and Upper Devonian and the Lone Mountain[1] dolomite which has been referred to the Silurian. No definitely determined Lower Devonian was seen in the North Nahanni or Root River sections; and from other parts of the Mackenzie valley, it is known that the Lower Devonian is absent, the Middle Devonian resting directly on the Silurian.

The North Nahanni river near its mouth cuts across Middle Devonian mountains, having flowed through a valley which for about 50 miles from the Mackenzie shows the influence of the rock structure on the course of the river. In this part there is a broad syncline with Middle Devonian exposed on the flanks as high mountains 2,000 to 3,000 feet above the river and with Upper Devonian forming the central part of the syncline. The river throughout this part has closely followed the south and east contact of the hard Middle Devonian limestones with the soft, lower shales of the Upper Devonian, and has been able to erode a deep, wide valley in the limestones and shales of the Upper Devonian. These now form cliffs or abrupt scarps from 1,000 to 2,000 feet above the river on the north side. About 50 miles from the mouth there is a change in the direction of the river where it has cut through hard Middle Devonian rocks which form the mountains on the western flank of the syncline. To the north of this point, the whole section from the Middle Devonian to the highest beds of the Upper Devonian is exposed across the axis of the syncline, although, as elsewhere, the shale members are commonly hidden by the heavy growth of forest and the limestones form cliffs at some distance back from the river.

Following up the river through the Middle Devonian mountains, the mountains themselves are seen to be an anticline with very steep dips on the east slope and with less steeply inclined rocks on the west. Due to the westward dip on the west side of this anticline, the hard Middle Devonian rocks are covered within a short distance by stratigraphically higher rocks which farther from the anticlinal ridge have only a slight westward dip. The river has cut so deeply into these sediments that on both sides high cliffs of Upper Devonian rise 1,200 feet or more above the bottom of the river valley. Viewed from a high elevation, this country underlain by Upper Devonian rocks appears to be a gently rolling plateau with a slight southwestward tilt and deeply dissected by North Nahanni river in its course from the southwest. This part of the river was not traversed, but this elevated plateau stretches for at least 20 to 30 miles to the west and terminates against high cliffs—certainly not of Upper Devonian rocks—that represent the edge of the next westward range. Nothing is known of the country to the south or west, between this plateau and the South Nahanni river, a long distance farther west.

The part of the North Nahanni traversed cuts across two ranges, both of hard, resistant Middle Devonian limestones, one range being about 2 miles from the mouth or junction with the Mackenzie and the other 50 miles up the

[1] Kindle, E. M., Geol. Surv., Can., Sum. Rept., 1920, pt. B, p. 44.

river. Both of these ranges rise between 2,000 to 3,000 feet above the river and between them lies the great synclinal structure containing Upper Devonian sediments, into which the river draining from the next southwestward valley has cut a deep trench along the strike of the rocks. The river in this part is, therefore, clearly following the structure, having found the line of least resistance along the contact between the hard Middle Devonian limestones and the soft shales of the lowest member of the Upper Devonian.

Root river also follows a structural valley, but one of a slightly different type from that of the North Nahanni. Mount Camsell range near the mouth of the North Nahanni continues with a slight break to the north and is seen as a high escarpment facing east on the west side of Root River valley. Throughout the greater part of this distance it is a fault face. The throw of the fault is some thousands of feet, for the upthrow side to the west brings up the high ridge of massive and resistant Middle Devonian limestones, underlain by the Lone Mountain dolomite into mountains 2,000 to 3,000 feet above the river and the downthrow side preserves some of the highest known Upper Devonian rocks in contact with the Lone Mountain dolomite. The actual contact is covered with talus from the high Middle Devonian mountains, but the dips and strikes leave no doubt about the character of the structure at this point.

About 6 miles above the mouth of Root river, an anticline in Upper Devonian rocks with a northerly strike is cut by the river, and the rocks on the west limb of this anticline dip toward the fault scarp on the west side of the valley. Root River valley is, therefore, on the west limb of an anticline, the river channel being in Upper Devonian strata. About 25 miles from the mouth the direction of the river changes after having cut through the Middle Devonian mountains to the west. The gap in the mountains is very sharply defined, being less than three-quarters of a mile wide, with the mountains rising precipitously on each side to over 2,000 feet above the bottom of the river valley. Upstream from this gap the valley widens to a great flood-plain several miles in extent, and several streams join from different valleys. This is in reality a continuation of the synclinal structure through which the North Nahanni flows for 50 miles above its mouth, but the anticline which made the prominent mountain range to the southwest of the Nahanni has here entirely died out and the structure is a part of the southwestward-dipping plateau which occurs farther up the North Nahanni. The rocks here are gently westerly dipping Upper Devonian sediments, similar to those west of the Nahanni basin.

Evidence of Faulting

There is considerable evidence of faulting on a large scale presumably during the orogenic movements that have resulted in the present mountainous topography.

As already mentioned the country east of Mackenzie mountains is a low plain, lying for the most part little above the level of the river and dotted with almost innumerable lakes and sloughs. The edge of the mountains rises abruptly from the flat plain with an escarpment in many places showing cliffs 1,500 feet high.

There are no outcrops on this flat plain in front of the mountains except along banks of the Mackenzie. A good exposure on the south side of the river about 5 miles upstream from the North Nahanni river consists of rocks of the Leiorhynchus zone. There is an anticlinal structure shown here with a dip down river well indicated. It seems, therefore, safe to say that the plain back of the Mackenzie is underlain by Upper Devonian rocks, probably mostly of the Simpson shale horizon, that have been brought in contact with the Lone Mountain dolomite by faulting along the base of the mountains. This would make a throw on the fault of approximately 3,000 feet for this particular section. The escarpment that now forms the eastward face of the mountains is thus the result of erosion along a former fault face. This escarpment shows many evidences of extreme brecciation. The limestone has been fractured and stringers of calcite cutting it in all directions are very plentiful. Brecciation of the limestone itself on a large scale was also noted and is further evidence of the intensity of the forces active in the mountain building.

The eastward-facing escarpment of the main range south of the North Nahanni is continued past Lone mountain which shows similar evidences of faulting. Blocks of fault breccia were seen in the talus slope of Lone mountain. It is evident, therefore, that this fault line scarp is not far removed from the former fault scarp. Between Lone mountain and Mount Camsell range there is a break through which North Nahanni river flows. The east face of Mount Camsell range is also faulted, but this fault trends in a direction slightly different to that of North Nahanni mountains to the south of that river. The faulted face of mount Camsell is continued into the mountain range on the west side of Root river, where the character of the faulting is clearly shown. For miles the escarpment, formed as a result of this faulting, is very prominent (Plate IV A) and is composed of Middle Devonian rocks with the Lone Mountain dolomite at the base. About 20 miles up Root river it becomes less steep and is seen to be a fold with the beds dipping up to 70 degrees on the eastward face. In this folding the evidences of movement are clear and the faulting is apparently a result of further movements that have accompanied extreme folding. At the base of the Root River escarpment, rocks high up in the Upper Devonian sequence occur close to the base of the mountains. The throw here is, therefore, between 5,000 and 6,000 feet.

The range to the west of the North Nahanni, from 20 to 50 miles from the mouth of that river, is of the same type as the Root River mountains. It shows very steep folding (Plate IV B) facing the river, with faulting in places. These mountains are unsymmetrical folds with steep dips on the Mackenzie River side and more gentle dips to the west. In places the beds on the eastward side have become so steeply tilted that faulting is more prominent than folding, but it is quite evident that both have played a large part in the mountain building.

ECONOMIC GEOLOGY

POSSIBILITIES OF THE OCCURRENCE OF OIL

The significance of the work accomplished in the Nahanni-Root River areas lies in the section that has been obtained. In a great many places in the Mackenzie valley only isolated outcrops occur, and it is extremely difficult to interpret the structure. The application of the Nahanni-Root River section to other parts of the Mackenzie River area should prove of great value in solving the structural problems involved in prospecting for petroleum.

In the mountains of the Nahanni-Root River areas the conditions are not favourable for oil accumulation. There is no horizon in the Middle Devonian which would be a suitable reservoir under the conditions of metamorphism to which the rock has been subjected, and any oil formerly in the Upper Devonian beds has probably not been retained in them.

In the flat plain to the east of the front range of mountains, suitable conditions may exist. An anticline on Mackenzie river some 5 miles distant from the mountains shows that there is folding on a moderate scale in this flat plain; but the rocks, if they are the same as in the mountain farther west, lack sandstone and very porous dolomite horizons such as would facilitate oil accumulation. It would be an unsafe and unjustifiable conclusion, though, that no suitable horizons exist, because, in the mountains, intensive metamorphism has greatly altered the rocks from the condition they would be expected to have farther east. The area from Simpson west to Mackenzie mountains offers favourable structures for oil prospects but concerning this too little is known of the geology to permit safe conclusions to be drawn in regard to possible oil reservoirs. It is a country overlain by muskeg in which rock outcrops are extremely rare and which is not easily accessible away from Mackenzie river on account of the lack of navigable streams.

TERTIARY PLANT REMAINS COLLECTED BY G. S. HUME IN THE MACKENZIE RIVER BASIN

By W. A. Bell

North side Mackenzie river, about 2 miles up Mackenzie river from Norman:

Sequoia langsdorfi (Brongniart) Heer
Corylus maquarrii (Forbes) Heer
Pterospermites dentatus Heer
Pterospermites spectabilis Heer
Populus arctica Heer
Populus hookeri? Heer
Quercus cf. *olafseni* Heer

West bank Mackenzie:
Acer cf. *arcticum* Heer

All the above species were described by Heer[1] in 1868 and 1880, from the collection made by Sir John Richardson from the lower part of Great Bear river, in 1851, in connexion with his search for Sir John Franklin. They were regarded by Heer, along with other Arctic Tertiary floras, as Miocene in age. Sir William Dawson,[2] however, in 1888-89, in a report on plant remains gathered by McConnell from the same locality in the Mackenzie basin, pointed out the strong resemblance of the flora to that of the Upper Laramie or Fort Union, as well as to the Tertiary floras of Greenland, Alaska, Spitzbergen, etc. He accordingly assigned the Mackenzie beds a Lower Eocene age.

Knowlton[3] in 1904 likewise placed the "Arctic Miocene" flora of Heer in the Eocene (Upper Eocene), and the Mackenzie River beds are referred to the Fort Union group; Penhallow[4] in 1908 came to a similar conclusion in agreement with Dawson's Lower Eocene correlation. On account, therefore, of the close similarity of the Mackenzie Tertiary flora to the other Arctic Tertiary floras it seems safe in the present state of our knowledge to regard the Mackenzie beds as pre-Miocene and to assign to them an Eocene age.

The flora shows a mixture of conifers with such hardwoods as oak, maple, birch, walnut, hazelnut, etc., and hence testifies to a temperate climate in Arctic regions during that part of the Eocene in which it flourished.

GOLD PROSPECTS ON CARIBOU ISLAND, GREAT SLAVE LAKE

Caribou island is situated close to the north shore of Great Slave lake, a few miles east of the southern end of the North arm. For some time gold prospects on it have attracted considerable attention and as the Aurous Gold

[1] Heer, Oswald, Flora Fossilis Arctica, vol. I, 1868, pp. 135-139; 1 Id., vol. VI, 1880, pp. 3-17.
[2] Dawson, Sir William, Geol. Surv., Can., N.S., vol. IV, 1888-89, p. 98 D.
[3] Knowlton, F. H., "Fossil Plants from Kukak Bay," Harriman Exp., IV, 1904.
[4] Penhallow, D. P., "Report on Tertiary Plants of B.C.," 1908, pp. 150-152.

Mining Company was taking an active interest in the development, the writer was instructed to report on the geology and economic value of the island.

Caribou island is in reality wrongly named. The Indians apply the name to a much smaller island and the one on which the gold claims are staked is known to them as White island or île Blanche. However, since the name Caribou has become so widely known to those interested in the gold claims it seems inadvisable to adopt the Indian name.

Caribou island is one of the larger among numerous islands in this part of the lake. It is said to be 10 miles in length in a general east and west direction. It is quite narrow, however, and as is usual in a country of Precambrian rocks the shoreline is much indented, with deep bays which in some cases extend almost across the island. One of these bays with deep water to the shore offers a very sheltered harbour and is situated close to the Aurous Gold Mining Company's claims. This fine harbour has been aptly named "Safety cove" and any one who has travelled on Great Slave lake, especially late in the summer, will appreciate its value. On the shore of Safety cove the Aurous Gold Mining Company has built a well-equipped and neatly constructed cabin which was used during the winter of 1920-21.

Most of the islands near Caribou island are almost barren of larger vegetation and forbidding in appearance. Caribou island, however, presumably on account of its larger size, has a rolling topography of low hills mostly of rocky character with wide valleys which support a thick growth of small spruce. Near the west end some trees, much above the average size, have been in part utilized in the construction of the cabin. One of the striking features at this part of the lake is the thick growth of white Caribou moss, a lichen which in places is several inches thick and covers what would otherwise be bare rock. Where the moss grows most plentifully trees are generally few.

Attention was directed particularly to the part of the island on which claims have been located. Rocks of only two distinct ages were seen. Of these the less conspicuous are green schists which occur as isolated small patches and which are believed to be older than the other and more abundant outcrops that have been incorrectly called granite. It is a pink arkose containing in conspicuous abundance rounded grains of quartz and pink feldspar. In thin sections quite a little calcite and some sericite are shown to be present as well. The rock is, therefore, of sedimentary origin instead of being igneous. It can be traced laterally by insensible gradations into quartzites. These quartzites are grey and it is in them that the most of the quartz veins occur. The quartz of the quartz veins is readily distinguishable from the quartzites.

Particularly across the part of the island west of Safety cove there is a general alignment of veins in the direction north 40 degrees east magnetic. This is apparently a result of vein filling along a former fracture system which has been responsible for the general arrangement. The rocks cut by the veins, as now visible, are all arkose and quartzites. In places the fracture system is evident only as a narrow zone 8 to 10 feet wide in which the vein quartz has been deposited as a mesh-work of small stringers. Hematite is present and stains the rock red. At other places the quartz veins are spread out over a much wider area and appear on the surface of the outcrop as elongated lenticular masses of vein quartz, no one of which can be traced without interruption for any great distance. In these the quartz is most frequently pure white with much less red stain but with veinlets of specularite. Siderite is also present.

Samples from the same fracture zone as that in which the prospect from which the Aurous Gold Mining Company is said to have obtained gold were submitted to the Mines Branch for assay. These samples were taken at various places across the fracture zone and also from individual veins where the fracture system was quite wide. The assays showed no gold. It is only fair to add that owing to the absence from the island of both officials and men of the Aurous Gold Mining Company the particular prospect where gold has been found was not seen. From this prospect very little rock had been excavated and as excavation had been made at many other points on the fracture zone the prospect might be easily overlooked. This was later learned from one of the officials of the company who was accompanying a party on the way to Caribou island when the writer was returning to Edmonton. The conclusion, therefore, is that the Aurous Gold Mining Company obtained the gold from a pocket the extent of which is as yet unknown.

No intrusive rocks were seen, but the east end of the island was not examined. The nearest geological investigation that has been done by the Geological Survey on the Precambrian of this[1] region is in the vicinity of Taltson river which flows into Great Slave lake from the south.

[1] Camsell, Charles, "An Exploration of the Tazin and Taltson Rivers, N.W.T.," Geol. Surv., Can., Mem. 84, 1916.

GEOLOGICAL STRUCTURE OF THE MACKENZIE RIVER REGION

By D. B. Dowling

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Illustrations

INTRODUCTION

The discovery of oil on the lower reaches of Mackenzie river in a well bored by the Imperial Oil Company, Limited, in 1920, led to the expectation that during the season several more wells would be drilled and that considerable drilling machinery would be shipped in. Existing transportation facilities on the Mackenzie were augmented by several power-boats, yet during the whole season of 1921 material sufficient for building only four standard drilling rigs was transported. Only one drill which was shipped in a knocked-down condition and quickly erected, was operated. This knock-down rig was placed by the Fort Norman Oil Company on the north shore of the river, 8 miles above the Imperial Oil Company's discovery well (Plate V). It was in operation for fifteen days and bored through shale to a depth of 1,500 feet, the limit allowed by the casing on hand. No distinct flow of oil is claimed to have been found; but a flow of gas was reached at that depth and piped to the cabin in which a caretaker was to spend the winter. Three derricks also were in course of erection in the Norman area during the summer of 1921. Drilling at Windy point on Great Slave lake proved that the measures beneath the Presqu'ile dolomite at that place are unproductive.

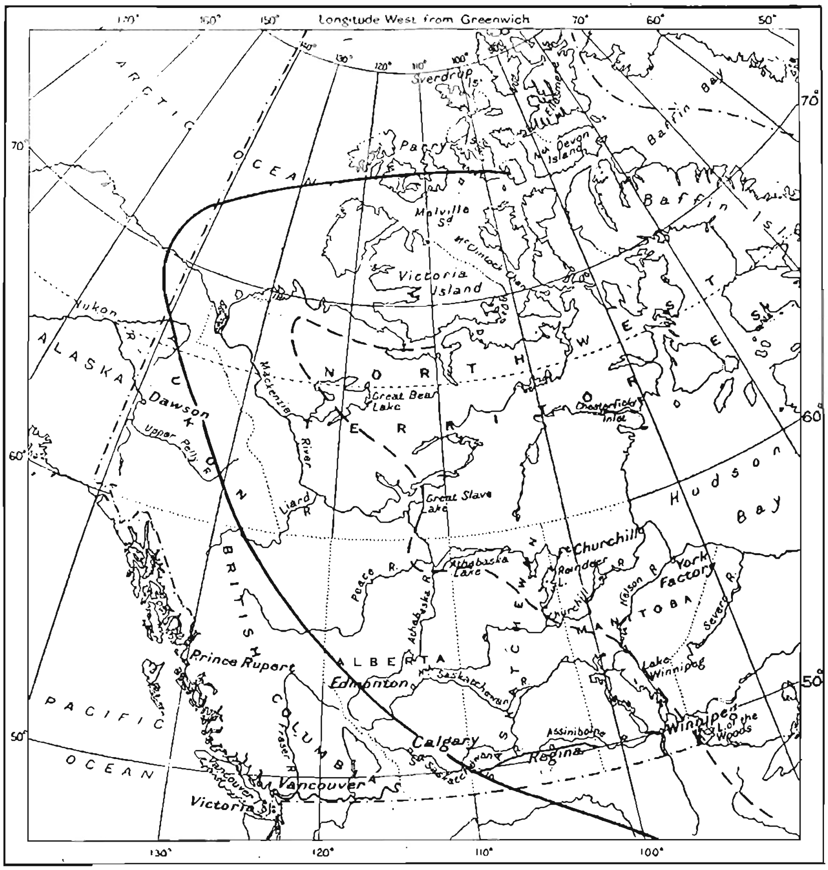
According to the reports mentioned below, the oil in the eastern section of the Mackenzie region, where the structure shows little disturbance, is heavier than that found in the vicinity of the closer folds of the Norman field. The Norman oil has produced, experimentally, a high-grade gasoline which is almost free of sulphur and passes the test for aeroplane use. The flow of oil in the discovery well, being from shale, declined during the summer of 1921 to a few barrels per day.

In this report the writer presents certain observations and opinions regarding the structure of the region as a whole which may shed some light upon its oil-bearing possibilities. Local studies of the Great Slave Lake field are contained in the Summary Reports of the Geological Survey for the years 1916 and 1917, and of the Norman field in the Summary Report for 1920. A review of the history of operations in these two fields may also be found in the Second Annual Report of the Mineral Resources of Alberta, 1920, pages 91 to 101.

GENERAL GEOLOGY

SUB-CRETACEOUS SURFACE

The Cretaceous sediments of the Great Plains rest, at their eastern edge, disconformably on Upper Devonian limestones, but, westward toward the Rocky mountains, later Palæozoic sediments are found beneath the Cretaceous.



It is surmised that these later Palæozoics had a western source and were due either to a general uplift or to a tilting whereby the eastern shore-line of the interior sea in which they were deposited gradually moved westward. In Carboniferous time (Figure 1) there emerged a large eastern and northern area

Figure 1. Sketch map showing the western shore-lines of the Palæozoic sea in northwestern Canada. The solid line represents the western shore of the sea in Upper Carboniferous time; the broken line its western shore in Devonian time; and the area between these lines represents the pre-Cretaceous area of erosion.

of erosion from which early Carboniferous and late Devonian sediments were removed, and in the western part, especially in Alberta, deposition was continuous, though the composition of the sediments indicates a shallowing or a general uplift of this part through Permian and Triassic time. North of the boundary of Alberta and east of the mountains no evidence has yet been found to show that the Cretaceous rests at any point on strata newer than the Devonian.

This sub-Cretaceous surface was subject to erosion as a land area from possibly the beginning of the Carboniferous period. The section in Jasper pass, made up of clastic material largely, is of the earlier Carboniferous period of marine sedimentation. That preserved on Banks island, though largely marine in its upper part, is coal bearing, showing that for a time the early Carboniferous deposits were forming in shallow water. This lends some support to the idea that the nearby Mackenzie area was at this time land. The westward retreat of the sea would also imply a longer period of erosion for the edges of the Palæozoic formations than indicated above and, as Mr. Kindle suggests,[1] that Devonian and earlier sediments were largely removed. In the vicinity of Nahanni mountains the Devonian section is apparently complete, but north and east therefrom the Upper Devonian was largely removed. The pre-Cretaceous surface near Norman is made up of the lower part of the Upper Devonian, but eastward on Bear river it is possible that most of the Devonian was removed, for the limestone exposures appear to be Silurian.

In the Mackenzie basin it would appear that previous to any mountain-building movements, the Palæozoic beds emerged from the sea in much the same manner as is now seen in Great Slave Lake area, that is, in broad bands paralleling their present eastern boundary. Various members were eroded before being resubmerged in the early Cretaceous sea. The material deposited in this sea may well have been derived from extensive areas of the softer beds exposed along its advancing shore, and unconformable relations between the newer deposits and the former land area could thus have been established without earth movements. If there was any folding at this time, it would conform to the general continental structure and might be limited to the ridges north of Bear river near Norman.

CRETACEOUS DEPOSITS

The exact age of the Cretaceous of this basin has not yet been deduced from its fossils. The earliest determinations are probably those by Sowerby, from the fossils obtained from Bear river by Dr. Richardson, naturalist to the second Franklin land expedition. Affinities between the forms found and those known from the oolites of the Oxford clay, were pointed out, and Dr. Richardson[2] suggests that the deposits are probably Lower Cretaceous.

Two fossils brought out by Mr. George Barnston, of the Hudson's Bay Company, were given to H. G. Hind[3] while he was in Manitoba in 1858-59. These were described as new species by Mr. F. B. Meek, palæontologist of the service for the exploration of the United States Territories. Their exact age, however, also the exact locality from which they were obtained, remain indefinite:

"The two ammonites from Mackenzie river are not alone sufficient to determine the age of the rock from which they were obtained; the larger one bears considerable resemblance in form and general appearance to several Jurassic species, though they may belong to the Cretaceous epoch."

1 Kindle, E. M., Geol. Surv., Can., Sum. Rept., 1920, pt. B, p. 46.
2 "Franklin's Second Expedition to the Shores of the Polar Sea, 1825-27."
3 "Assiniboine and Saskatchewan Exploring Expedition," report by H. Y. Hind, Chap. XIX, 1859.

Fossils collected by Charles Camsell[1] on Peel river, which flows through the western part of the Cretaceous basin, were examined by Whiteaves, who made no definite determinations, as they were mainly new forms, but listed them as possibly belonging to the following genera—*Panopoea, Thracia, Tellina, Inoceramus,* and two species of *Desmoceras* nearly related to those described from Peace, Loon, and Liard rivers. The formations on Peel river from which these fossils were obtained are no doubt the Loon River shales. In discussing the age of these and the overlying Athabaska sandstones, F. H. McLearn[2] remarks: "Both this formation and the Loon river have a common fauna, and this is now being studied. The affinities of this fauna are Lower Cretaceous (Albian and Aptian rather than Neocomian) and pre-Dakota, taking Cenomanian as the base of the Upper Cretaceous."

The Cretaceous measures which now remain do not appear to be thick, and from the localities cited above they appear to be generally Lower Cretaceous. It is possible that later measures exist in the syncline at the mouth of Mackenzie river. Deposits of Colorado age—the lower part of the Upper Cretaceous—may be represented by *Inoceramus* beds of the upper measures noted by McConnell on Porcupine river, on the Mackenzie above Norman, and by Camsell on mount Goodenough west of the delta. One loose specimen of a *Scaphite* picked up above Norman this season by a member of the topographical survey party headed by Mr. Bowman, seems to confirm the presence of Benton shales.

Later deposits appear to be all coarser sediments, judging by the presence of such formations as the Dunvegan sandstone of Peace river in the section south of Liard river. These in many places are distinctly land deposits, but the absence of fossils in the sands that cap the Mount Goodenough section leaves the question there not decided. The description of the Goodenough section and of that on Porcupine river leaves the impression, however, that they are shore deposits.

Land deposits in the south, and shore deposits in the west indicate a great contraction in the marine area at the close of the Colorado; that is, the inauguration of the general uplift which expelled the Cretaceous sea can be located with some probability at this period for the area which lies north of the boundary of Alberta. An area of erosion resulted to which reference will be made in the discussion of the physiographic details.

It is generally supposed that the debris deposited in the sea during Cretaceous time was derived from a long, narrow land area now represented by the central part of the Cordilleras. The eastern shore of the Cretaceous sea which moved northward and eastward over the Palæozoic floor and reached beyond the existing stratified rocks, would probably receive reassorted material derived from the denudation of the land in that direction. This material would, however, be in small amount east of the Palæozoic beds, for the Precambrian area in that direction had been already cleaned by long exposure and there appear to have been no great disturbances to elevate it. There is little of this material in the edge of the present Cretaceous terrace. In the vicinity of Great Bear lake and on Mackenzie river the deposits have characteristics which suggest that they originated from the underlying sandstones and shales or from beds that outcropped during the advance of the shore-line. Other deposits—especially those reported on Great Bear lake—seem to be of material derived from a land area consisting of harder and more siliceous materials.

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1 Geol. Surv., Can., Ann. Rept., vol. XVI, pt. CC, p. 48.
2 Geol. Surv., Can., Sum. Rept., 1917, pt. C, p. 16.

Judging by the description of the deposits west of the mouth of Mackenzie river the material brought to the sea was thickest in that direction. Hence, with the shallowing of the sea in the east by continental uplift, the upward movement in the west under the greater load may have been retarded; or the removal of the thinner shore deposits of the east may have commenced while the deposition of the upper sands continued to the west. With the meagre fossil evidence at hand we can only assume that the denudation of the north-eastern edge of the Cretaceous deposits commenced before the Colorado period. This would allow of continuous erosion of this northern part following its elevation.

The topography previous to the formation of the mountains and the deposition of the Tertiary beds can only be inferred. On Wind river the Cretaceous rocks were eroded to the Devonian, and eastward to the Ramparts a mass of Cretaceous was probably preserved in a shallow synclinal trough. Southward the present configuration of the Rocky mountains and the far extended anticlinal ridges suggest that no great load of loosely assembled Cretaceous material lay on the hardened Palæozoic beds.

TERTIARY

The Tertiary beds overlying the Cretaceous at Norman, distinguished by containing burning beds of lignite, are undisturbed by the forces which elevated the steep anticlinal ridges in the older formations of the vicinity. They are slightly tilted, but abut directly against the broken and elevated eastern end of Bear rock. They contain a fossil flora that has been assigned by European writers to the Miocene. Sir Wm. Dawson, after describing the flora of the freshwater deposits which lie conformably above the Cretaceous of Alberta and Saskatchewan, correlated these northern beds with the Laramie, that is, with the early Eocene of Canada. As there is an erosion interval beneath the Norman beds, Dawson's correlation depends entirely on the plant remains. The similarity of floras is equally marked between the plants of the Norman beds and those of the Miocene of Greenland. The fact that the foothills and outer mountain ranges of Alberta were upthrust in late Eocene time also indicates a Miocene age, at least, for these Norman beds, since they are undisturbed. However, Camsell found on Wind river, west of the Norman area and near the mountains, that similar Tertiary beds are there deformed by pressure. In physical condition, the northern beds are, therefore, like the Eocene beds farther south, slightly tilted at a distance from the mountains and more folded on approaching the disturbed zone of the mountains. The latest mountain building, as determined by evidence in Alberta, was at the close of the Eocene, so that the above observations on the physical condition of the northern Tertiary deposits imply an Eocene age and corroborate Sir Wm. Dawson's views.

STRUCTURAL GEOLOGY

The mountains on either side of the Mackenzie valley below Liard river are at variance in some respects with the ranges found along the western border of Alberta. The rectilinear Alberta ranges give place in the north to a rather divergent series which projects farther eastward, almost across what has been called the Rocky Mountain geosyncline. The Alberta mountains are formed from the fractured and folded extra-thick beds of the western part of this geosyncline. The northern mountains, on the other hand, are formed from much thinner deposits that overlie the Precambrian; and they present phenomena which suggest that in their formation a comparatively thin sheet of the stratified crust was crumpled by compressive strain. The northern mountains, particularly those near the outer eastern margin, appear to have been elevated before the Tertiary beds at Norman were deposited. Accepting Sir William Dawson's opinion that these beds are Eocene, and considering the apparent deformation of the Cretaceous, it would seem that the northern mountains were formed early in the period of crustal compression which was inaugurated towards the close of the Cretaceous. They, therefore, antedate the outer ranges of Alberta which were formed at the close of the Eocene.

As mountain building involves movements of wide extent, these two mountain-building operations no doubt each affected the mountain structure of both regions. The effect of the early Eocene or late Cretaceous movement in the north is shown in the ridges near Norman, the main ranges of the Mackenzie mountains, and in the formation of the basins holding Tertiary beds in the Yukon plateau to the west. The effect of the post-Eocene movements is shown

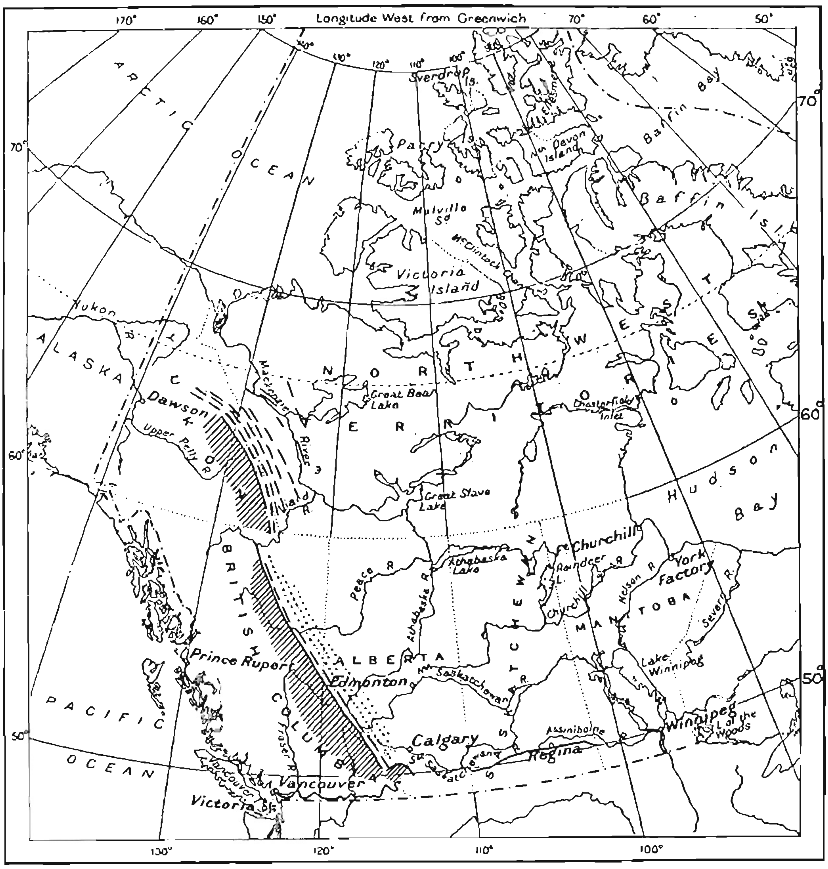


Figure 2. Sketch map of the Eastern belt of the Canadian Cordilleras, showing: (*a*) area of uplift, normal faulting, and trenching, in oblique line shading; (*b*) area of compression and overthrust during late Cretaceous time, in broken lines; (*c*) area of compression and overthrust during late Eocene time, in dotted lines.

in the overthrusts of the outer Rocky mountains, in tilting of the Tertiary beds at Norman, and in folding of the Tertiary beds of Wind River plateau to the west. The order of formation within the two groups of mountains seems to have been opposite in direction. The Rocky mountains, originating in a series of large fault blocks followed by the formation of overthrust fault blocks that formed mountain ridges to the east, show a progression from west to east. Mackenzie mountains, with which may be grouped Franklin mountains, originating with crustal movements and folds followed by the regular Rocky Mountain type of thrust fault blocks, show progressive development from east to west (Figure 2). The sediments in the Rocky Mountain geosyncline, as exposed in the several ranges, are much thicker than corresponding beds in the plains to the east. This greater thickness, and the coarse composition of these sediments, indicate a western derivation.

During the long period from the earliest Cambrian and to the close of the Carboniferous, there was steady erosion of a western land area, but there is little evidence in this time of mountain building. The great mass of sedimentary material laid down in the sea shows merely a gradual expansion and contraction of this sea, from a maximum—probably in Silurian time—to a minimum at the close of the Carboniferous.

Strains then followed which were continental in extent and caused an elevation of the western part of the continent which reached a maximum at the close of the Palæozoic era, and may have been general enough to disclose the unequal loading of this ancient sea-bottom. The normal faulting found in the Selkirks and even eastward may have commenced at an early date, although Jurassic batholithic intrusions[1] of the Pacific coast and southern interior of British Columbia represent the period of adjustment.

There are indications in the Cretaceous deposits of revived denudation of the land area to the west, and of a depression of the central part of the continent, to allow of the invasion of the Cretaceous sea which reached a maximum for the southern interior of the continent during the Colorado period. Very coarse conglomerates appear along the western margin, covering the marine Jurassic beds and in greater amount the land deposits of the early Cretaceous. These conglomerates in turn in the vicinity of Coleman are overlain by erupted material, probably the best evidence in the Cretaceous of a nearby elevated land area and of probable differential movements of the land concurrent with the sinking of the eastern area beneath the Cretaceous sea. The first marks changes in elevation at the close of the Jurassic which affected the land areas; the second the inauguration of a greater subsidence occupied by the sea during late Cretaceous time.

The fault blocks forming what may be described as the British Columbia portion of the Rocky mountains are separated by fractures of generally high dip. The various elevations of the mountains during Cretaceous time can, therefore, be attributed not so much to lateral pressures as to the deeper-seated forces which caused the elevation of the land mass of the central part of the Cordillera and the sinking of the eastern geosyncline. These blocks have been so greatly eroded that their elevation must antedate by a long period the fracturing which produced the slip planes for the series of overthrust blocks which form the eastern Rocky mountains.

There seem to be two physical causes for these mountain areas, an earlier one of isostatic adjustment just mentioned, and a later one of crustal compression. Certain foldings observed in these early fault blocks that are not involved in later faultings of the overthrust type are certainly due to compression. The probable re-elevation of the eastern series of blocks relative to those to the west seems also to have been due to compression. This re-elevation of the marginal blocks established structural lateral channels and greatly

[1] Schofield, S. J., "Origin of Purcell Trench," Trans. R.S.C., vol XIII, 3rd series, Sec. iv, p. 28.

changed the lines of drainage.[1] The valleys so formed and sculptured are older looking than the denuded channels that were cut through mountains formed during the early Miocene period of stress. The revived drainage into the Mid-Cretaceous sea may date from a period of pressure which caused the changes in the eastern margin of the Cretaceous sea (Figure 3), and the change in the sediments noted above. The later Cretaceous sediments indicate a nearby erosion area. The early Cretaceous that is preserved in the outer mountains, though a land deposit, is only occasionally of coarse material and represents the erosion products from land elevated during the close of the Jurassic. Marine beds to the east and north are finer sediments.

The Mid-Cretaceous disturbance is marked, as noted elsewhere, by heavy beds of conglomerate covering the early Cretaceous near the mountains. The retreat of the Cretaceous sea is marked by changes in sedimentation that show

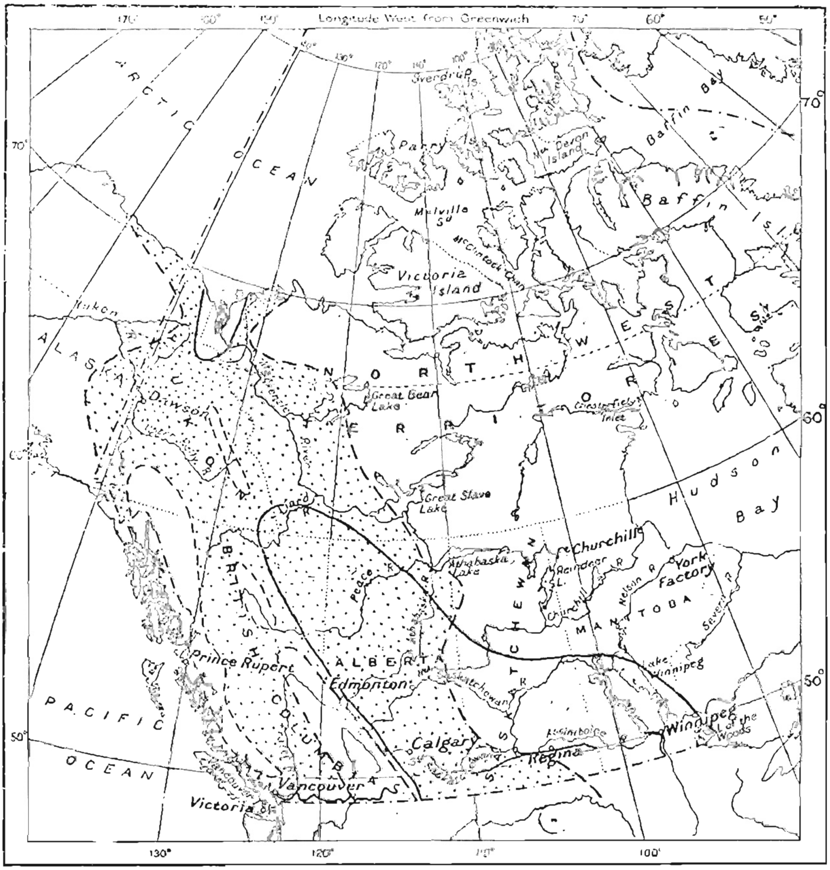


Figure 3. Sketch map showing northern uplift in western Canada during late Cretaceous time. The stippled part with broken-line boundaries represents the area submerged during the advance of the sea in Lower Cretaceous time, the unstippled parts representing islands. The two solid-line boundaries define areas of marine retreat during Upper Cretaceous time.

an irregularity in the movement and no doubt indicate minor periods of stress and probably some deformation as well. It is probable that most of the material which reached the Cretaceous sea in its later stages was removed from the

[1] Schofield, S. J., "Rocky Mountain Trench," Trans. R. S. C., vol. XIV, 3rd series, Sec. IV, p. 62.

immediate front of the mountains, and the large amount of this material suggests that former shore deposits were being redistributed from a rapidly rising land surface.

The Eocene deposits indicate no great disturbance. The general Eocene uprise is shown by the activity of the rivers in bringing material eastward from the fractured and elevated tributary land. This is marked by abundant crossbedding in the great sand deposits that were laid down in thick beds. The close of the Eocene is generally credited with the maximum uprise and surface displacement, the inauguration of volcanic outflows marked prominently in maps of southern British Columbia, overthrusting at the edge of the preexisting mountains, the formation of new mountains in the fractured zone, and the deformation of the Eocene beds along with the underlying formations.

The deposition of coarse sediments, mainly conglomerates, on the plain far to the east of the mountains, is attributed to the denudation of the newly risen mountains. The summit of Cypress hills exhibits this material. Vertebrate remains discovered in the debris point to the age as Oligocene. The last mountain building is thus placed at the close of the Eocene and, probably, was contemporaneous with the period of vulcanism in British Columbia, which is placed in early Miocene time.

NORTHERN RANGES

North of the sixtieth parallel the mountain ranges do not lie along the western edge of the great geosyncline, as in Alberta, but cross the geosyncline northward to near its eastern edge. The sediments are greatly reduced in thickness as compared with those in the south. There was a lessening in the amount of sedimentation, and a total lack of it from Carboniferous to early Cretaceous time. Denudation probably lasted from Carboniferous to Cretaceous time (Figure 2). Cretaceous sedimentation was also limited to the early part of the period. The foundation material for the formation of these northern mountains seems, therefore, to be quite different from that in the area of normal faulting in Alberta.

A great part of the northern mountain structure seems to be limited in time to the periods of compressive strain in the ranges to the west and in Alberta. In Yukon granitic batholithic intrusions are found in the western part of Mackenzie mountains and are tentatively held to be of Cretaceous age. They are intimately associated with the earlier intrusions of the Coast range, but although very similar, lithologically, they were apparently intruded somewhat later. During the period of subsidence marked by the spread of the early Cretaceous sea over this part of the continent there was little other disturbance. The elevation of a large area in the north over which there seems to have been little deposition of Upper Cretaceous sediments, may have been accompanied by some folding and intrusion. D. D. Cairnes found evidence of the intrusion of the Laberge series by the granite in Atlin[1] and White River districts,[2] which indicates some of the intrusion to be post-Lower Cretaceous. Evidence of the deformation of the Cretaceous before Tertiary time is contained in the following quotation:[3]

"During early Tertiary time freshwater sediments were deposited throughout considerable portions of Yukon and Alaska. These beds were apparently, for the greater part at least, deposited in isolated basins, and now consist mainly of friable, partly consolidated sandstones, shales, and clays, which in places contain seams of lignite. In Upper White River district these beds,

1 Geol. Surv., Can., Mem. 37, p. 69.
2 Geol. Surv., Can., Mem. 50, p. 95.
3 Cairnes, D. D., Geol. Surv., Can., Mem. 50, p. 115.

which are considered to belong to the Kenai series, have only a slight development but occur through three small areas. They are nearly flat-lying wherever exposed, and are thus contrasted with the Mesozoic sediments which are extensively and in places even minutely deformed, closed folding being characteristic of the structure in many localities."

Apparently, therefore, the country west of the Mackenzie was deformed and invaded by granite between early Cretaceous and Eocene times. The mountains between Mackenzie and Yukon rivers may have been outlined at this early period, and the early Miocene disturbances may have been confined mainly to the uplift of the Yukon plateau, minor changes in elevation of the mountains, and to a mild deformation of the Tertiary beds.

The early Miocene disturbances, because of their magnitude, would be the first to be credited with mountain building in the north were it not that disturbed Eocene beds lie against folded Palæozoic rocks at Norman and against Mesozoic beds on White river in Yukon. A pre-Cretaceous age can not be assumed for the mountains unless great unconformities can be found beneath the Cretaceous at more favourable places than at this distant point. In the Rocky mountains the Kootenay formation lies conformably above the Jurassic at the top of a complete section. On lower Athabaska river slight undulations in the Devonian overlain by the Cretaceous may be, and probably are, the result of later strains. Finally, in Mackenzie valley the Cretaceous measures appear to be conformable with the underlying Palæozoic rocks and are folded with them.[1] Mr. Link, of the Imperial Oil Company, informed the writer that on Little Bear river, west of one of the pitching anticlines, the Cretaceous conforms with the anticlinal structure; also, that west of Franklin range and Mackenzie river the prevailing dip in the Cretaceous is to the west away from the range. The eastern ranges were largely constructed between the period of uprise in the late Cretaceous time and the deposition of the Eocene sediments. Little is known of the earlier mountain structure which lies to the west. Older mountains or land areas no doubt existed, as in the south, but probably did not attain as great elevation; nor were they of the same block formation. Keele's[2] description of Mackenzie mountains contains the following summary: "The topography of the western portion bears evidence of long-continued differential erosion while the eastern portion has the appearance of being in a more youthful topographic stage. Both in geology and structure the eastern portion of these mountains is closely related to the Rocky mountains in southern Canada."

LATE CRETACEOUS SEDIMENTATION AND DENUDATION

The Cretaceous rocks on Peel river are predominantly sandy. A section measured by Camsell[3] near the mouth of Mackenzie river shows the lower shale series capped by a thick sandy formation which represents the later Cretaceous deposits. Whether this was deposited in the sea or is a delta deposit can only be inferred. Its proximity to the present coast suggests marine deposition. It was evidently derived from a nearby land area. As there are other evidences of an uplift in the north dating from the middle of the Colorado period the land area no doubt formed a broad band in front of the older mountains, over which the debris from the mountain area was spread. The maximum uplift was probably within the area denoted on geological maps by the absence of Cretaceous deposits, that is west of Great Slave and Great Bear Lake basins. An ancient land area was thus formed between the southern Cretaceous sea and Arctic waters. The shore deposits of the sea which retreated south have

[1] See Plate VI.
[2] Geol. Surv., Can., Pub. No. 1097, p. 18.
[3] Geol. Surv., Can., Ann. Rept., 1906, vol. XVI, pt. CC, p. 46.

been largely removed except along its western shore-line, represented by the broken areas of the foothills. There are some masses of coarse sediments, however, which may have been derived from the land barrier to the west (Figure 3). The Dunvegan sandstone, the Wapti formation, and the Edmonton formation, all of which decrease in thickness to the southeast, are examples of the Cretaceous sand formations, which in their southern extension lose this character.

Pre-Tertiary denudation of the Cretaceous measures in the northern basin may have been complete in certain elevated parts, for example, in Wind River basin where the Tertiary rests directly on upturned Devonian beds,[1] or on the northward slope and near the crest of the Cretaceous land barrier, where the continued removal of material may have reached down to Devonian beds. In less elevated areas, the measures covering the Palæozoic floor include beds which seem to have been deposited before the uplift. These are the marine shales above Norman containing *Inoceramus* and *Scaphites* and supposed to be of Colorado age.

Continued uplift expelled the Cretaceous sea from the present continent, after which followed a period of tranquillity through Eocene time. Mountain building which did not deform the Eocene deposits but is recorded in folding and tilting of the Cretaceous must, therefore, have taken place during the period in which the land areas assumed their present extent, i.e., the close of the Cretaceous period.

This late Cretaceous activity is not registered along the Alberta ranges, although fractures with low horizontal dip may have been formed and masked beneath the incompetent mass of Cretaceous sediments, which were largely of continental formation. Surface movement probably spent itself in overthrusting and in the elevation of this unconsolidated mass. Northward the conditions were changed by the introduction of granitic intrusions in the area to the west, the denudation of a large part of the crustal load, and by the presence near the surface of competent beds to transmit compressional stresses. The strains of this period were thus locally greater and were transmitted much farther eastward than in Alberta. The character and extent of the resultant folding suggests that the plane of sliding was not a deep one. The margin of the disturbed belt north of Liard river includes a triangular area bordered by ridges or folds. The east side bears nearly north to beyond Great Bear river. The north side extends in a slight northward curve, from a plateau remnant of Cretaceous at the mouth of Mackenzie river eastward to meet the line of folding that forms the eastern boundary. The western side of the triangle consists mainly of folds and possibly overthrusts bowing inwards, each succeeding westward range straightening this alignment. The western ranges are not yet definitely outlined nor is their history known. The structure outlined by Keele[2] exemplifies the prevailing folding of Mackenzie mountains.

MOUNTAINS EAST OF MACKENZIE RIVER

The eastern edge of the area affected by mountain building consists of several close folds lying *en échelon* and forming Franklin mountains (Plate VI). The structure shows the effect of a lateral pressure and also of a relative northward movement of the crust on the west side of these mountains. This line of movement may perhaps be compared with the line observable between the current of a stream and the backwater caused by an obstruction. In this case the area east of the line of movement was protected behind the Cretaceous plateau. The movement of the crust was through the gap between the Liard plateau and the Peel plateau. The line of deformation should,

[1] Geol. Surv., Can., Ann. Rept., 1904, p. 41 CC.
[2] Keele, J., Geol. Surv., Can., Pub. No. 1097.

therefore, be somewhat arc-like, but as the direction of strain appears to have been from the south for the first part of the movement, a different alignment was actually produced. The most northern fold bears nearly east and west, normal to the direction of pressure. The eastern folds show the effect of a lateral strain. Following the elevation of the ridges along the east side, the resistance offered by the accumulating weight in the folds deflected the zone of stress westward and developed a zone of shearing. The parting of the crust along the western side of this shear zone allowed further northward movement and several concentric folds were formed along the northern edge, ending abruptly at the shear zone. The succeeding movements produced more extended folds which appear to have been caused by pressure from the southwest. These form the western edge of the triangular area referred to already and the succeeding movements of the crust produced additional steeper folds lying against them to the westward.

NORMAN PLAIN

An almost level plain extends between the general mass of the Mackenzie mountains and the outer edge of the mountain-built area described above. It is in some parts about 30 miles wide and is presumably underlain by rocks that are not sharply folded. Bedrock is masked by vegetation—spruce, willows, and moss. Near the river there appears to be a cover of drift but the higher ground, back from the stream, may expose some of the hard bedrock, which is probably largely Cretaceous, although, as compression of the beds has produced an irregular series of buckles, occasional exposures of the Palæozoic beds may be expected.

The plain seems to be divided into two parts by the inferred line of shear (Plate VI).

The eastern part, which contains Mackenzie river in its course above Norman, is probably crossed diagonally by several buried ridges and hollows and is depressed in the vicinity of the ends of the ridges normal to the Franklin range. The southern part of this strip is narrow and may be merely a syncline between the mountain ridges on either side of the river. West of the shear zone the Norman plain shows a few ridges which may be structural. Near the northern border the dip of the beds into the basin rapidly flattens and it is surmised that a wide area is available for prospecting with the drill, as the basin does not appear to be deep.

Determination of the structure will depend on the determination of the Cretaceous section, for these beds probably rest almost conformably on the pre-Cretaceous formations. A determination of the thickness of the Cretaceous to be drilled through will, therefore, help in estimating the probable depth to the oil horizons in the Devonian. The westward extent of this basin as an oil field is not determined. Westward of the end of the ridges bordering the Mackenzie on the north, the plain seems to extend far, since no mountain chain can be seen from the river. It may be, however, that the measures dip beneath an added thickness of Cretaceous, as they do on the Mackenzie below the Ramparts, and that the available oil field is restricted in that direction to a zone bordering the mountains to the south. Mr. Link found along these mountains the upturned beds from the basin as on the north side, so the structure of the plain is probably that of a flat basin with its edge upturned on two sides.

Deep depressions such as would be possible along the shear zone or in the centres of synclines would form basins for the collection of debris during Eocene denudation. The presence of Eocene beds should, therefore, indicate areas where the Middle Devonian beds are at a maximum depth.

KANANASKIS LAKES-PALLISER RIVER MAP-AREA

By J. R. Marshall

CONTENTS

INTRODUCTION

During the field season of 1921, the writer continued the structural and stratigraphic mapping of the Kootenay coal-bearing rocks and associated formations on the eastern slope of the Rocky mountains. Up to 1920 this investigation covered the territory comprising the eastern and western slopes of the Rocky mountains in Alberta, south of parallel 50° 30′ north latitude. From June to October, 1921, mapping was carried northward into Kananaskis Lakes-Palliser River map-area, special attention being devoted to the areas in which economic deposits of coal occur or are likely to be found. Such areas are the south branch of Sheep creek, in the upper 6 miles of its course; the valleys of Mist and Storm creeks (the headwaters of Highwood river) and Pocaterra creek, flowing to Kananaskis river.

Very efficient assistance was rendered in the field by J. Drybrough and M. L. Urquhart.

Sincere thanks are also tendered to Mr. P. Burns and the officials of the P. Burns mine for the many courtesies extended during the season.

The area explored may readily be reached from Okotoks, on the Calgary-McLeod branch of the Canadian Pacific railway, or direct from Calgary by automobile. A good wagon road is available from Okotoks to the P. Burns coal property on Sheep creek,[1] about 45 miles. Automobiles commonly travel to within 10 miles of the mine, the remainder of the distance being covered by wagon. From the P. Burns property good pack trails lead to the various parts of the area.

GENERAL GEOLOGY

The stratigraphic column consists of an apparently conformable succession of rocks ranging from Devono-Carboniferous to Upper Cretaceous. The rock succession and lithological and structural features are in the main similar to those of the northern part of the Crowsnest coal field, and Highwood River coal area, both of which have been described in previous summary reports.[2]

The Kootenay formation carries all the workable coal in the area examined and alone is described in detail here:

Table of Formations

Pleistocene and Recent	Superficial deposits
Upper Cretaceous	Allison formation
	Benton formation
	Blairmore formation
Lower Cretaceous	Kootenay formation
Jurassic	Fernie formation
Triassic	Upper Banff formation
Devono-Carboniferous	

[1] The Geographic Board now applies the name Sheep creek to the branch formerly known as the South branch.

[2] Geol. Surv., Can., Sum. Rept., 1918, pp. 13 C-16 C; 1919, pp. 14 C-20 C.

KOOTENAY FORMATION

The Kootenay formation maintains its typical aspect across the area. It is characterized by crossbedded grey sandstones, dark shales, and intercalated coal seams. The prominent conglomerate band, at the top, which in the area to the south separates the productive Kootenay measures from the non-productive Blairmore formation above, is present, wherever the Kootenay is overlaid by younger formations. As in the adjacent Highwood River area, and the Crowsnest field farther south, the Kootenay of the Kananaskis-Palliser area contains extensive and important coal deposits not too far distant from existing railways. The measures have been prospected on Picklejar creek at the southern border of Kananaskis map-sheet; and on Pocaterra creek, across the divide separating the Highwood and Kananaskis waters, and have been considerably developed on the Burns property, Sheep creek, where the most extensive exposure of the measures may be seen. This exposure, 6 miles from the source of the creek, is the easternmost band of the area and forms the western slope of Highwood range. It extends south across Picklejar creek and connects with the easternmost band of Highwood River coal area. From the Burns mine westward across the Highwood range, the Kootenay formation is four-fifths of a mile wide. Northward along Sheep creek the width increases up to 1¼ miles on the north side of Burns creek, beyond which the band is greatly restricted and at the head of Sheep creek disappears entirely, where its limestone is thrust eastward upon Fernie shales.

The continuity of the band just referred to is worthy of note. From the Crowsnest area northward across the Oldman-Highwood River divide three main bands of Kootenay measures are exposed almost continuously.[1] Two of the bands cross the Highwood area, this particular band being the easternmost. There is, therefore, a continuous exposure for about 100 miles from Crowsnest pass to the head of Sheep creek.

A second band of Kootenay measures outcrops on the west side of Mist Creek valley. North of the head of Mist creek it joins the band from P. Burns mine. Southward it continues across the tops of the ridges on the west side of Mist creek to the junction of Storm and Mist creeks, where it unites with a band from Storm creek to form the western band of the Highwood area.

The band on Storm creek continues across the divide into Pocaterra creek where it forms a high sandstone ridge along the western side of the creek. About 5 miles from the head of Pocaterra this band crosses the creek and continues northward as a narrow belt between two limestone ridges which appear to unite in a distance of 10 miles.

ECONOMIC GEOLOGY

Coal is the only mineral of economic importance in the district. All the workable coal is contained in the Kootenay formation, and is the high carbon bituminous variety, so characteristic of the eastern slope of the Rocky mountains in southern Alberta. There are no working mines in the area; for transportation facilities are limited to wagon roads, and the nearest railway is 45 miles distant. A preliminary survey for a railway has, however, been made along Sheep creek to the P. Burns mine, and a right-of-way has been cut.

Considerable prospecting has been done over the band of Kootenay rocks which extends from the head of Sheep creek along the western slope of the Highwood range and across Picklejar creek to connect with the easternmost band of Kootenay rocks in the Highwood River area. Coal seams have also

[1] Geol. Surv., Can., Sum. Rept., 1918, p. 16 C.

been opened up in the Kootenay rocks on Pecaterra creek. No prospecting appears to have been done along the western side of Mist creek, nor on Storm creek, on both of which are numerous showings of coal. The measures, however, are more broken by faulting and more intensely folded than in the prospected areas and are, therefore, less adapted for mining on a large scale.

On the P. Burns property coal seams have been uncovered on almost all the west tributaries of Sheep creek in the upper 6 miles of its course. A tunnel driven for 2,250 feet across the measures cuts twelve or fourteen seams of coal ranging in width from a few inches to 39 feet. There are at least seven workable seams, the first of which, 1,376 feet from the tunnel entrance, is reported to be 39 feet thick. At 1,500 feet from the portal there is a 21-foot seam. Neither of these seams could be conveniently sampled. Both dip 75 to 80 degrees west and the coal where the absence of timbering permitted a view was considerably crushed and broken.

At 2,200 feet from the entry a seam 12 feet wide was crossed. In it the coal is of the lump variety and considerably harder than the coal in the first two seams. There are 8 feet of clear coal and the remaining 4 feet contain two bands of shale, 1 inch and 2 inches in thickness. These, however, can readily be separated from the coal. A selected sample was taken from this seam, also a channel sample across the entire width, but both bands of shale were omitted. Below are given results of analyses made by the Mines Branch.

Analyses

—		1	2
Proximate analysis:			
Moisture	%	0·4	0·4
Ash	%	4·4	13·9
Volatile matter	%	16·4	14·7
Fixed carbon (by difference)	%	78·8	71·0
Ultimate analysis:			
Sulphur	%	0·9	0·9
Calorific value in B.T.U. per lb		14030	13250

1. Selected sample—forms poor coke.
2. Sample across seam—agglomerates.

On Sharp creek, the first creek tributary to the Sheep, northwest from the main tunnel, a number of shorter tunnels cut the same seams that are intersected in the main tunnel. Some of the tunnels still afford access to the coal, of which there are at least 70 feet workable. A sample from one of these seams, 15 feet in width, was analysed by the Mines Branch, Ottawa, with the following result:

Proximate analysis:[1]		
Moisture	%	0·5
Ash	%	15·4
Volatile matter	%	13·4
Fixed carbon (by difference)	%	70·7
Ultimate analysis:		
Sulphur	%	0·4
Calorific value in B.T.U. per lb		12930

To correlate any of the seams exposed on Sharp creek with those observed in the tunnel, or to trace the continuity of seams along the strike of the for-

[1] Non-coking.

mation, would involve much more time than is available, in one field season. The measures, however, were traced continuously from the head of Sheep creek to and across Picklejar creek into the Highwood River area.[1] Along the strike between the P. Burns property and Picklejar creek good indications of coal can be seen at many points.

A traverse up Picklejar creek across the measures proved the existence of workable seams in that locality. Two seams 10 feet and 7 feet in width respectively were observed. A seam about 50 feet in width is reported on Picklejar creek, but was not seen by the writer.

A sample of coal from the 9-foot seam on the slope north of Pocaterra creek was analysed by the Mines Branch and gave:

Proximate analysis:	
Moisture %	0·6
Ash %	6·0
Volatile matter %	17·1
Fixed carbon (by difference)	76·3
Ultimate analysis:	
Sulphur %	0·6
Calorific value in B.T.U. per lb	14510

Agglomerates
Coal crushed, pulverulent type

The exposures on Sheep creek offer the best opportunities for mining on a large scale. The structural features, judging from the sections available, are less complex than in other parts of the area. Folding appears to be the main factor involved. The section exposed in the Burns tunnel shows some sharp folds in the Kootenay, and these may involve minor faults, but this can be determined only as development progresses.

The faulting characteristic of the Kootenay which crosses the Highwood area extends into that formation on Picklejar creek and renders the structure there somewhat more complicated. Faulting and intense folding are factors to be considered on the west side of Mist creek and on Storm creek. On Pocaterra creek the outcrop of the Kootenay is greatly restricted by faulting, and the rocks are intensely folded.

There are, without doubt, extensive reserves of high carbon bituminous coal within the area examined, and it is reasonable to expect that with more intense prospecting and as development progresses, more and even better coal seams may be uncovered.

Mining methods adopted in other coal fields of the Rocky mountains will apply in this area and the deposits are so situated that railway communication may be provided with little difficulty.

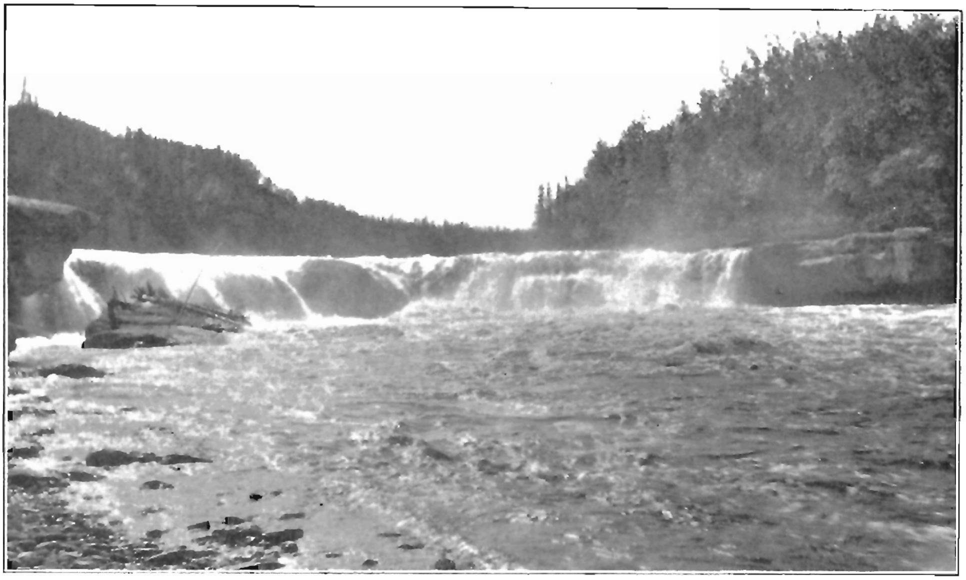
[1] Geol. Surv., Can., Sum. Rept., 1919, pp. 14 C-20 C.

PLATE I

A. Nearly treeless plateau on top of Horn mountains. (Page 47.)

B. Soft crumbling Cretaceous shales. Near head of small creek, southeast end Horn mountains. (Page 54.)

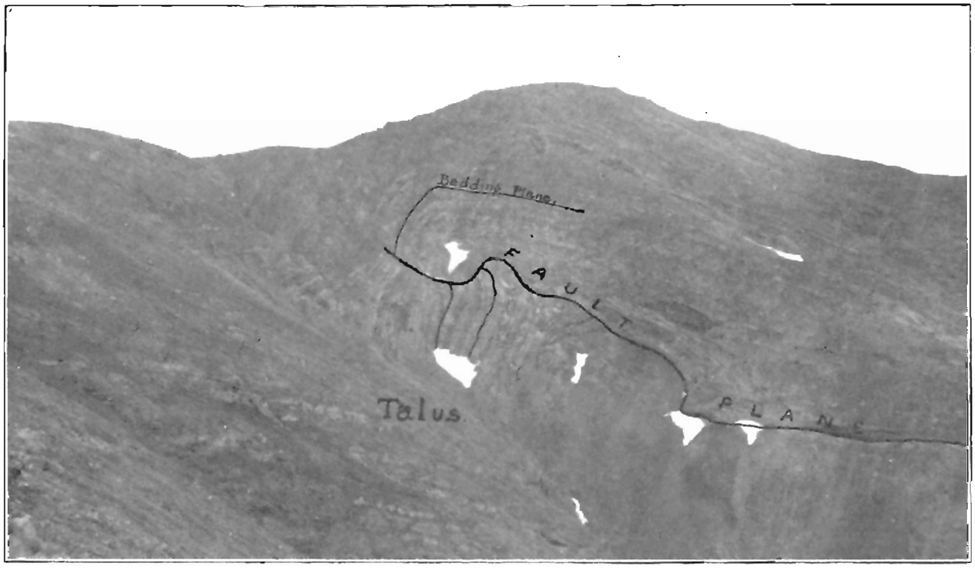
PLATE II



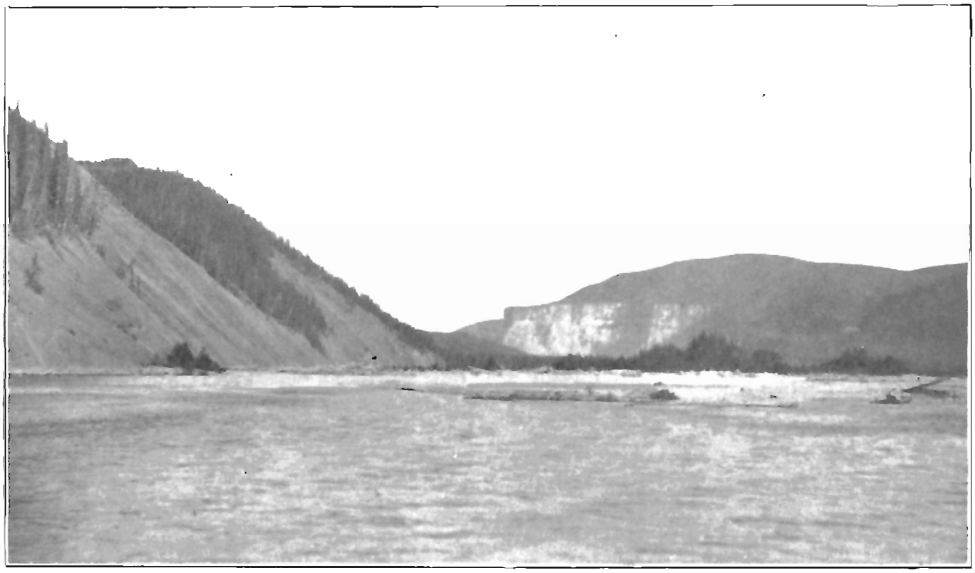
A. Third falls, Trout river. Heavy-bedded limestone of *Cryptonella* zone is shown at the right. (Page 53.)

B. Submarine unconformity between beds of the *Spirifer whitneyi* zone and the *Cryptonella* zone near lower edge of picture. One mile above Third falls, Trout river. (Page 53.)

PLATE III

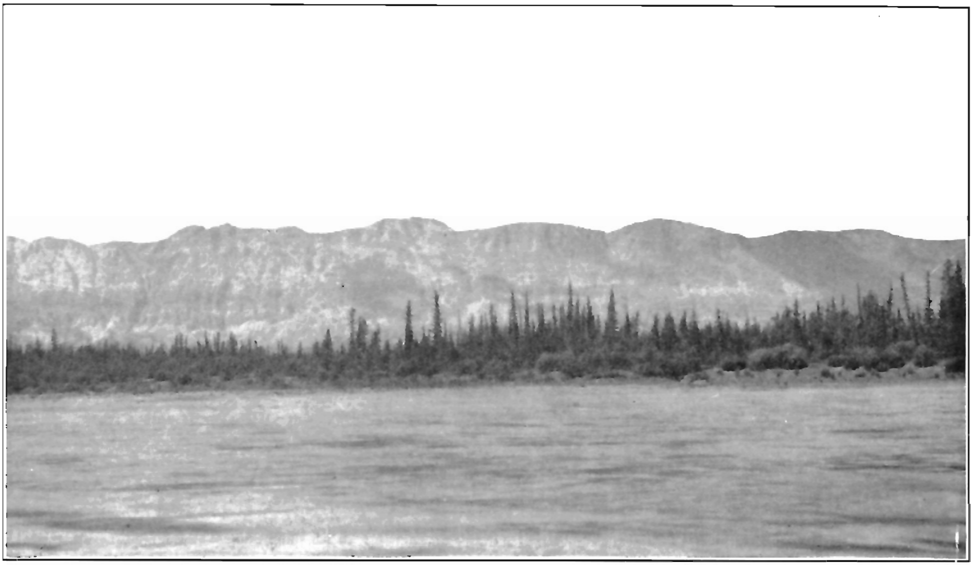


A. Thrust fault of unknown throw exposed on the north slope of Nahanni peak. (Page 70.)

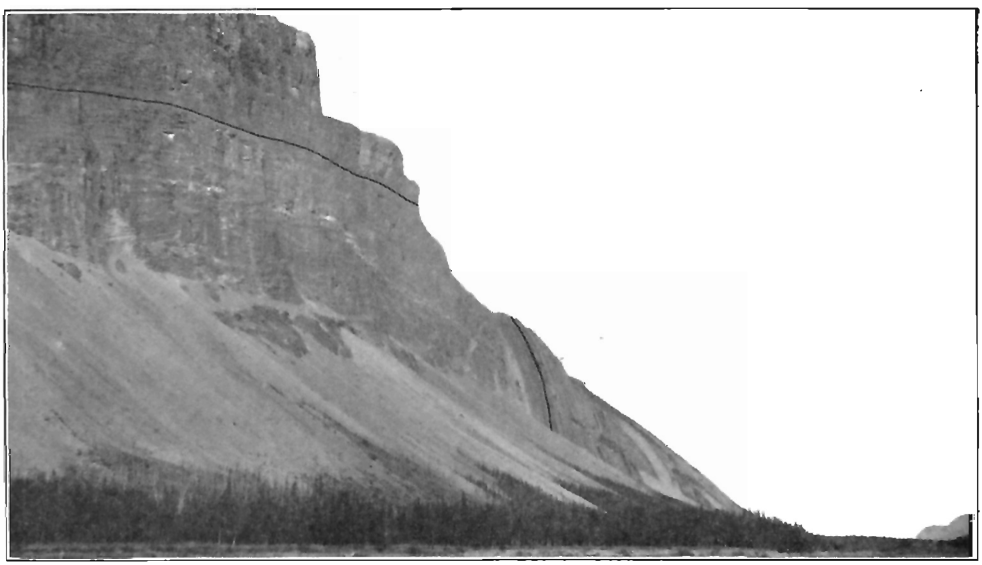


B. Contact between heavy Middle Devonian limestones and Upper Devonian shales about 50 miles up North Nahanni river. The shale in left of picture is the same as the shale which occurs above the limestone cliff on right of picture, the limestone having a dip to the left. (Page 70.)

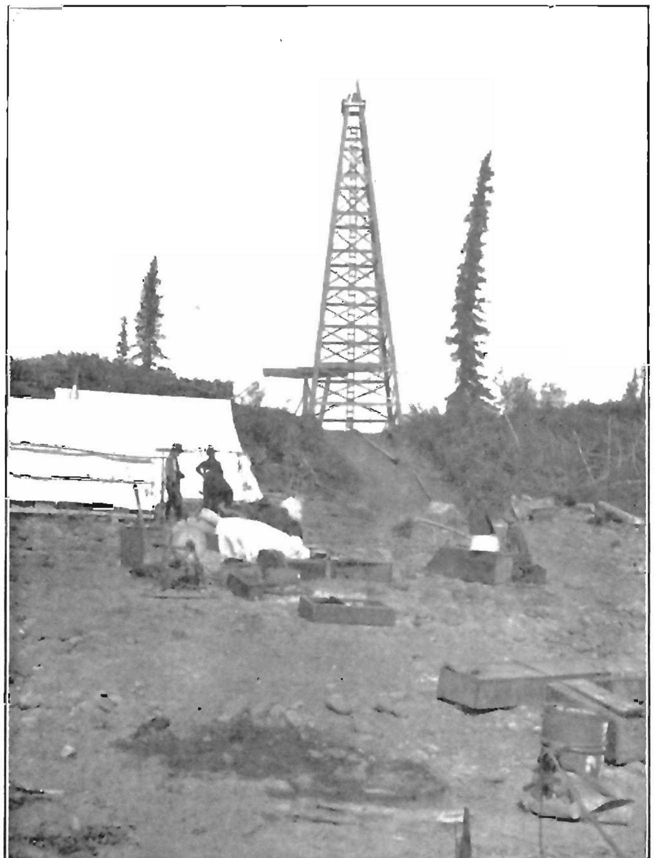
PLATE IV



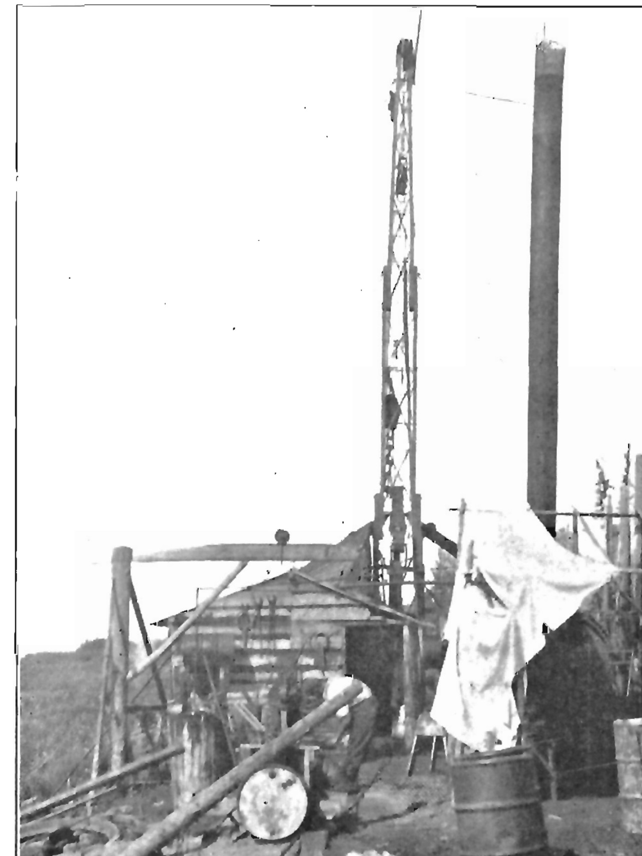
A. Fault line scarp west of Root river. The throw on this fault is between 5,000 and 6,000 feet. (Page 75.)



B. Folded rocks on the west side of North Nahanni river about 40 miles from the Mackenzie. The height to the top of the steeply tilted part is 1,000 feet above the valley bottom. The strata on the top dip away from the face shown in the picture. Faulting has accomplished the folding at various places. (Page 75.)



A. Camp and drilling rig of Fort Norman Oil Company under construction, near Norman. (Page 79.)



B. Drilling rig of Imperial Oil Company at Discovery well, Norman. (Page 79.)

PLATE VI

Relief model showing approximately the positions of the mountain ranges near Norman.
(page 90.)

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