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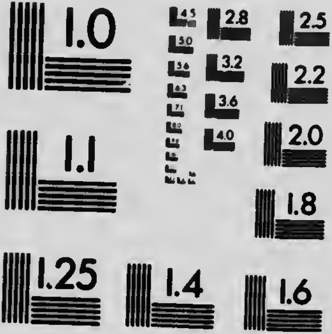

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GEOLOGICAL SURVEY

MEMOIR 82

No. 68, GEOLOGICAL SERIES

Rainy River District, Ontario. Surficial Geology and Soils

BY

W. A. Johnston

OTTAWA
GOVERNMENT PRINTING BUREAU
1915

No. 1572

PLATE I.

Looking down Rainy river from north side, 8 miles below Fort Frances, showing steep banks and trench-like character of valley. (See page 25.)

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Hon. Louis Coderre, Minister; R. G. McConnell, Deputy Minister.

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CHAPTER I.

INTRODUCTION.

GENERAL STATEMENT.

Rainy River district has long been known to form an exceptional portion of the generally rocky and inhospitable country lying between Lake Superior and the fertile plains of Manitoba, in that it is essentially an agricultural region. It was known that the area was deeply covered with drift deposits which, for the most part, conceal the solid rock, and that a considerable part of the drift consists of calcareous material, forming soils of exceptional fertility. It was also known that the greater part of the district had been at a former period covered by the waters of pro-glacial Lake Agassiz, an immense lake which, at the close of the Glacial period, occupied Red River valley and the adjoining regions; and that lacustrine sediments laid down in this lake have added to the fertility of the soils. Very little field work has been done in the district since the work of Dr. A. C. Lawson in 1886 and 1887. At that time the greater part of the district was practically inaccessible on account of the absence of roads or other means of travel, so that little was learned as to the extent and character of the drift deposits and their geological history.

The purpose of the present investigation has been to determine the distribution and character of the different soils of the region and to learn something of the geology of the various unconsolidated rocks of the drift deposits upon which the different soils have been developed. The object of the present report and accompanying map is to set forth, as clearly as possible, the results which have been obtained.

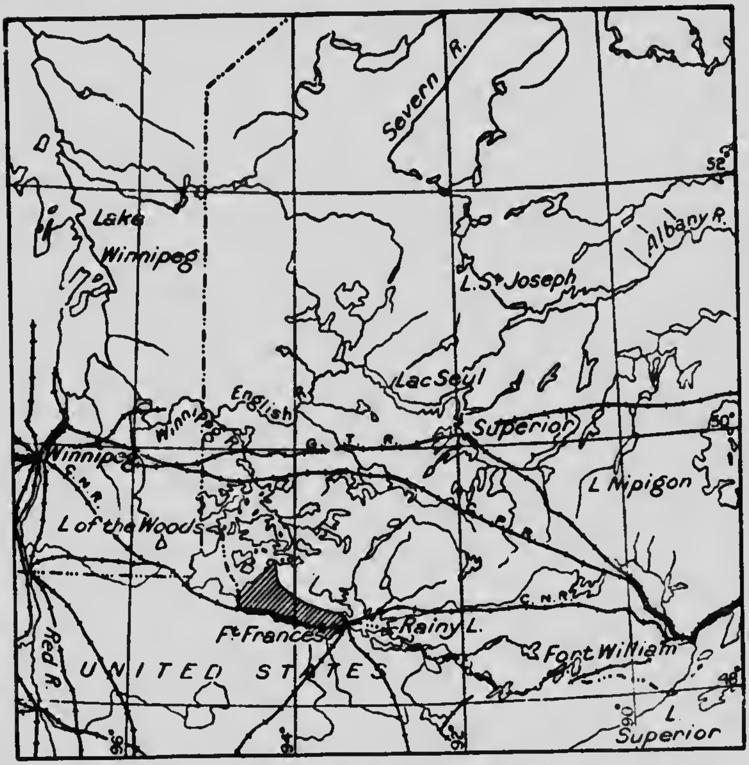

Fig. 1. Index map showing location of area.

The map which accompanies this report is on the scale of 2 miles to 1 inch and has been compiled in the office of the Survey from the township plans of the district and from other sources of information. The colours shown on the map represent the different soils and also the unconsolidated rocks upon which the soils are developed. The descriptive names of the different soils are based on the relative proportions of the various sized particles comprising the soil, as determined by mechanical analysis. The classification of soil material as adopted by the United States Bureau of Soils has been followed.

FIELD WORK AND ACKNOWLEDGMENTS.

The field work upon which the present report is based was done, in greater part, during the field season of 1913. A canoe trip was made in the early part of the season down Rainy river from Fort Frances to Lake of the Woods and around the lake, following the southwesterly and westerly shore to the northern end of the lake and returning along the eastern side. In the autumn of 1914 about six weeks were spent in the field by the writer.

Special acknowledgments are due to Mr. Frank Leverett, of the United States Geological Survey, for advice and information during the prosecution of the field work. Thanks are also owing to many individuals in the district, whose assistance in supplying information was always freely given.

LOCATION AND AREA.

The district described in the present report lies along the International Boundary, about midway between the western end of Lake Superior and Red river of Manitoba. It includes the greater part of that portion of the province of Ontario lying between Rainy lake and Lake of the Woods. The total area of the district, not including the township of Mathieu, the Indian Reserves, and the unsubdivided portion, is 1,051 square miles, of which 755 square miles were mapped. Considerable information was gained also regarding the remaining portion. The area is bounded on the south by Rainy river which connects Rainy lake and Lake of the Woods and forms, for a distance of 82 miles, the International Boundary between the province of Ontario and the state of Minnesota.

GEOGRAPHICAL RELATIONS.

The district lies about 150 miles west of the divide separating the Lake Superior and Hudson Bay drainage systems and is within the Hudson Bay drainage basin. Rainy river, which flows westward from Rainy lake, drains the area and discharges into Lake of the Woods which drains northwestward to Lake Winnipeg and thence to Hudson bay.

HISTORY.

General History.

In the early days of exploration and travel, the regular route from Lake Superior to Manitoba was by way of the chain of lakes and rivers of which Rainy river forms an important link. As early as 1872 a steamboat plied regularly on Lake of the Woods between a government immigration station on North-west Angle inlet and another post, known as Hungry Hall, near the mouth of Rainy river. Two Hudson's Bay Company posts were, for a long time, maintained on the river, one near the mouth and another where the town of Fort Frances now stands; and considerable trade with the Indians, hunting over a wide extent of country, was carried on. Upon the construction in 1881 of the Canadian Pacific railway as far as Rat Portage, now called Kenora, at the foot of Lake of the Woods, better means of communication with the district were established. At this time a number of settlers had already entered Rainy River district and had undertaken farming operations at various points along Rainy river; but for the next ten years the superior features of the prairies as compared with the densely wooded Rainy River district attracted most of the immigration. In the early nineties many settlers entered the district, coming chiefly from eastern Canada; and most of the land along Rainy river which was naturally drained, or could be readily drained, was taken up. The construction of the Canadian Northern railway through the district in 1901 gave still further impetus to immigration and industrial development and furnished much needed means of communication and transportation facilities. During the past ten years progress in manufacturing is noteworthy. Water-power at Fort Frances on Rainy river furnishes power for two large paper mills, one on the American side and one on the Canadian side. The mills utilize the abundant supply of pulp wood, found in the region. A number of large sawmills and allied industries have also been established on both sides of the line. Agricultural development has not been so marked, and although practially all the homesteads have been taken up in the accessible portions of the district, not over 5 per cent of the land is under cultivation.

Previous Work.

The published results of the geological work previously done in Rainy River district, referring only to the main observations made with regard to the drift deposits, may be briefly summarized as follows:

Dr. J. J. Bigsby was one of the first to undertake geological work in the district. This work was apparently done in 1823 or 1824 during a visit to Rainy lake and Lake of the Woods in his capacity as medical officer to the International Boundary Commission survey. It was not until nearly thirty years later, however, that the results were published in three papers which appeared in the Quarterly Journal Geological Society of London, in 1851, 1852, and 1854. Geological maps of Lake of the Woods and Rainy lake accompanied two of these papers. Dr. Bigsby noted the large numbers of limestone boulders in the southern portion of the district and their absence in the northern portion. He concluded that some of the limestone masses were in place and that the southern part of Lake of the Woods was underlain by limestone of Silurian age. He also noted the "abundance of primitive travelled blocks," but no observations on striæ were given.

In 1873–74 Dr. G. M. Dawson, acting as geologist and botanist to the British North American Boundary Commission, investigated the region in the vicinity of the 49th parallel, from Lake of the Woods to the Rocky mountains. The results of his work were published in 1875 in the "Report on the geology and resources of the region in the vicinity of the forty-ninth Parallel." In this report Dr. Dawson devotes considerable attention to the glacial phenomena and superficial deposits of Lake of the Woods region and its resources with reference to settlement. He failed to find any limestone in place, as Dr.

Bigsby had reported, and considered that the most probable supposition as to the occurrence of abundant limestone debris in the southern portion of the Lake of the Woods region, was that it had been transported eastward from Red River valley by floating ice, during a period of submergence of the region. He described the character of the country lying to the south and west of Lake of the Woods, referring at some length to its agricultural possibilities but said little regarding Rainy River district as, apparently, he did not visit this portion of the region, excepting the vicinity of Lake of the Woods.

The geological work of Dr. A. C. Lawson in Lake of the Woods, Rainy River, and Rainy Lake regions, extending over the years 1883–1887, has been widely recognized as an important contribution to the geology of Canada. The results of this work were published as parts of the annual reports of the Geological Survey of Canada for 1885 and 1888. Dr. Lawson deals principally, in these reports, with the geology of the solid rocks of this region, but also refers in some detail to the glacial drift and the character of the "alluvial plain or river country" of Rainy River district, as contrasted with "the rocky lake country."

Dr. Lawson noted the close similarity of the limestone drift of the southern portion of Lake of the Woods to the limestones of Manitoba. He held that this resemblance, together with the fact that southeastward bearing striæ, with a trend nearly at right angles to the general direction of glaciation, had been found in Manitoba, in eastern Minnesota, and occasionally on Lake of the Woods, pointed to an origin of the limestone drift in Manitoba and that it was carried by glacial ice moving in a southeasterly direction.

An extensive list of directions of glacial striæ was also given, which showed that the general direction of glaciation had been in a southwesterly direction.

In the "Report on the Geology of the Rainy Lake Region" Dr. Lawson described the character of the drift as exposed in sections along Rainy river and the widespread distribution of sediments laid down in the waters of Lake Agassiz, and he noted that the northern limit of the distribution of the limestone drift was defined approximately by a line drawn from the southwestern corner of Rainy lake to Bigsby island in Lake of the Woods. He found beach deposits of Lake Agassiz in the southern portion of the district, but none in the northern portion, and concluded that the line which defined the northern limit of the limestone drift was, approximately, also the line of the ice barrier which dammed the waters of the lake. Dr. Lawson also confirmed the favourable reports of earlier explorers as to the general fertility and excellence of the soils of the region.

In a recent report, entitled "The Archæan Geology of Rainy Lake Re-studied," Memoir 40, Geological Survey, Canada, by Dr. Lawson, the author doubtfully refers to the occurrence of an outlier of Richmond (upper Ordovician) limestone about 6 miles west of Fort Frances.

CHAPTER II.

DEVELOPMENT AND GENERAL CHARACTER OF DISTRICT.

DEVELOPMENT.

GENERAL STATEMENT

The two principal towns in the district are: Fort Frances situated on Rainy river, 2 miles from Rainy lake, at the eastern end of the district, and the town of Rainy River situated on Rainy river, 12 miles from Lake of the Woods, at the western end, each having a population of nearly 1,700. Across the river from Fort Frances is the town of International Falls, formerly Koochiching, and across from the town of Rainy River are Spooner and Baudette. The main line of the Canadian Northern railway, coming from Winnipeg, after crossing a portion of the state of Minnesota by running around the southern end of Lake of the Woods, enters the district at the town of Rainy River. It traverses the district from the town of Rainy River to Fort Frances and thence runs eastward to Port Arthur. A branch line also runs from Fort Frances southeastward into northern Minnesota and affords connexions with Duluth and Chicago, so that means of daily communication and transportation are afforded to points west, east, and southeast. Fort Frances is 208 miles distant from Winnipeg and 232 miles from Port Arthur, at the head of Lake Superior. The district has been, until recently, very poorly supplied with good highways; but within the past three years considerable money has been spent by the Provincial Government in the construction of colonization roads, which have greatly improved conditions of travel. There are still many areas, however, in which much of the land has been taken up by settlers. but which have no roads that can be travelled in the open season, except on foot. Rainy river from Fort Frances down to Lake of the Woods is navigable for steamboats of light draught. During the summer months a small steamboat makes tri-weekly trips between Fort Frances and Rainy River. The passengers are then transferred to a larger boat plying on Lake of the Woods and affording connexions with Kenora, situated at the foot or northern end of the lake and on the main line of the Canadian Pacific railway. The river and lake trips are attractive to summer tourists, and both Rainy lake and Lake of the Woods are fast becoming popular summer resorts.

The following data regarding the population, land areas, and agriculture of the district have been compiled from the census reports for 1911.

POPULATION.

Rural population in 1911	4,430
Town population in 1911, including towns of Fort Frances and Rainy River, and unincorporated villages of Emo and Devlin	3,707
Total population	8,134

LAND AREAS.

Area of the district, not including Indian Reserves, the township of Mathieu, and the unsubdivided areas, ... 672,924 acres
or .... 1,051 square miles

Occupied land, 223,550 acres or 33·2 per cent of entire area.

Improved land, 31,233 acres or 13·4 per cent of the total occupied land and 4·6 per cent of the total area.

AGRICULTURE.

Field Crops 1910.

Fall wheat	110	acres,	production	2,298 bushels
Spring wheat	478	"	"	8,982 "
Barley	505	"	"	10,351 "
Oats	3,649	"	"	95,972 "
Hay	11,974	"	"	9,808 tons
Potatoes	483	"	"	44,834 bushels

It should be noted that 1910 was an exceptionally dry year; the total rainfall during the season of growth (the months of April to September inclusive) was only 11·12 inches at International Falls near the eastern portion of the district, and only 9·38 inches at Baudette near the western portion, whereas the normal rainfall for these months at International Falls is 17·8 inches and at Baudette slightly less (18) [1](See section under heading of "Climate").

Exceptionally large yields of grain are reported as having been obtained in previous years. Mr. D. Matheson of Devlin stated that in 1912 he had harvested an average of 57 bushels of wheat per acre from a 20 acre field. Other yields of wheat of 53 and 55 bushels per acre, are also reported in the same year.

LUMBERING.

Lumbering is still an important industry in the region. Large sawmills are situated near Fort Frances in the eastern portion of the district and near the town of Rainy River in the western portion. The pine has been largely removed from the district, but it is stated that in the areas lying to the north and northeast a sufficient quantity still exists to supply the mills for a number of years. During the past twenty years great quantities of material for railway ties, fence posts, and telegraph poles have been removed from the district and a large supply still remains. In more recent years since the establishment of paper mills at International Falls and at Fort Frances, large quantities of pulp-wood, of which there is a great amount in the region, have been used. At present only spruce, used in the manufacture of mechanical pulp, is utilized. In recent years, also, there has been a demand for poplar and balm of Gilead logs, the sale of which has been a source of revenue to many of the settlers and has lessened the cost of the clearing of farm land, much of which is densely forested (Plate II).

CLIMATE.

Rainy River district, because of its inland situation, has a climate that is continental in character. Such a climate is characterized by greater temperature extremes, and less humidity and rainfall, than that of regions near the coast or near very

[1]Figures in brackets refer to the Bibliography, page 93.

large bodies of fresh water. This district forms no exception to the rule. The winters are cold and the summers are warm. Summer temperatures are, however, equalized and moderated by the effect of winds from the two comparatively large bodies of water in the district—Lake of the Woods and Rainy lake. The annual precipitation, averaging nearly 25 inches, is considerably less than that of most coastal regions of Canada, but greater than that of much of the plains region to the west; for the district is far removed from the mountains to the west, which are athwart the rain-bearing winds, and lies in the path of many of the low-pressure areas which move across the continent from west to east, usually accompanied by cloudy weather or precipitation. These storms occur at fairly regular intervals, are generally preceded by southerly winds and higher temperatures and are followed by northerly winds and lower temperatures. They give on the average, one or two days of stormy or cloudy weather a week with intervening days of fine weather.

No climatological records have been kept within the district for any considerable time, but for a number of years records have been kept at several stations in northern Minnesota adjoining Rainy River district, on the south. One of these is at International Falls, in the eastern portion of the district, another at Baudette in the western portion of the district, and a third at Warroad at the southwestern end of Lake of the Woods. Nearly complete records have been kept at International Falls for eleven years, 1904 to 1914, with fragmentary data extending back to 1892; at Baudette 6 years, 1909 to 1914; and at Warroad 5 years, 1910 to 1914. The records obtained at these stations have been published in the monthly Weather Bureau reports of the United States Department of Agriculture, for 1909 to 1914 and in a special section report No. 57, also of the United States Weather Bureau publications. The following data have been compiled from these reports (18).

The annual average precipitation of the eastern portion of the district, as shown by the records of observations at the climatological station at International Falls for a period of twenty-two years, 1892 to 1914 inclusive, is 25·62 inches and for the growing season, April to September inclusive, is 17·80 inches.

The year with the greatest annual precipitation was 1905, when the total was 33·0 inches. The driest year was 1910, with a total of 19·40 inches. The rainfall during the growing season of 1910 was 11·12 inches. Nearly 70 per cent of the total precipitation comes in the season of growth, and is well distributed.

In the western portion of the district the average precipitation, as shown by the observations at Baudette, is about 23 inches, but records have not been kept long enough to establish a definite average. In 1910 the total precipitation at Baudette was 13·12 inches and for the growing season 9·38 inches.

The following table shows the average monthly and annual precipitation in inches (rainfall and melted snow) for the eastern portion of the district over twenty-two years, 1892 to 1914:

Jan.	Feb.	Mar.	Apr.	May	June
0·88	1·05	1·02	1·81	2·83	3·22

July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
3·18	4·20	2·56	2·67	1·18	1·02	25·62

August is the wettest month, with an average rainfall of 4·20 inches, and June and July come next. The month with the least precipitation is January. The greatest rainfall in one month was 6·43 inches in August, 1911. The lowest was 0·07 inch in December, 1913.

The snowfall averages nearly 50 inches annually in the eastern portion, and somewhat less in the western portion, near Lake of the Woods. The average per month is nearly the same for December, January, February, and March, but slightly greater for February. The greatest annual snowfall was in 1911, with a total fall of 92·6 inches or 9·26 inches of the total precipitation. The least annual snowfall was in 1912, with a total fall of 29·5 inches.

The average annual number of days with 0·01 inch or more of precipitation is about 85; the greatest in one month occurs generally in July, but the number of days per month is nearly the same for June, July, August, and September. The other months of the year have on an average about one-half as many days with precipitation, and the number of days in each month is nearly equal. Nearly all the precipitation during the winter months is in the form of snow, and winter thaws very rarely occur.

The wooded character of a large portion of the district favours evaporation during the summer months, for much of the rainfall is transpired by the trees. The large swampy areas also present broad surfaces of water to the sun's rays. The shallow lower portion of Lake of the Woods, which at times has a maximum surface temperature of 72 degrees, also supplies moisture to the atmosphere by evaporation, the effect of which is to equalize summer temperatures to some extent. The amount of evaporation is unknown. It is of importance as a climatic factor only in exceptionally dry seasons.

The mean annual temperature for the eastern portion of the district, as determined from the records of the observations made at International Falls, is 38·5 degrees (Fahrenheit) and the mean temperature for the growing months is 57·5 degrees. The mean temperatures for the western portion of the district are slightly lower.

January is the coldest month, with a mean temperature of 2 degrees, and July is the warmest month, with a mean temperature of 67 degrees, February is, however, generally nearly as cold as January and in some years colder. The mean temperature for June or August in some years also exceeds that of July. The lowest temperatures recorded are: −55 degrees on January 6, 1912; −35 degrees in 1911 and 1913; and −40 degrees in 1914, the month of December in this year being the coldest on record, the lowest temperature reaching −25 degrees and the highest 40 degrees, with a mean of 6·5. Very low temperatures occur as a rule only for a few days during the winter.

The highest temperature recorded is 101 degrees on June 21, 1910, and on July 1, 1911. In 1913 the highest temperature was 98 degrees on June 29, and temperatures of 90 degrees or over were recorded in June, July, August, and September. In 1914, temperatures ranging from 90 to 95 degrees were recorded in June, July, and August. Temperatures of 90 degrees or over occur as a rule only on one or two days during the month.

Frosts have been known to occur in the district in every month of the year, but damaging frosts very rarely occur during June, July, and August, and are comparatively rare in the first half of September. The average date of the last damaging frost in spring is about June 1 and the first killing frost in autumn is about September 10. Light frosts have occurred in a number of years in the latter part of August, but have rarely done more than local damage. The influence of winds from the comparatively large bodies of water in the region has a marked effect in lessening the danger of early damaging frosts. In 1914, a light frost occurred in the western portion of the region on August 24, but did only local damage. A light frost also occurred on September 22, but no killing frost occurred until October 14, giving a crop season of 135 days free from damaging frosts. In 1913, the last killing frost in the spring was on May 10 and the first in the autumn, September 23. In 1912, the first killing frost in the autumn was on September 27, but light frosts occurred in May and on June 16. The average length of the crop season free from killing frosts is about 100 days, but varies greatly from year to year.

The directions of the prevailing winds vary from month to month and from year to year. During the winter months, the winds are generally from the west, northwest, and north. During the spring months, easterly and northeasterly winds occur more frequently than at any other season, but there is also great variation. During the summer months, south and southwesterly winds more commonly occur, and during the autumn months, southwesterly to westerly winds. The strong winds generally come in the spring or late in the autumn, and are usually from the northwest. It was noted that most of the windfalls in the timbered areas lie towards the southeast. Destructive wind storms, however, very rarely occur in the region.

The average wind velocity per month varies from 6 to 12 miles per hour and is least in July and August and greatest in April and November.

One of the most important factors in the relation of climate to agriculture is the length of the crop season or the period of growth free from killing frosts. Rainy River district has a crop season of about 100 days on the average, which compares favourably with that of southern Manitoba and even with that of portions of south central Ontario and is sufficient, when other conditions are favourable, for the growth and maturing of most of the ordinary farm crops common to the temperate zone.

Another important factor is the relative distribution of rainfall during the year, especially when the annual rainfall is not large. The annual rainfall of the district is small as compared with the more humid regions to the east, but nearly 70 per cent of the total precipitation occurs in the growing season, and is well distributed, affording highly favourable conditions for growth. In 1910, when the total precipitation in the eastern portion of the district was only 19·4 inches and in the western portion only 13·1 inches, the crops were not a failure because a large proportion of the rainfall came in the growing season.

Other factors are temperature and the amount of sunshine; both of these are favourable in the district, since summer temperatures are high and the sunshine averages nearly 50 per cent of the highest amount possible. Seasons of exceptional dryness occasionally occur, during which there is danger from drought; but the facts that a large proportion of the annual precipitation comes in the growing season and that the ground-water level over much of the region is near the surface, largely offset the danger from drought. Exceptionally dry summer seasons are stated to have occurred in 1886, 1896, and 1910, and in these years considerable damage to standing timber was done by forest fires. During these seasons, it is stated, many of the swamps were dry, but general crop failures did not occur.

VEGETATION.

A large part of the area is clothed with a dense growth of arboreal vegetation. The abundant forest growth is favoured, in spite of the comparatively small amount of rainfall and occasionally dry seasons, by the nearness to the surface of the ground-water level over a large part of the region.

The flora of the northern, more rocky, and more sandy portion of the district resembles that characteristic of the great

Laurentian Plateau region of Canada. The majority of the forest trees are coniferous, the Banksian or scrub pine occurring most abundantly. Red and white pine formerly were widely distributed over the rocky areas and to a less extent in the southern, drift covered portion of the district, but have been largely removed by lumbering operations or destroyed by forest fires. Several groves of young pine occur in Mathieu and Dewart townships, and, in the Wild Land Reserve in the southern portion of the district, there are also a few groves of virgin, white and red pine.

In the southern portion of the district deciduous trees more commonly occur. The aspen and balsam poplar are the most abundant and grow to a considerable size. They occupy for the most part the clayey areas, in compar .· with the kindred species cottonwood and balm of Gilead. The sandy and gravelly ridges are generally marked by groves of birch and scrub pine, with occasional trees of red or white pine. The poorly drained areas which constitute a large proportion of the district are generally clothed with cedar, tamarack, and the spruces. Cedar and spruce most frequently occur where the surface drainage is poorly developed and where the subsoil is sandy and not deeply covered with muck or peat. The deeper bogs are clothed mainly with tamarack, except in their central portions, which are frequently treeless and covered with grasses or moss. Elm, oak, and box-elder or ash-leafed maple occur sparingly in the better drained areas and most commonly along the banks of the streams. In certain portions of the region where, because of the slight relief, surface drainage is developed only sufficiently to prevent swampy conditions, nearly all the more common species of trees of the district may sometimes be seen growing within a radius of 100 or 200 feet.

CHAPTER III.

SUMMARY AND CONCLUSIONS.

PHYSIOGRAPHY.

Rainy River district lies just at the margin of the great Laurentian Plateau region of Canada. Although underlain for the most part at least by Pre-Cambrian rocks, the district is generally deeply covered with glacial and lacustrine deposits, has very little relief, and slopes in general towards the west, so that it really forms part of the eastern margin of the wooded portion of the prairie plains of Manitoba and northern Minnesota, from which it is separated by the shallow basin of the lower portion of Lake of the Woods. The waters of pro-glacial (glacial-marginal) Lake Agassiz at their maximum extension covered nearly the whole area, and the deposition of lacustrine sediments lessened the relief and gave part of the surface the character of a plain. A large part of the area, however, where till or boulder clay forms the surface, is gently undulating, but even in these areas the general relief is slight. Notable features in the character of the surface are the general absence of lakes due to the evenly aggraded character of the drift deposits, and the large swampy areas where drainage is poorly or not at all developed. Owing to the recency, in geological time, of the disappearance of Lake Agassiz, the process of denundation of the drift covered areas has just begun and the region is still in its physiographic infancy. The rocky areas which border the district on the east and northeast have little or no drift covering and present features in common with the great Laurentian Plateau region, the general character of which is that of an uplifted, slightly dissected and intensely glaciated plain, with a surface generally devoid of prominent elevations, but hummocky and irregular (Plates III and IV).

SURFICIAL GEOLOGY.

A considerable portion of the superficial deposits of the region consists of calcareous till or boulder clay containing a large proportion of limestone, similar to that which outcrops near Winnipeg in Manitoba. This till sheet occupies large areas in the southern portion of the region, but is entirely absent in the northern portion, and in the eastern part does not extend farther than Fort Frances. That this till was brought into the region by a lobe of the Keewatin glacier advancing from the direction of Manitoba is shown, as Dr. Lawson concluded, by the character of the drift and by the fact that southeasterly and easterly bearing striæ occur in the district at numerous places, and as far east as the vicinity of Fort Frances. These striæ cross older, southwesterly bearing striæ, but were not seen to be themselves crossed by later striæ.

The calcareous or grey till is underlain in places by "red drift," consisting of non-calcareous till and fluvio-glacial sands and gravels, derived from an ice sheet advancing from the north-east, across a region underlaid by Pre-Cambrian crystalline rocks. Hence the red drift contains no limestone.

At one locality the red drift was seen to be underlain by a still older deposit of calcareous drift which was, presumably, derived from the northwest. Closely associated with the calcareous till is a series of glacio-lacustrine, strongly laminated clays. They were deposited in a lake ponded between the margin of a lobe of the Keewatin glacier, which brought in the calcareous till, and the higher ground to the south. These clays frequently contain striated stones and boulders and were evidently deposited in standing water and at no great distance from the ice margin.

Later than all these deposits are the lacustrine and littoral deposits of pro-glacial Lake Agassiz. They occupy considerable areas in the district and occur through a range of altitudes of nearly 100 feet. Their maximum thickness is, in places, at least 30 feet.

A remarkable feature in connexion with these lacustrine deposits is that they are separated from the underlying glacio-lacustrine clays and calcareous till by a marked unconformity, showing an interval of erosion. During this erosion period stream valleys of considerable size were formed and vegetation had to some extent obtained a foothold. The unconformity at the base of the lacustrine deposits extends throughout the vertical range of these deposits

Tyrrell has shown (15) that the latest advance of glacial ice in the region lying to the south and west of Hudson bay was from the northeast and that the junction of this glacier (Labradorean) with the Keewatin glacier, which after retreating well towards its source had again slightly readvanced, blocked the drainage towards the north and caused the ponding in the valleys to the south. This last advance of the ice from the northeast, apparently never reached as far as Rainy River district, for no red till was found to overlie the calcareous till.

The lacustrine deposits, in their lower portions, contain numerous freshwater shells and occasionally, small amounts of peaty material. Some of the beach ridges also, contain similar shells in considerable abundance.

Below the contact of the lacustrine deposits and the underlying glacio-lacustrine clay and calcareous till, the latter are in many places deeply weathered, and it was evident from the thickness of the overlying deposits, that the weathering must have taken place before the deposition of the lacustrine sediments. Stream valleys had been cut in the till to a depth of at least 25 feet, and later filled with lacustrine sediments. Hence it is evident that subsequent to the deposition of the calcareous till, a considerable interval ensued, during which there was comparatively free drainage to the north and that, as Tyrrell has maintained (15), the waters of pro-glacial Lake Agassiz had a rising stage during part of their history. The pro-glacial lake in which the glacio-lacustrine clays were laid down was associated with the lobe of the Keewatin glacier which brought in the calcareous till; but this lake preceded Lake Agassiz and was at least partly, if not wholly, drained before Lake Agassiz came into existence.

SOILS.

A large proportion of the soils of the district is developed upon calcareous drift. Such soils are highly prized for agricultural purposes because of their general fertility. The soils of Rainy River district form no exception to this rule. Their natural fertility is also attested by the crop records; and the general favourableness of climatic conditions is shown by the fact that even in seasons of exceptional dryness the crops were not a failure.

The total area mapped in the district includes about 755 square miles. Of this area a region of approximately 240 square miles is poorly drained and generally swampy in character, and requires artificial drainage before it can be utilized for farm purposes. Much of the surface soil consists of muck or peat one foot or more in thickness, but in general not exceeding 3 feet. The greater portion of the swampy areas can be drained and rendered available for farm lands. Up to the present very little attempt has been made to utilize the swamp soils.

The soils which have been most widely utilized are the gravelly fine sandy loam, loam, clay loam, and clay soils developed upon the calcareous till and glacio-lacustrine deposits. These soils occur in areas where the surface is of a gently rolling character and where drainage is naturally better developed than in the flatter areas. These soils occupy a combined area of 307 square miles. Much of the soil is still virgin and is generally highly productive.

The soils developed upon the lacustrine deposits, usually occur along the valleys of the streams, or near their mouths, and consist of fine sand, clay loam, and clay soils. The fine sand soil occupies an area of 32 square miles and the clay loam and clay soils 88 square miles. These soils are, for the most part, drained naturally in the areas near the streams and are among the most productive and longest utilized soils in the region.

The soils developed upon the old beach ridges consist of gravelly sandy loam, generally excessively drained and poorly productive. They occupy an area of 10 square miles.

Small areas of alluvial clay loam occur along some of the streams on their overflow terraces. They occupy an area of 12 square miles, and are subject to overflow by the stream in time of flood.

In the northern portion of the district the soils are largely developed upon non-calcareous drift and are more variable in character, but usually consist of gravelly sand and gravelly sandy loam. They occupy an area of 38 square miles.

The bed-rock areas in the district, upon which there is little or no soil, cover an area of 27 square miles. The region lying to the north and northeast of the district largely consists of barren rocky ridges.

Dune sand and beach sand, which form unproductive soils, occupy only small areas on the islands and along the shores near the mouth of Rainy river.

In addition to the area mapped, it is stated that a large proportion of the surface of Sutherland, Richardson, Potts, Fleming, and Dance townships consists of land suitable for agriculture.

FUTURE POSSIBILITIES.

Lumbering and allied industries in the region have been, and are still, of importance. Considerable supplies of timber and especially pulp-wood still exist, but agriculture is becoming of increasing importance and it seems probable that in the future, the district must largely depend on its agricultural resources for its economic development.

The district embraces an area of approximately 1,050 square miles, exclusive of the Indian Reserves, the township of Mathieu (not open to settlement), and the unsubdivided areas. Of this area approximately 250 square miles consist of swampy muck and peat lands, much of which can be drained. The area of waste land is approximately 100 square miles. The occupied land in 1911 was 33·2 per cent of the entire area, and 13·4 per cent of this was improved. The improved land, which forms only 4·6 per cent of the total area, in 1911 afforded support for a rural population of 4,430. Even leaving out of account the swampy areas and waste land, it is evident that the soils of the region are capable of producing sufficient crops to support several times the present population. Nearly all the unimproved land is forested to some extent. Clearing of the land, it is stated, costs from $10 to $50 per acre. One of the most pressing needs of the district, besides the construction of highways, is to improve the drainage. Many of the streams are blocked in numerous places by accumulations of drift wood and also by occasional rock barriers in their beds, which prevent free drainage. The removal of the obstructions in the streams should be the first step in undertaking drainage projects.

CHAPTER IV.

PHYSIOGRAPHY.

GENERAL STATEMENT.

Rainy River district may be considered as forming part of the eastern margin of the wooded portion of the prairie plains of Manitoba and northern Minnesota. It lies at the border of the rocky upland region stretching westward from the head of Lake Superior, and its eastern edge is about 150 miles west of the watershed separating the Lake Superior drainage from the Hudson Bay drainage. The general altitude of this divide is nearly 1,600 feet and the general altitude of Rainy River district, about 500 feet lower. Hence Rainy lake forms a collecting basin for the drainage of a large region lying to the east, the average slope of which does not greatly exceed 3 feet per mile. The slope of the rocky plateau region is apparently continued beneath the drift deposits of Rainy River district, which differs essentially from the adjoining rocky region, in that the drift deposits are of sufficient thickness to conceal for the most part the solid or bed-rocks. In general the drift becomes thicker and the bed-rock outcrops fewer towards the southwest, but outcrops of bed-rock do occasionally occur even around the southern end of Lake of the Woods. These rocks are all, so far as known, Pre-Cambrian crystalline rocks, and no positive evidence was found in the district of the occurrence of younger rocks in place.

The character of the surface of the district is for the most part that of a well wooded plain, the general level of which is slightly lower than that of the rocky plateau region. Several factors have been operative in producing the plain-like character. Well borings show the drift to have a maximum thickness in places of 100 feet and occasionally rocky knobs rise 100 feet above the general level of the plain. This amount of relief of the rock floor corresponds to the general maximum relief of the adjoining rocky plateau. The average relief is still less and it is evident that the general low relief of the surface of the underlying rocks was one factor in the production of the plain-like surface.

A considerable part of the surface of the plain is occupied by calcareous till with only a slight covering, a few inches in thickness, of lake silt, and has a slightly undulating character, for the till was disposed, in greater part, as ground moraine and has very slight relief. Terminal moraines are not at all conspicuous and in most cases the slight ridges of till which do occur are due to the nearness to the surface of the underlying rocks which frequently outcrop along these ridges. Near the eastern limit of the calcareous till a somewhat definite ridge, possibly marking a terminal moraine, occurs and in the northeastern part of the district forms the divide for several miles, but even in this case the relief is only a few feet above the surrounding country. Wave action during the lifetime of Lake Agassiz served to plane off many of the irregularities of the surface and the deposition of lacustrine sediments still further decreased the relief. Since the disappearance of the lake, deposits of swamp muck and peat have filled many of the shallow depressions and occupied much of the surface where natural drainage is, as yet, poorly developed. The deposits conceal minor irregularities and give an appearance of extreme flatness to much of the plain surface.

The drainage of the region is consequent in character, that is, if all the valleys made by recent erosion were filled up and the original surface restored, the directions of drainage would be practically the same as at present and would be consequent upon the general slope. In general the stream valleys are few in number and small in extent. Large interstream areas are virtually untouched by stream erosion and as a whole the region is just beginning a new cycle of denudation.

DETAILED ACCOUNT.

RELIEF.

Rainy lake, at the eastern end of the district, has a present mean elevation of nearly 1,106 feet above sea-level and Lake of the Woods, at the western end, 1,060 feet, as determined from bench-marks established by the United States Geological Survey (25). The highest portions of the drift covered area lying between the lakes are along a poorly defined ridge extending from a point 6 miles west of Fort Frances in a northwesterly direction for about 20 miles. This ridge forms a watershed separating the streams tributary to Rainy river draining southwesterly, and those draining north and northeasterly. The altitude of the divide varies from 1,175 feet near the eastern portion, to about 1,250 in the northwestern portion and occasionally rocky knobs rise nearly 100 feet higher. The maximum relief of the district does not greatly exceed 300 feet and the average relief is very much less. Rainy river flows, throughout the greater part of its course, in a markedly trench-like valley with relatively high steep banks. The average slope of the upland bordering the river is less than one foot per mile. The general slope in a southwesterly direction towards Rainy river is somewhat greater, but the slope is interrupted by isolated areas nearly as high as the highest portion forming the divide. In the western portion near Lake of the Woods the relief is distinctly less. In a traverse northward from a point on Rainy river, 20 miles east of Lake of the Woods, the highest point was found to be only 75 feet above the lake and the greater portion of the area lying to the west of this line is still lower.

DRAINAGE.

General Statement.

Notable features in the surface of the plain are the general absence of lakes, due to the evenly aggraded character of the drift deposits, and the large, swampy, undrained areas. A few small lakes or ponds occur, but in most cases the original depressions in the surface of the drift were so shallow that they have been filled by the growth of vegetation. The swampy, poorly drained areas are due mainly to the low surface gradients, the nearly impervious character of the sub-soil, and the growth of a dense mat of vegetation which holds the water like a sponge so that the run-off is mainly by ground-water and hence exceedingly slow. In some cases beach ridges and barriers behind which lagoons formerly existed, act as dams and prevent natural drainage. Extensive areas are practically untouched by stream erosion, partly because of the youthful stage of the cycle of erosion and partly because the headwater growth of streams is effectually checked by the mat of vegetation and by the nearness to the surface of the ground-water level.

Rainy River.

Rainy river, the principal stream of the region, is a remarkable river in that it nearly fits its valley and has few meanders (Plate I). Throughout much of its course, the banks rise abruptly on both sides almost from the water's edge, and, except where active undercutting is going on, the banks have generally rounded, smooth, grass-covered slopes. In the upper part of its course the immediate banks are generally from 25 to 35 feet high and this height is frequently reached within a few yards of the water's edge. Above this height faintly terraced slopes rise somewhat higher, but at many points the valley in which the river flows is not greater than two or three times the width of the river itself. The river, although it has a very slight gradient, has few meanders and very little flood-plain even in its lower portion. Long, straight stretches frequently occur and the artificial appearance of the waterway in these stretches, resembling a great trench cut through the drift deposits, is striking. The average width of the river is about 200 yards and its depth in mid-channel, except at rapids, varies from 10 to 20 feet. In its lower portion, near Lake of the Woods, the immediate banks are generally only 10 to 20 feet high and are for the most part being rapidly undercut. In this part the terraces corresponding to stages of former levels of Lake Agassiz are better developed than in the upper portion of the river. At some of the more pronounced bends in the river, active erosion of the bank on the outside of the curves is going on and deposition taking place on the inside, resulting in short stretches of valley flats which are sometimes one-quarter mile wide, but are not extensively developed.

Although the river has a very small gradient, it has a strong current because of its volume. Below the dam at Fort Frances, where the river may be said practically to begin, since the water above the dam is only a few tenths of a foot below the level of Rainy lake, there are only two obstructions to the flow of the river, causing rapids. The first occurs at Manitou rapids 35 miles down stream from Fort Frances, where a rocky barrier causes a constriction of the channel of the river to about half its normal width. The fall here is only about 1½ feet at the mean stage of the water. Seven miles farther down stream the Long Sault rapids begin. They are caused mainly by boulders in the bed of the stream and extend for nearly 2 miles, with an estimated total fall of 5½ feet. This estimate was checked by determining the altitude of the surface of the river at points above and below the rapids from bench-marks set in connexion with the precise levels taken by the United States Geological Survey, and is probably not over 1 foot out. The altitude of the water surface of the river below the dam at Fort Frances, as determined from the bench-mark established by the United States Geological Survey in the town of International Falls, across the river from Fort Frances, was found to be 1,077·5 feet in July, 1913, the river being apparently at a medium stage. At the railway bridge near the town of Rainy River, 70 miles down stream from Fort Frances, the altitude of the water, as determined from a bench-mark of the United States Geological Survey at the bridge, was found to be 1,062·5 feet, giving an average gradient for the surface of the water of 2½ inches per mile for 70 miles. Neglecting the two rapids, this is reduced to 1½ inches per mile. Below the town of Rainy River the gradient was found to be still less, averaging only 1 inch per mile for 12 miles. In spite of the very slight slope the river has a noticeably strong current. In the upper part the slope of the river varies greatly from time to time. When flood waters are brought down by tributaries and enter the river above Manitou rapids, they are unable to escape freely at the rapids, and thus "back up" and raise the level of the river several feet at the foot of the dam at Fort Frances.

The consequent character of Rainy river is well shown by the course which it takes. The river was initiated on the plain which formed part of the bed of Lake Agassiz, immediately upon the withdrawal of the lake waters, and furnished an outlet for the waters of which Rainy lake formed a collecting basin. After flowing west from Fort Frances for 3 miles the river turns abruptly southward for 3 miles, then flows westward, and farther down again flows northward. In each case the abrupt turns were made because the river sought out the lowest portions of the original surface of the plain. It quickly entrenched itself in its valley and the remarkable canal-like character of much of its course appears to be due, principally, to the soft character of the materials which it had to excavate and to the great volume of water with which the river was supplied, giving greatly increased efficiency for downward cutting over lateral erosion.

There is evidence also, that the valley of Rainy river was, in part at least, excavated by stream erosion before Lake Agassiz came into existence, and was partly filled by deposition of sediments during the existence of the lake. These sediments have been in large part removed by the present stream, but at many points they were seen to form portions of the sides of the valley and to rest unconformably on the underlying drift deposits. The present stream appears for the most part to have followed the course of the previous stream, but it is not known if it did so entirely.

Minor Drainage.

The tributaries of Rainy riv[illegible] enter from the Minnesota side are generally much larg[illegible] hose on the Canadian side, as they have greater drainage a[illegible]. On the Canadian side the principal tributaries are La Vallée, Sturgeon, and Pine rivers. The tributaries in the lower portions of their courses have much the same general character as Rainy river. Their banks are generally high and steep, their channels relatively broad and deep and sunk sharply below the general level of the plain. This character, however, extends up the tributary streams only a short distance and in their middle portions they become markedly tortuous with the ba[illegible] rapidly becoming lower; but they are generally high enough to prevent overflowing in times of flood. In their upper portions, where the streams frequently traverse swampy areas they often overflow and in some cases natural levees are formed along the banks. Many of the smaller tributaries, where they enter Rainy river, have the appearance of streams of considerable size with wide, deep channels, but their total length is frequently not over 1 or 2 miles. Swampy, undrained areas sometimes occur within one-quarter mile of Rainy river and at a height of 40 feet above the river. The tributaries easily and deeply erode their channels in the areas within which the ground-water level has been lowered by the nearness to the trunk stream, but as the ground-water level approaches the surface of the ground, the power of the streams to erode diminishes and the dense growth of vegetation serves also to prevent headwater growth. The result is that very many of the tributary streams, while they may have a wide deep channel at their mouths, frequently have a much steepened gradient in their upper portions and are very short; so that extensive swampy areas occur virtually untouched by stream erosion. In many cases rock ridges form natural dams or local base-levels of erosion on the tributary streams. The markedly winding character of many of the tributary streams, in contrast to the general straightness of Rainy river, may be due to these local dams, which prevented the streams from cutting down their channels, and to the fact that the volume of the waters of the tributaries was relatively small.

In the northeastern part of the district, Big Grassy and Little Grassy rivers drain westward into Lake of the Woods. Both these rivers in the lower portions of their courses are characterized by relatively broad, deep channels cut for the most part in the soft lacustrine clays. In the case of Little Grassy river, the main stream near its mouth is 200 to 300 feet wide, and 4 miles up stream is still 100 to 200 feet wide and 8 to 10 feet deep at the present average stage of the water. The level of Lake of the Woods extends up stream about 5 miles to the first point, where solid rock outcrops in the bed of the stream. Above this point the stream rapidly diminishes in size and becomes markedly tortuous, whereas the lower portion has relatively few meanders. The banks of the lower portion of the stream are generally steep on either side, becoming progressively higher up stream, being only 2 to 3 feet above the water near the mouth, but 15 to 20 feet high 4 to 5 miles up stream. The water commonly fills the valley nearly from bank to bank, and the valley as a whole is merely a trench cut in the plain. Within the valley, however, there is a narrow, winding channel bordered by a small flood-plain which is submerged generally to a depth of 2 to 3 feet at the present average stage of the water. This feature, giving an appearance of drowning, which is common to practically all of the larger sized streams, entering the southern portion of Lake of the Woods, is apparently due to former low stages of the lake, for it is known that the lake has varied greatly in level from time to time.

Big Grassy river, which enters the lake about 10 miles farther north, has much the same general character except that because the drift deposits were not so abundantly or evenly deposited in the area through which it flows, small lake-like expanses occur along its course, due to uneven disposition of the drift and not to subsequent erosion.

In the highest portion of the area, near the headwaters of some of the tributary streams, the general character of the stream valleys is in marked contrast to the very youthful appearance of the greater portion of their courses. In some instances, as in the headward portion of Pine river in Mather township, the stream valley is wide, with gently sloping sides, in contrast to the narrow, steep-sided lower portion, showing a marked topographical unconformity. This appears to be due partly to stream erosion during the existence of Lake Agassiz, when the waters stood at a slightly lower level than the general level of the headwater region of these streams, and partly to stream erosion before the rise of the waters which brought Lake Agassiz into existence.

Lakes and Swamps.

The two largest lakes of the district are Rainy lake and Lake of the Woods, which may in a sense be considered as diminutive successors of pro-glacial Lake Agassiz, which formerly covered nearly the whole region. Lake Agassiz was, however, an ice-bound lake in its northern portion, while these lakes are partly rock-rimmed, and in their southwesterly portions dammed by drift deposits.

Lake of the Woods, which lies at the western margin of the district, has a maximum length in a north and south direction of nearly 70 miles and a maximum width in the southern portion of about 40 miles. The lake, as has been pointed out by previous writers, is naturally divided into two distinct portions, a northern portion characterized by a very irregular, rocky coast-line and having its surface thickly dotted with islands, and a southern portion generally free from islands and bounded by low, sandy or marshy, shores with gently curving outlines. The southern portion of the lake or that portion lying to the southwest of Bigsby and Big islands is for the most part shallow and represents a flooded portion of the deeply drift-covered plain. The water is frequently not over 20 feet in depth at a distance of 1½ miles from shore and it is stated that throughout the greater portion of the southern part of the basin the maximum depth does not exceed 50 feet. In the northern portion of the lake the greatest depth found by Dr. G. M. Dawson in a number of soundings was in Rat Portage bay near the outlet of the lake, where the water was found to have a depth of 84 feet (9, page 204). In the southern portion of the lake, the deepest part is near the northern fringe of islands and the shallowest around the south and southwestern sides. The land bordering these shores is generally low and marshy with occasional higher areas and outcrops of crystalline rocks. Southwestward from the lake the summit of the divide separating the waters which drain westward to Red river and those draining into Lake of the Woods is generally composed of drift deposits, is swampy in character, and for some distance is not over 30 feet above the lake. Hence the wooded plains of Rainy River district and the southern portion of Lake of the Woods are practically continuous with those of northern Minnesota and southeastern Manitoba.

Lake of the Woods was found to have an altitude of 1,061 feet in July, 1913, as determined from the bench-mark established at Warroad, Minn., by the United States Geological Survey. A water mark which is visible on the rocks in sheltered places around the shores of the lake has an altitude of 1,062·5 feet. It is stated that during the past ten years, the lake has had a maximum variation in altitude of about 5 feet. During previous years it is probable that the variations in level were still greater. Dr. Lawson stated that the lake "had a rise and fall through a range of ten feet" (10, page 18 CC).

Rainy lake with its island dotted surface and ragged, rocky shores, resembles the northern portion of Lake of the Woods. The lake has a maximum length of about 50 miles and is very irregular in outline. It embraces a total area of nearly 350 square miles, about 40 square miles of which is taken up by islands. The maximum depth of the lake, as found by Dr. Lawson in a number of soundings, is at a point 2 miles south of Little Rocky narrows, where the water was found to have a depth of 110 feet. The average of 51 soundings gave a mean depth of 47·4 feet, which Dr. Lawson states is probably not far from the average depth (11, page 16F). The lake occupies a basin which is probably in part a rock basin, but is also partly dammed by drift deposits at its southwestern side and represents a slightly flooded portion of the glaciated rocky plateau country. The shallowness of the lake and the great number of islands, the mean altitude of which above the water does not greatly exceed the average depth of the water, well illustrates the general low relief but irregular, mamillary character of much of the surface of the glaciated rocky plateau.

Rainy lake was found to have an altitude of 1,110 feet in June, 1913, the water being at a high stage. It is stated that water in the lake is ponded to a depth of 4 feet by the dam on Rainy river at Fort Frances by which the outflow is regulated. Former low stages of lake level are suggested by the deep and flooded character of the channels of the lower portion of some of the streams entering the lake, as in the case of the stream at the southern end of Stanjikoming bay.

The large swampy, undrained, areas are marked features of the district (Plate V). In some cases on the surface of the plain, the swamps occupy original, shallow depressions which are not naturally drained. In other cases, beach ridges formed during the existence of Lake Agassiz act as dams and prevent free drainage. The wet swampy condition of the surface is also in many cases due to the very gentle gradients of the surface, the nearly impervious character of the sub-soil, especially the calcareous till, and the slight development of stream valleys. The swamps are generally well timbered, but the central portions are often nearly treeless and consist in most cases of moss-covered muck or peat bogs to which the term "muskeg" is more particularly applied. These bogs, which occupy a relatively small part of the swampy areas, are usually deep and frequently form quaking or floating bogs which are wet throughout the summer months, except in unusually dry seasons. The quaking bogs represent portions of shallow lake basins which have been partly or wholly reclaimed by the gradual growth of vegetation from the shores towards the middle. In some cases, ponds of open water varying in extent from a few acres up to half a square mile still exist and all stages in the process of filling may be observed. The depth of peaty material is sometimes as much as 20 feet, but over much of the swampy areas, the average depth is not over 3 to 4 feet. Owing to the almost continuous wet character of many of the bogs little chance for aeration or oxidation of the vegetable accumulation is afforded, with the result that most of the material is only partially decomposed and is peaty in character. Near the margins of the bogs and along streams which overflow their banks considerable mineral matter is introduced and oxidation is more complete, giving the material a mucky character.

GLACIAL EROSION AND DEPOSITION.

The whole region has been intensely glaciated by ice-sheets advancing from different directions, at different times, during the Glacial period. The dominant direction of glaciation as shown by glacial striæ, grooves, etc., was toward the southwest. This glaciation appears to have produced the greatest erosive effects and its marks are generally well preserved. Another advance of the ice was made in a more southerly direction or in a south-southwesterly direction. Whether this advance was later or earlier than the movement towards the southwest, could not be definitely determined. Another set of striæ which cross these nearly at right angles show an advance of the ice, in a southeasterly to easterly direction. These striæ were seen only in the southern part of the district where the calcareous till occurs. In some cases, these striæ were seen to cross grooves made by the ice which had previously advanced from the northeast and they were not seen to be themselves crossed by later striæ, except possibly in one or two cases near the northern border of the calcareous drift. In these cases it is possible that the easterly bearing striæ refer to an advance of the ice from the Keewatin centre which was the earliest of all, as old calcareous drift does occasionally occur in the district underlying the red drift.

The erosive effects produced by the ice-sheets are shown by the marked development of roches moutonnées surfaces over much of the rocky plateau region (Plate III). In the northern part of the district there is generally very little drift covering and large areas occur where there is scarcely any mineral soil. Bare, rounded domes and ridges of rock, scraped and polished by the ice, frequently protrude. On their surfaces, striæ are sometimes preserved, even where there is no drift covering.

The ice-sheet which brought in the calcareous till from the northwest produced comparatively little erosion in the district, but deposited a considerable amount of material, in contrast to the small amount transported by the ice-sheet advancing from the northeast.

CHAPTER V.

DESCRIPTIVE GEOLOGY.

GENERAL STATEMENT.

The solid rocks or bed-rocks of Rainy River district consist, so far as known, of rocks of Pre-Cambrian age (11). These rocks are overlain unconformably by superficial deposits of Quaternary (Pleistocene and Recent) age. The former do not outcrop extensively, except in the northern portion of the district. The superficial deposits or unconsolidated rocks consist, in part, of drift boulders and glacial till or boulder clay deposited through the agency of the vast continental glaciers which once covered the region; another part consists of stratified fluvio-glacial deposits formed by streams associated with the ice sheets; a third part consists of lacustrine deposits laid down in lakes formed during the retreat or melting away of the ice sheets at the close of the Pleistocene or Glacial period. The superficial deposits also include Recent deposits consisting of flood-plain alluvium, wind-blown sand, and swamp muck and peat.

At least two distinct till sheets occur in the district. One of these till sheets, which is characterized by the presence in it of considerable quantities of limestone boulders and by a high percentage of clay, was deposited by a lobe of the Keewatin glacier advancing from the northwest. This till sheet is underlain in places by till which is generally sandier in character and contains no limestone boulders similar to those found in the overlying till. This till was brought into the district by a lobe of the Labradorean glacier advancing from the northeast. Small quantities of calcareous drift underlying the non-calcareous till also occur in the district and form the oldest of the drift deposits. This old calcareous drift was, apparently, derived from the northwest, but the evidence as to its character and origin is not clear, owing to the poorness of the exposures.

The calcareous till is overlain and in places also underlain by strongly laminated calcareous clays, which frequently contain small stones and occasionally boulders. These clays were deposited in a pro-glacial (glacial-marginal) lake ponded in front of the lobe of the Keewatin glacier which brought into the district the calcareous till, and were mainly derived from material in process of transportation by the ice sheet. These stony, laminated clays may be referred to as glacio-lacustrine deposits, in order to distinguish them from the later lacustrine deposits which were mainly derived from erosion of land surfaces and deposited in lake waters at a considerable distance from any ice margin. The pro-glacial lake in which the glacio-lacustrine clays were deposited is herein referred to as Early Lake Agassiz. This lake was largely drained and a period of erosion ensued before the later pro-glacial Lake Agassiz came into existence.

The calcareous till and glacio-lacustrine clays are unconformably overlain by the lacustrine deposits of pro-glacial Lake Agassiz and these are in turn followed by Recent deposits of alluvium, wind blown sand, and swamp muck and peat.

The following table shows the succession of events and the character of unconsolidated rock formations which unconformably overlie the Pre-Cambrian crystalline rocks. The unconsolidated rocks will be described in the order of their age beginning with the oldest.

Table of Formations.

System.	Series.	Succession of events.	Lithology and general character of deposits.
	Recent	Recent erosion and deposition following the disappearance of pro-glacial Lake Agassiz.	Swamp muck and peat, chiefly organic material; littoral sands and gravels, and wind-blown sand along shores of present lakes; brown to black silty clays of the low overflow terraces of some portions of present streams.
Quaternary	Pleistocene or Glacial	Advance of ice-sheets in the region lying to the north, blocking of northward drainage, and ponding of pro-glacial Lake Agassiz; erosion and deposition during the rising stages of the lake and also during the subsiding stages, following the final retreat of the ice-sheets; crustal upwarping during the subsiding stages of the lake.	Littoral sands and gravels, stratified and cross-bedded, in places containing freshwater shells; lacustrine and fluvio-lacustrine stratified sands, silts, and clays generally calcareous and yellowish in colour, in places containing thin beds and lenses of gravel and in their lower portions freshwater shells and occasionally small quantities of organic material; iceberg deposits of boulders? (rarely occurring).
		Disappearance of pro-glacial Early Lake Agassiz at least in part; interval of weathering and erosion.	No deposits recognized.

Table of Formations—Continued.

System.	Series.	Succession of events.	Lithology and general character of deposits.
		Advance of Keewatin glacier from the northwest; ponding of pro-glacial Early Lake Agassiz along margin of ice-sheet; deposition in lake of material derived chiefly from the ice-front; overriding by the ice-sheet of lake deposits formed in advance of the ice; retreat of Keewatin glacier and deposition in lake during retreat.	Grey or calcareous drift consisting of glacial (calcareous) till or boulder clay, unassorted material, yellowish in colour where weathered, and bluish-grey where unweathered; glacio-lacustrine well laminated calcareous silty clays generally bluish-grey in colour and in places containing stones and boulders; boulder deposits, the product of floating ice.
Quaternary	Pleistocene or Glacial	Interval of erosion, probably short, intervening between retreat of Labradorean glacier and advance of Keewatin glacier.	No deposits known.
		Advance of Labradorean glacier from the northeast over the whole region.	Red drift, non-calcareous till or boulder clay and associated fluvio-glacial sands and gravels.
		Interval of erosion.	No deposits known.
		Probable advance of Keewatin glacier from the northwest.	Old calcareous drift, sand, and gravel, partly stratified, and much oxidized and leached.

QUATERNARY SYSTEM.

PLEISTOCENE SERIES.

OLD CALCAREOUS DRIFT OF KEEWATIN GLACIER.

The old calcareous drift is not known to occur at the surface in the district, but is exposed in one section near the middle of Carpenter township. In this section a few feet of reddish sand and gravel containing limestone pebbles are exposed at the base. The sand and gravel deposit is poorly stratified, and highly oxidized and leached throughout the thickness exposed, which is only about 6 feet. It occurs in a protected position near the base of a rock knob and is overlain by a boulder deposit 2 to 10 feet in thickness, generally free from limestone and apparently belonging to the red drift. The boulder deposit is overlain on the sides of the hill, at lower levels, by glacio-lacustrine clays. It is not known to what stage of glaciation or deglaciation the old calcareous drift belongs. The calcareous character of this old drift seems to show, however, that it was associated with an early advance of the ice from the northwest, i.e., from the Keewatin centre of glaciation.

RED DRIFT OF LABRADOREAN GLACIER.

The term red drift has frequently been applied to the glacial till and fluvio-glacial deposits derived from regions underlain by Pre-Cambrian rocks. In Rainy River district this portion of the drift deposits is generally reddish in colour in its upper weathered portion only, the lower portion being usually grey.

Red Till.

The glacial till of the red drift was brought into the district by a lobe of the Labradorean ice-sheet which advanced from the northeast, as is shown by the trend of glacial striæ developed on rock surfaces underlying the till. The till contains no limestone pebbles or boulders, since the glacier traversed a region in which no limestone bed-rock is known to occur, at least for a distance of several hundred miles, in a northeasterly direction.

The glacial till of the red drift consists of unassorted material composed of angular, subangular, and subrounded fragments of rock of all sizes up to several feet in diameter, set indiscriminately in a matrix of sand and silt or rock flour, with a small amount of material as fine as clay. Many of the boulders and smaller fragments of rock show well developed facets which are often polished and striated. The till occurs at the surface most abundantly in the northern portion of the district, but is generally small in amount and in many places forms merely a thin veneer over the solid rocks. In the southern part it is generally concealed by a thick covering of calcareous drift and is rarely exposed except in sections. One of the best sections seen in which the red drift occurs is in a cutting along the Canadian Northern railway, near the west side of Rainy lake. This section shows at the bottom 5 to 20 feet of till containing no limestone.

Fluvioglacial Deposits.

Forming a portion of the red drift is a series of irregularly bedded sands and gravels of fluvioglacial origin. They are generally exposed only in section, because they underlie the calcareous till. Their widespread occurrence is shown by the numerous well borings which, after penetrating the calcareous till, usually find water in underlying sand and gravel. The sands and gravels are well exposed in section in a large gravel pit 1½ miles west of Fort Frances. They overlie and are wrapped around a well glaciated knob of crystalline rock, showing striæ trending in a southwesterly direction. They originally occurred in the form of a crag and tail kame deposit, the top of which was planed off by wave action, while sands and gravels were redeposited on the sides, the latter beds showing a discordant relation to the underlying deposits. Nearly 30 feet of the sands and gravels are exposed in section in the pit. The sand and gravel consist of well water-worn material derived from crystalline rocks and contain no limestone so far as seen. Much of the material is fine, but many small boulders also occur and a few large ones, the great proportion being well water-worn. The bedding is generally steeply inclined, and also shows quaquaversal dips. Somewhat similar deposits were seen in the gravel pits near Farrington and Mine Centre. No fluvioglacial deposits were noted as occurring associated with the calcareous drift; their absence being probably due to the fact that an ice-marginal lake was ponded in front of the ice lobe which deposited the calcareous till. Hence the outwash deposits from the glacier were glacio-lacustrine in character.

GREY OR CALCAREOUS DRIFT OF KEEWATIN GLACIER.

Glacial (Calcareous) Till.

The calcareous till was brought into the district by a lobe of the Keewatin glacier advancing from the northwest, as is shown by the trend of striæ on rock surfaces, which underlie the till, and by the character of the material composing the till. Much of the material consists of ground-up limestone, sandstone, and shale dervied from the sedimentary rocks which occur as bed-rock formations in the province of Manitoba. Fossils collected by Mr. A. C. Lawson from a mass of limestone, occurring about 6 miles west of Fort Frances, were determined by Mr. P. E. Raymond as belonging to the Richmond limestone (upper Ordovician) (17, page 110). The mass of limestone referred to by Mr. Lawson as a possible occurrence of limestone in place was found on excavation by the writer to be merely a large boulder included in the drift.

Fragments of shale and coal occasionally occur in the till, together with large boulders and smaller angular and subangular fragments of limestone and also of crystalline rocks. The most striking characteristics of the till are the high proportion of silt and clay and the fewness of the boulders scattered through the mass. In sections, the till is seen to consist of unstratified silty and clayey material containing angular, subangular, and subrounded pebbles and boulders arranged heterogeneously. The boulders comprise many varieties of rocks derived both from the Pre-Cambrian and from sedimentary rocks of later age. In some sections, the limestone boulders were found to be the most numerous. Much of the till, however, contains comparatively few boulders and a high percentage of clay. Where unweathered, the till is bluish grey in colour. On weathering it becomes yellowish and sometimes develops a rude columnar structure due to shrinkage. Where surface draining is poor or swamp conditions prevail, oxidation of the iron content has been prevented and the colour remains bluish-grey or becomes blackened by introduction of organic material. The till is nearly impervious because of its high content of clay and in some cases is leached only to a very slight depth from the surface. In one case a sample of the till taken at a depth of one foot from the surface of the ground was found, when treated with dilute, cold hydrochloric acid, to lose 26·5 per cent of its constituents. [illegible] from a depth of several feet below the surface was [illegible] lose 27·5 per cent. The high percentage of soluble constituents in the till is in part due to the large amount of ground-up limestone which it contains, and in general to the method of derivation; for the glacier derived a portion of the material which it transported from unweathered rocks, and little opportunity for weathering was afforded either during the time of transportation or after deposition. The mechanical composition or texture of the material less than 2 millimetres in diameter, composing the till, is shown by the following table, in which the figures represent percentages.

Description	Fine gravel 2—1 mm.	Coarse sand. 1—0·5 mm.	Medium sand 0·5—0·25 mm.	Fine sand 0·25—0·1 mm.	Very fine sand 0·1—0·05 mm.	Silt 0·05—0·005 mm.	Clay 0·005mm.—
Unweathered till.	2·4	2·7	2·5	7·9	10·3	34·8	39·4
Weathered till. . .	5·6	4·7	4·8	13·4	20·6	32·2	18·7

The high percentage of material as fine as clay, in till, which is the result mainly of mechanical processes, is exceptional and is apparently due to the derivation of much of the material from the soft Cretaceous shales which outcrop in Manitoba.

The process of weathering has reduced the quantity of clay and to a less extent the silt, with a consequent increase in the proportions of the sands. An examination of the sands shows a large proportion of minerals other than quartz. In the weathered portion the quartz is slightly in larger quantity than in the unweathered portion. The light colour, generally some shade of yellow, of the weathered till, shows that the iron in the unweathered till is in the ferrous state and of small amount. The silt is largely "rock flour," that is, it is the result of mechanical disintegration rather than chemical decomposition.

The boulders contained in the till are dominantly angular or subangular in shape and frequently show well polished and striated facets. A less proportion of the smaller fragments of rock also shows faceted and polished surfaces. Crystalline rocks are probably more numerous, but limestone boulders are also abundant. In some cases masses of cream-coloured, bedded limestone, 8 feet square and 3 to 4 feet thick, were observed.

One of the most remarkable features about the calcareous till is that it, apparently, does not greatly reflect the character of the underlying rocks. It is possible that small isolated areas of limestone or shale occur as bed-rock in the region, but it is at least certain that the greater portion of the district is underlain by Pre-Cambrian rocks, as indicated by their numerous outcrops even in the southwestern portion of the district. Outcrops occur at various places around the southern end of Lake of the Woods and on the southwestern side near the Manitoba boundary. Hence it is evident that the ice advanced for more than 100 miles over a region underlain dominantly by crystalline rocks; yet the greater portion of the material, especially the finer part, was derived from sedimentary rocks. A probable explanation seems to be that the sedimentary rocks in Manitoba, because of their easily erodible character, supplied an abundance of material to the glacier; in Rainy River district the crystalline rocks offered greater resistance to erosion and the glacier was depositing rather than eroding.

The calcareous till occurs throughout the greater portion of Rainy River district and occupies the surface over an area of at least 190 square miles, with only a slight covering, a few inches in thickness, of lacustrine sand and silt. In places it has a maximum thickness, as shown by well borings of nearly 100 feet, but the average thickness is much less. Sections showing more than 10 feet of the till rarely occur in the district. Numerous sections occur along Rainy river, especially in its lower portion below the town of Rainy River, exposing 10 to 20 feet of the till. Fresh cuttings made in the construction of highways also afford sections. One of these cuttings, 1½ miles east of the town of Rainy River, exposes 10 feet of the weathered yellow till overlain by 4 feet of glacio-lacustrine and lacustrine clays. A similar road cutting recently made one-quarter mile northeast of the village of Emo, exposes 8 feet of bluish-grey unweathered till, overlain by 3 to 8 feet of yellow till and bluish-grey glacio-lacustrine clays. A good exposure of the calcareous till was also seen in the section exposed in the gravel pit 1½ miles west of Fort Frances, where till 6 feet in thickness occurs at the surface, overlying stratified sand and clay (Plate VI). The stratified sand is seen in places to have been minutely folded and overthrust by the overriding of the ice-sheet (Plate VIII) and masses of the underlying laminated clays were ploughed up and included in the till. This occurrence of the till is near the easterly limit of its extension in the district. No calcareous till was seen to occur east of Fort Frances or in the northern portion of the district.

Terminal Moraines. Most of the calcareous till in the district was deposited in the form of ground moraine. The fact that much of the till was transported a considerable distance and is not local in character seems to show, that it was largely englacial material. The till of the ground moraine exhibits very little irregular thickening except in general to mask the uneven surface of the underlying rocks. In places, the underlying rocks form ridges which are in part concealed by a veneer of till.

Near the eastern edge of the calcareous till area, however, a broad ridge occurs which presents slight undulations not due to the irregularities in the surface of the underlying rocks. This ridge or series of low swells, generally rising not over 10 to 20 feet above the adjacent country, extends in a northwesterly direction from a point a few miles west of Fort Frances and forms the divide between streams draining northeasterly and southwesterly. In some places the limit of the extension of the till is fairly closely defined by the ridge and it may be considered as a terminal moraine of the lobe of the Keewatin glacier which brought the calcareous till into the district. No definite evidence was noted of moraines formed later, as the ice withdrew.

The very low relief which the areas of the till present is doubtless partly due to the fact that an ice-marginal lake was ponded by the ice-sheet and that a portion of the material was deposited through the agency of floating ice; this would probably result in a more even distribution of the material than in the case of deposition by ice-sheets on land. Much of the material was probably also englacial in character and was left as the ice melted, without being concentrated in restricted areas. Wave action, also, during the existence of the glacial-marginal lakes, was effective in planing off the surface to some extent and reducing the relief.

Stage of Glaciation. Both the red till and the overlying calcareous till are referred to the Wisconsin stage of glaciation (possibly early Wisconsin), for it has been generally held that the Wisconsin ice-sheet extended far south of Rainy River district. No evidence was found of erosion or weathering of the red till having taken place before the deposition of the calcareous till, and the time interval between the deposition of the two till sheets was probably not long. There is evidence, however, of weathering and of erosion by stream action subsequent to the deposition of the calcareous till and associated glacio-lacustrine silty clays of Early Lake Agassiz and before the deposition of the lacustrine sediments of Lake Agassiz. The weathering of the calcareous till extends to a depth of 6 to 8 feet in places where it was evident, because of the thickness and impervious character of overlying beds, that the weathering must have taken place before the deposition of the overlying lake clays of Lake Agassiz, but no great amount of leaching took place and it is possible that the time interval was not very long. Tyrrell has shown (16), as already stated, that the last advance of the ice was from the northeast and that the Keewatin glacier had retreated well towards its source before this took place. The advance from the northeast was also met by a slight readvance of the Keewatin glacier. It is possible that these advances, however, which brought pro-glacial Lake Agassiz into existence, merely marked the closing stage of Wisconsin glaciation and preceded the final disappearance of the ice-sheets.

Deposits of Pro-Glacial Early Lake Agassiz.

Glacio-lacustrine Clays. These clays are characterized by being well laminated. The laminæ consist of alternate bands of diverse character and colour. One is greyish-white in colour and consists dominantly of silt or rock-flour, while the other is bluish-grey in colour and consists dominantly of material as fine as clay. The clay bands are generally much thicker than the silt bands and both vary in thickness in different portions of a section. An average foot of the section contains about 50 of the greyish-white bands and 50 of the bluish-grey bands. The bands are generally much thinner in the upper part of the section than in the lower portion. Scattered pebbles and more rarely boulders, occur in the clays, especially in the lower portion. The following table shows the mechanical composition of samples of the two bands of the clay in percentages:

Description	Fine gravel 2—1 mm.	Coarse sand 1—0·5 mm.	Medium sand 0·5—0·25 mm.	Fine sand 0·25—0·1mm.	Very fine sand 0·1—0·05 mm.	Silt 0·05—0·005 mm.	Clay 0·005 mm.—
Greyish-white band........	0·5	0·5	0·6	3·4	6·2	68·8	20·0
Bluish-grey band	0·7	0·3	0·5	1·5	2·0	10·0	85·0

The clays are generally highly calcareous and effervesce freely in acid. Soluble material was found to be present in some cases in nearly equal amounts in the clay band and in the silty band. The upper portion of the beds frequently contains concretionary nodules composed principally of calcium carbonate. The concretions are irregular in shape, but as a rule, are roughly almond-shaped, with their longer axes parallel to the planes of bedding. Where the concretions occur, the dividing planes of the silty layers are hardly distinguishable and the bedding is commonly disturbed and bulged around the concretions, apparently due to the expansive force exerted by the concretions in making room for themselves.

The glacio-lacustrine clays were found in some cases to underlie the calcareous till as well as to overlie it. One of the best sections occurs in the gravel-pit 1½ miles west of Fort Frances. The section exposed here shows cross-bedded and ripple-marked sand, gradually passing upward into laminated clay which is overlain at the top by compact calcareous till, 6 to 8 feet in thickness (Plate VII). It is evident that the ice-sheet which brought in the calcareous till advanced into an ice-marginal lake, overrode the glacio-lacustrine clays deposited there and deposited the till upon them. The clays are in places disturbed and ploughed up by the ice and included in the overlying till. At other points in this section the clays are absent and the till rests on stratified sand which is, in places, minutely folded and over-thrust by the overriding of the ice-sheet (Plate VIII).

The laminated glacio-lacustrine clays also occur overlying the calcareous till and occupy a surface area in the district of over 100 square miles, but they are usually only a few feet thick. In many sections there is a gradual transition upwards from the calcareous till into the clays, that is, in the upper portion of the till, thin bands of clay occur separated by material which has the general character of the underlying till, except that it contains less fine material. The bands of clay at the base in some cases are nearly a foot apart, with the intervening material unstratified and resembling till. Passing upwards, the clay bands come closer together and the till-like material commonly disappears within a vertical interval of 8 or 10 feet, its place being taken by the silty band. The till-like material is regarded as having been deposited from floating ice, for the clay bands are not disturbed and were evidently not overridden by the ice. The clays were deposited on a somewhat irregular surface of the till and in their lower portion, roughly conform to the irregularities of the underlying surface, dipping down into the hollows and arching over the rises, but the unevenness of bedding tends rapidly to die out and the beds become nearly horizontal within a few feet. The thickness of these clays does not exceed 15 feet in any of the sections examined.

It is evident that the laminated silty clays were deposited from suspension in a standing body of water and that the water was deep enough to prevent disturbance of the bottom by wave action. It has been supposed by many geologists that laminated clays of this character represent seasonal deposits, one light and one dark-coloured layer forming the amount of deposition for the whole year. The silty layer is regarded by some geologists as the summer deposit, and by others as the winter deposit. In the sections observed in the Rainy River district the iceberg deposits, which appear to be represented by the silty layers, intervene between the clayey layers, and it is presumed that most of the material was derived from the ice during the summer or warm season. It is possible that a small amount of material was derived from melting at the bottom of the glacier during the winter season; but as the glacier was fronted by a considerable body of standing water it seems probable that currents of outflow from the bottom of the glacier would be largely prevented. If the material was mostly derived during the warm season, as seems probable, then the silt may possibly be regarded as mainly the summer deposit and the clay mainly the winter deposit. As shown by the mechanical analyses, the greyish-white layer is composed largely of silt which would remain in suspension only a short time, and the bluish-grey layer is very largely composed of material as fine as clay, most of which, when thoroughly deflocculated, will remain in suspension in a column of water 8 inches high for 24 hours or longer. Hence it would probably take several months for the clay to subside. The presence of calcium bicarbonate in the water would, however, cause the clay particles to flocculate and subside more quickly, and other disturbing factors might come into operation. It is possible that if the material were supplied at intervals several silty bands with relatively thin intervening clay bands might be deposited in one season, since much of the silt would settle through a depth of 100 feet of undisturbed water in the course of a few days and nearly all of it within a few weeks. In most cases, however, the clay bands are much thicker than the silt bands. It is not known in what depth of water the clays were deposited, but it must have been below wave base as the beds are not ripple-marked nor disturbed. That the material was largely derived from the glacier is shown by the occasional presence of pebbles and boulders in the deposit and by the fact that in some cases land areas were far removed from places where the clays were deposited. The material is similar to that which would be derived from the calcareous till and the clays are for the most part confined to the region occupied by this till. The clays also lack the sandy character which the lacustrine clays derived from land erosion possess. The even character of the lamination suggests that the material was supplied regularly and there seems good reason to suppose that the deposits are seasonal in character.

Boulder Deposits. Deposits of boulders with sand and gravel occur at several places in the district. The boulders in these deposits commonly show fewer signs of glacial wear and are more water-worn than those found in the true till. The deposits are generally too coarse to show stratification. They frequently contain boulders up to 3 and 4 feet in diameter, the finer material consisting chiefly of sand and gravel with very little silt or clay.

In the section exposed along the Canadian Northern railway, near the west side of Rainy lake, the till of the red drift is overlain by 1 to 3 feet of glacio-lacustrine laminated clay containing limestone pebbles, which is in turn overlain by 2 to 4 feet of sand, gravel, and boulders, forming the crest of the ridge. Similar sand and boulder deposits overlying laminated clay were also noted in sections exposed in gravel pits along the line of the Canadian Northern railway at points 2½ miles east of Farrington and 3½ miles east of Mine Centre. These places are respectively 31 and 41 miles east of Fort Frances. In both sections conditions are somewhat similar. A small thickness of laminated clay and sand overlies, unconformably, stratified fluvioglacial sands and gravels of the red drift and is in turn overlain by a deposit of sand and boulders 1 to 3 feet in thickness. No limestone pebbles nor boulders, however, were seen in any of the deposits east of Rainy lake; but the laminated clays are similar to those which occur near Fort Frances, as, except for the absence of limestone, is also the boulder deposit which overlies them. The bedding of the clays is not disturbed and it seems evident that they were not overridden by the ice-sheet. Hence the boulder deposits are regarded as having been derived from floating ice.

A considerable boulder deposit also occurs in the western portion of the region and is well exposed along the shores and on islands near the central portion of Lake of the Woods. Near the southeastern end of Bigsby island the boulder deposit was seen to be overlain by several feet of lacustrine clay; but in the more northern portions of the lake it has only a thin covering of sand or gravel. Scattered boulders also occur on the surface of some portions of the lacustrine deposits; but rarely in these deposits. No considerable deposits of boulders nor any till were seen to overlie the calcareous till in the district. The boulder deposits occur most abundantly just beyond the margin of the calcareous till and near this margin they sometimes contain fragments of limestone similar to that found in the calcareous till. Generally no limestone was found to occur among the boulders at a greater distance than one mile from the margin of the calcareous till. In the northern portion of Lake of the Woods the mass of sand and boulders is frequently 10 to 20 feet thick and forms a rude terrace fringing the shore at many places and rising to a height of 15 to 20 feet above the lake. The greater portion of the deposit consists of boulders averaging a foot or more in diameter. Many of the boulders show signs of glacial wear; but more commonly they are water-worn to some extent, lacking the distinctly polished and striated surfaces frequently seen on boulders embedded in till. The materials forming the deposit are generally too coarse to show distinct bedding. The deposit also differs from true till in that the matrix contains very little silt or clay.

It is possible that the boulder deposits above described belong to the red drift and were derived from the northeast by an advance of an ice lobe subsequent to the deposition of the calcareous till. It seems more probable, however, that they are at least in part berg-deposits associated with the ice lobe which advanced from the northwest and brought into the district the calcareous till; for it is known that a glacial-marginal lake, earlier than Lake Agassiz, was ponded by this glacier. In this lake the glacio-lacustrine clays of the district were deposited.

The presence of occasional boulders on the surface of the lacustrine deposits of Lake Agassiz, which was later formed by an advance of the ice from the northeast causing a ponding and rise of the waters, seems to imply the presence of floating ice in the lake. The boulders more frequently occur at high levels corresponding to high stages of the lake. At lower levels the lacustrine deposits are generally free from boulders either within their body or on their surface. It, therefore, seems probable that during the higher stages of the lake, iceberg drift was deposited and that the boulder deposits are in part later than the calcareous drift. The absence of any red till overlying the calcareous till shows that the last advance of the ice did not reach as far as Rainy River district.

Pro-Glacial, Early Lake Agassiz. The glacio-lacustrine clays were deposited in a pro-glacial lake, which may be called Early Lake Agassiz. This lake was in part at least, if not wholly, drained away before Lake Agassiz, the last pro-glacial lake of the region, came into existence. This is shown by the weathering and erosion of these clays, which took place before the deposition of the overlying lacustrine clays of Lake Agassiz. The evidence on which this statement is based is discussed in a following chapter on " Historical Geology." It is not known what was the extension of Early Lake Agassiz, nor are any of its shore-lines known. The clays occur in Rainy River district up to an altitude of at least 1,250 feet. It is possible that some of the higher shore-lines in the region to the south, which have been ascribed to "glacial Lake Agassiz" (14), in reality mark the southern limits of the pro-glacial lake in which the glacio-lacustrine clays were deposited.

DEPOSITS OF PRO-GLACIAL LAKE AGASSIZ.

Lacustrine and Fluvio-lacustrine Deposits.

The lacustrine and fluvio-lacustrine deposits differ from the glacio-lacustrine silty clays in that they were derived for the most part from erosion of land surfaces by streams and wave erosion. They differ in character, also, in that they usually lack the regular lamination and are more diverse in composition. The lacustrine deposits were derived mainly from wave erosion of the shores and the shallow bottom of the lake. The fluvio-lacustrine deposits are mostly sub-aqueous valley-fill and delta deposits and are concentrated in areas where streams entered the lake. They were deposited, for the most part, in relatively shallow water near the debouchure of the stream and as valley-fill for some distance up the streams. In some cases the stream valleys had previously been excavated and the fluvio-lacustrine sands and clays were concentrated in these valleys. At many places the lacustrine and fluvio-lacustrine deposits are intermingled because wave-induced alongshore currents transported the delta material and mingled with it other material derived from the erosion of the shores and bottom.

The most widespread deposit on the floor of the lake consists of lacustrine fine sand and silt which mantles the surface of much of the area, but to a depth, generally, of only a few inches. The fine sand and silt appear to have been derived mainly by wave erosion from the calcareous till and glacio-lacustrine silty clays over which they are spread. They consist in large part of "rock flour," that is, material ground up by glacier ice. When wet it has somewhat the properties of clay, being slightly plastic; but when dry is incoherent and mealy.

The lacustrine and fluvio-lacustrine sandy and silty clays in the district are generally evenly bedded, but are characterized by an irregular alternation of sandy and clayey layers, and occasionally thin gravelly layers or thin lenses of gravel. The gravelly layers occur chiefly in the lacustrine beds which were derived from wave erosion and deposited in near shore shallow waters. The beds are commonly more sandy towards their base, near the contact with the underlying sediments, and are frequently ripple-marked, but no cross-bedding was noted. The laminæ of sand vary in thickness from a fraction of an inch up to several inches. The clay laminæ are more regular in thickness, averaging about one-quarter inch. In some portions of the delta deposits the laminæ are more regular in occurrence and consist of alternation of sandy silt layers with sandy clay layers. The gravelly layers are generally thin, consisting of sand and gravel, and occur frequently as continuous beds extending for some distance. In other cases, gravel lenses 2 to 3 inches in thickness occur without having any great lateral extent. The gravel beds are present at frequent intervals throughout some of the sections. In other sections of deposits, which are apparently sub-aqueous delta deposits, the gravel is absent. In colour the beds are generally yellowish-grey, but are bluish-grey in some portions of the delta deposits. They are as a rule calcareous, except their upper portion, where leaching has been effective. The material, which was derived mostly from wave erosion of the shores, has a more noticeable yellow shade of colour and is more leached than the fluvio-lacustrine clays. In some sections the yellow colour extends downward to a depth of 12 to 14 feet. In the upper 3 or 4 feet of the section recent weathering and leaching have given the clay layers a reddish-brown colour in places. Much of the material was derived from erosion of the calcareous till and glacio-lacustrine clays which had been weathered to some extent. This would account for the somewhat leached character of the silty clays. An average sample of the fluvio-lacustrine clay was found on mechanical analysis to be composed as follows:

Description	Fine gravel 2—1 mm.	Coarse sand 1—0·5 mm.	Medium sand 0·5—0·25 mm.	Fine sand 0·25—0·10 mm.	Very fine sand 0·10—0·05 mm.	Silt 0·05—0·005 mm.	Clay 0·005 mm.—
	0·9	2·3	3·9	7·9	18·2	46·6	20·2

The upper portion of the delta and shallow water deposits in places consists of fine sand, varing in thickness from a few inches to 2 or 3 feet. An average sample of this material was found to contain 87 per cent of fine, and very fine, sand, consisting largely of quartz; but with a considerable percentage of feldspar and other minerals. Most of the particles are angular; but some of the quartz grains are rounded.

The peculiar character of the lacustrine and fluvio-lacustrine deposits, simulating to some extent that of fluvial deposits, is due to the fact that they were in part laid down during the rising stage of the water. The presence of the thin beds of gravel is due to wave action planing away gravel beach ridges, as the waters rose, and spreading the gravel out in a thin layer over the shallow bottom near shore. The rise of the waters also explains the ripple-marked sandy beds occurring below clay beds in many of the sections. A portion of the deposits was laid down during the rising stages of the waters, and a portion during the subsiding stages.

The lacustrine and fluvio-lacustrine deposits occupy a surface area in the district of at least 120 square miles, or about one-sixth of the total area, and probably underlie much of the muck and peat deposits which make up nearly one-third of the total surface. Numerous sections exposing the clays occur along Rainy river and its tributaries. Just below the dam at Fort Frances a section shows 12 feet of the yellowish-grey, silty, and gravelly clays which form a portion of the valley-fill (Plate IX). The total thickness of the clays here is at least 25 feet. They partially fill a stream valley which was eroded before the deposition of the clays took place. At the brick-yard on the river bank 1½ miles below Fort Frances a thickness of 10 feet of fluvio-lacustrine clays free from gravel or boulders was found to be exposed. This deposit also forms a portion of the valley-fill, the greater part of which has been eroded by the present stream. A short distance back from the river calcareous till comes to the surface. Numerous sections also occur along the lower portion of Rainy river, but generally with only thin beds of the clays exposed. A widespread delta and shallow water deposit occurs in the northwestern portion of the district. This deposit has been trenched by Little Grassy river and its tributaries and a portion of its material has been removed to form a sub-aqueous delta at a lower level in Lake of the Woods. The surface of the old delta slopes gradually from a height of 2 to 3 feet above the water at the lake, up to a height of 30 feet above the lake at a distance of 4 to 5 miles inland. The first strong beach which marks the stage of the water during the time when most of the material in the delta was deposited is nearly 65 feet above the lake. The maximum thickness of the delta deposits is not known, but they are in places at least 30 feet thick. A large proportion of the material was apparently deposited in water varying from 30 to 60 feet deep. Some of the clays and sands derived from wave erosion of the shores were deposited in water of still less depth. An important factor in causing the deposition of the clays in shallow water is calcium bicarbonate in solution, as it tends to flocculate the clay, forming larger granules which settle quickly. It was noted that after the cessation of a storm in Lake of the Woods the water cleared within a few hours. Much of the material held in suspension is calcareous. The great amount of material held in suspension during a storm also causes quick deposition, as the coarser material carries down the finer with it. This explains why the clays derived from wave erosion were deposited in relatively shallow water; for much of the material eroded was coarse in character and very abundant. No evidence was noted of subaërial deposition of the delta material.

Fossils. Fossil freshwater shells occur in considerable numbers in some portions of the lacustrine and fluvio-lacustrine deposits and in some of the littoral deposits of Lake Agassiz in Rainy River district. Fossil shells have also been found in Lake Agassiz deposits at other places in the basin. Upham stated (14, page 237) that fossils shells had been found in the deposits of Lake Agassiz at two localities; in the Campbell beach about 6 miles southwest of Campbell, Minnesota, at an elevation approximately 985 feet above the sea; and in the Gladstone beach one-half mile northeast of Gladstone, Manitoba, about 875 feet above the sea and 165 feet above Lake Winnipeg. Fossil shells were also found in numerous places in deposits which Upham regarded as post Lake Agassiz fluvial sediments (14, pages 201 and 253).

In Rainy River district, fossil shells were found by Lawson in a gravel beach ridge at the first rapid on Pine river, also in the beds on Rainy river at the confluence of Pine river, and at various points below this, particularly in the bedded sands and clays at the mouth of Baudette river (11, page 172E). Freshwater shells were also found by A. P. Coleman in Lake Agassiz clays near Fort Frances (24, page 147).

Fossil freshwater shells were found by the writer to occur in Rainy River district at five different localities in sand and gravel beaches of Lake Agassiz and at numerous places in the lacustrine and fluvio-lacustrine deposits of the lake. They occur abundantly in the sandy and gravelly stratified clays which are exposed in section on the bank of the river at Fort Frances (Plate IX). In this section the shells are most abundant in the sandy and gravelly thin beds and lenses. In the clays exposed at the clay pit on the bank of the river 1½ miles below Fort Frances an occasional large Unio occurs. In the sections exposed along Rainy river below the town of Rainy River the fluvio-lacustrine clays contain numerous shells in their lower portion. These are more abundant in the sandy layers, although they also occur scattered through the clays. Frequently there was seen to be a line of Unios in the sandy bed at the base of the clays and along the contact with the underlying calcareous till or glacio-lacustrine clays. The Unios are nearly always poorly preserved and fall to pieces on removal from the matrix, due to their aragonitic character which renders them easily susceptible to leaching. Sections of the fossiliferous sands and clays are well exposed along the bank of the river about a mile below the railway bridge at the town of Rainy River. In the upper portion of the fluvio-lacustrine deposit, or in that portion which was apparently laid down during the subsiding stages of Lake Agassiz, no fossil shells were found.

Fossil shells also occur in some of the beach ridges and not in others. A strong beach which occurs near the north bank of Rainy river at a point about 8 miles below Fort Frances contains numerous shells. There is exposed in the beach a 12-foot section of stratified sand and gravel, cross-bedded in places, and containing shells near the bottom and in various layers up to 1½ feet from the surface of the ground (Plate X). The altitude of the crest of the ridge is 1,149 feet above sea-level, or 40 feet above the level of Rainy lake and 88 feet above Lake of the Woods. Fossil shells were also found in beach sand and gravel in section 3 of Crozier township, at an altitude of 1,141 feet; 1½ miles northwest of Emo at an altitude of 1.141 feet; near the southwest corner of Aylesworth township at an altitude of 1,118 feet; and in section 33 of Dilke township. In some instances beaches which had apparently been formed at halts during the rising stage of the water were partially cut away as the water rose and the sand and gravel were spread out laterally. In some cases, also, beach sand and gravel are overlain by clay a foot or so in thickness. It was not determined whether fossil shells are confined to the earlier or later set of beaches. In one case, however, fossil shells were found in a spit which was, apparently, made during the rising stage of the water.

Littoral Deposits.

The littoral deposits of pro-glacial Lake Agassiz in the district consist of beach sand and gravel disposed generally in the form of long and relatively narrow even crested ridges. The material composing the beach ridges, barriers, spits, etc., contains a large amount of limestone gravel derived from the erosion of the calcareous till. In some cases quartzose and feldspathic sand is the most abundant material. The beach ridges vary in height from 2 to 15 feet, and in breadth from 50 to 500 feet, or even more in places where the rising waters enabled the waves to plane away part of the deposit and spread it out over the shallow bottom. In such cases, however, the deposit was in part formed sub-aqueously. The bedding of the material composing the beaches is in general conformable to the surface contour of the ridge. In places the beds are diagonal or cross-bedded; the greatest thickness observed was 21 feet; the average thickness is considerably less. The greatest thickness occurs in places where spits were built into relatively deep water or where deposition continued during the rise of the waters.

The beaches occur at irregular vertical intervals. Some of the intervals are large and there is comparatively little evidence of wave action in the intervals between beaches. Owing to the slight relief of the region, sand and gravel ridges are the dominant features of the shore-lines and shore cliffs are poorly developed, or absent. Much of the material in the beaches was derived by wave erosion of the shallow bottom, but boulder strewn terraces are not conspicuous because much of the till eroded contains comparatively few boulders. The correlation of beaches in the region is difficult on account of the densely wooded character of much of the surface and the consequent difficulty of continuous tracing. There is also the difficulty that strong beaches, spits, etc., were built during the rising stage of the water, and were in some cases preserved and in other cases largely cut away. There is one well-marked strand line in the region, however, which is readily recognized.

In the southwestern portion of the district, near Lake of the Woods, a faintly marked beach occurs at a height of 30 feet above the lake and a corresponding terrace extends for some distance up Rainy river. The first strong beach is 56 feet above the lake. This is the best marked shore-line in the region and is probably the strong Campbell beach referred to by Upham as one of the best developed beaches of Lake Agassiz (14). This beach is well developed in Curran township north of the town of Rainy River, in the adjacent portion of the Wild Land Reserve, and in Spohn township. It also occurs with considerable strength 1½ miles east of Sleemans in Worthington township and northward in Blue, Pratt, and Sutherland townships. The beach extends for some distance up the valley of Rainy river and is developed near Pinewood and also at Barwick. The occurrences of the beaches so far up the valley, and in restricted portions of the valley, show that Rainy River valley was excavated in part before the lake came into existence.

Near the town of Rainy River this strong beach, which is referred to as the Campbell beach, has an altitude of 1,117 feet. A weaker beach, or off-shore bars, occurs near the same place at an altitude of 1,110 feet. Eleven miles north of this locality, in Spohn township, the beach was found to have an altitude of

1,125 feet (barometer). At Gameland, in Pratt township, 10 miles northeast, it has an altitude of 1,125 feet (barometer), and in lot 3, concession I, of Morson township, 24 miles northeast, the altitude was found to be 1,140 feet (barometer). At the latter locality beaches also occur at 1,130 and 1,135 feet (barometer), but none were found at lower levels down to the level of Lake of the Woods. The strength of this beach is in places remarkable. In the Wild Land Reserve, north of the town of Rainy River, the "embankment" of sand and gravel is in places 1,500 feet wide with a maximum thickness of at least 15 feet. This beach appears to mark a long continued stand of the waters of Lake Agassiz both during the rising stage and again during the subsiding stage; for the beach was partially cut away and spread out and, later, cross ridges were in places built on the surface by wave action. From the data collected in the district, which are not very satisfactory, the direction of maximum upwarping, as shown by the altitudes of the Campbell beach in different places, is north 35 degrees east and is at the rate of nearly 1 foot per mile. Higher beaches occur in the district up to altitudes of at least 1,200 feet, but are not nearly so well developed, and at these higher altitudes the greater portion of the area was submerged. In the northeastern portion of the region, which is the highest portion, at altitudes ranging from 1,225 to 1,275 feet, little evidence of wave action was seen, even in the drift-covered areas where conditions were favourable for the production and preserval of shore-line features. In the still higher rocky region to the northeast so far as seen, beaches also appear to be absent; but, because of the general paucity of drift in the rocky areas, conditions were not very favourable for the making of shore records. In northern Minnesota beaches occur at altitudes considerably above 1,200 feet (19). Their apparent absence in the northeastern portion of Rainy River district suggests either, that during the highest stages of Lake Agassiz the region to the north was blocked by ice, or, that some of the highest shore-lines, referred to Lake Agassiz, belong to the earlier pro-glacial lake associated with the Keewatin ice-lobe which brought in the calcareous till.

Following is a list of altitudes (above mean sea-level) of the crests of beach ridges, spits, etc., of Lake Agassiz, and the localities at which they occur. The altitudes were all determined by levelling, and the levels were based on the precise levels taken and bench-marks established by the United States Geological Survey and Canadian Geodetic Survey in the region (20 and 21). In this list the first three refer to the strong beach which is regarded as the Campbell beach.

(1.)	Near west side of section 3 of Curran township.	Feet.
	Crest of strong sand and gravel spit	1,117
	Weaker bars 1 mile south	1,110
(2.)	Near middle of section 28 of Worthington township.	
	Crest of strong sand and gravel spit	1,116
	Crest of weak bar	1,109
(3.)	At southwest corner section 36 of Barwick township.	
	Crest of strong beach ridge	1,113
	Crest of weak bar	1,105
(4.)	In section 21, Aylesworth township, near river road.	
	Crest of beach ridge	1,119
(5.)	At southwest corner of section 36 of Barwick township.	
	Crest of beach ridge	1,126
(6.)	In section 33 of Dilke township.	
	Crest of gravel bar	1,133
(7.)	Near Rainy river 3 miles below Fort Frances.	
	Crest of sand and gravel spit	1,131
(8.)	In section 31 of Lash township.	
	Crest of sand and gravel bar	1,133
(9.)	In section 29 of Lash township.	
	Crest of sand and gravel bar	1,140
(10.)	In section 36 of Lash township.	
	Crest of sand and gravel spit	1,141
(11.)	Near east side of section 1 of Shenstone township.	
	Crest of beach ridge	1,136
(12.)	East side of section 3, Crozier township.	
	Crest of sand and gravel spit	1,145
(13.)	Near Rainy river, 8 miles below Fort Frances.	
	Crest of strong sand and gravel spit	1,149
(14.)	In section 22 of Morley township.	
	Crest of sand and gravel bar	1,177
(15.)	In section 28 of Devlin township.	
	Crest of sand and gravel bar	1,200

RECENT SERIES.

ALLUVIUM.

The alluvium consists of recent flood-plain deposits of sand, silt, and clay, which border some portions of the streams of the district. Rainy river has very little flood-plain because the immediate banks are generally sufficiently high to contain the flood waters. Some of the tributary streams in their upper portions overflow their banks in time of flood, and deposit sand, silt, and clay, building up natural levees in places, which help to produce swampy conditions by preventing free drainage. This occurs where the streams have not cut down their channels owing to the presence of a rock barrier in the bed of the stream or where the surface gradients are slight. The alluvium is generally only 1 to 3 feet in thickness and extends in a narrow border, rarely exceeding one-quarter mile in width along the streams. The material is somewhat sandier near the bank of the stream and more clayey farther away.

DUNE SAND AND BEACH SAND.

Deposits of wind-blown sand occur near the mouth of Rainy river on the series of wave and current-built bars which extend in a northeasterly direction for nearly 12 miles. The material consists mostly of fine to coarse quartzose and feldspathic sand which has been washed up by the waves, dried on the beach and blown up on the bars to form dunes. In places the dunes rise to a height of 30 feet above the lake. They were formerly more extensive than at present and were in part clothed with a scanty vegetation. In recent years the dunes have been partially destroyed and much of the sand has been blown away and deposited in the lagoon behind the bars. The waves have also cut into the lakeward side of the bars, killing the protecting vegetation and exposing the loose sand to the action of the wind. Much of the material has also been transported northeastward by the wave-induced alongshore currents and the bars are constantly being extended in that direction.

MUCK AND PEAT.

Nearly one-third of the whole area is poorly drained or swampy in character, and much of the surface is covered with deposits of muck and peat, which vary in thickness from 1 to 20 feet, or poscibly more in places. The average thickness, however, is probably not over 3 feet. Most of the material is peaty in character and consists almost entirely of organic matter in a partially decomposed condition, the fibrous nature and vegetable origin of the material being usually quite apparent. The peat has been formed by the accumulation of the remains of various plants, sphagnum moss being especially abundant in some places, and owes its origin to the undrained character of the surface and the humid conditions which retard the decay of the vegetable matter and enable successive generations of the plants to be preserved by burial. The muck contains a larger percentage of mineral matter than the peat, and decomposition, brought about by better drainage and aëration, has progressed farther, so that much of the fibrous structure has disappeared. The mineral matter has been largely introduced by streams in time of flood depositing it on their flood-plains or low overflow terraces.

CHAPTER VI.

HISTORICAL GEOLOGY.

QUATERNARY PERIOD.

PLEISTOCENE EPOCH.

The Tertiary period, which immediately preceded the Quaternary period, was largely characterized by warm or temperate climates throughout the world. At the close of the Tertiary period the warmth of a temperate climate gave way to arctic cold. Great ice-sheets or continental glaciers spread outward from different centres in Canada and extended far south. One of these centres of glaciation was in the region lying west of Hudson bay and has been called the Keewatin centre of glaciation, and the ice-sheet which spread out from it the Keewatin glacier. Another glacier had its centre in Labrador and has been called the Labradorean glacier. During the Pleistocene epoch or Ice age, various advances of the ice-sheets from the two centres of ice-dispersal were made at various times. There were also intervals of deglaciation, during which time the ice retreated or melted away from a large part of the regions which it had previously covered. It is not known whether the ice-sheets were entirely melted away from the continent during any of these intervals of deglaciation, but that some of the intervals were of long duration is undoubted; nor is it doubted that the duration of the Ice age as a whole was very much longer than the time which has elapsed since the disappearance of the glaciers.

Succession of Events.

In Rainy River district there is evidence of at least three advances of the ice. Two of these came from the direction of the Keewatin centre of glaciation and at least one from the Labrador centre. This is shown by the trend of the glacial striæ impressed on the bed-rock over which the glacier moved and by the character of the material which the glacier transported.

It is concluded from the evidence found in the district that the following series of events took place, beginning with the oldest:

(1.) An advance of the ice from the direction of the Keewatin centre, which brought into the district the old calcareous drift. No striæ definitely referable to this ice advance were found in the district, but old calcareous drift was found, at one place, near the middle of Carpenter township, to be overlain by drift derived from the northeast.

(2.) An advance of the ice-sheet from the northeast or from the direction of the Labrador centre. This is shown by the trend of striæ and by the till which contains no limestone. Associated with this ice-sheet considerable fluvio-glacial deposits of sand and gravel were formed by streams derived from the melting of the ice-sheet.

(3.) A second advance of the ice from the Keewatin centre, which brought the calcareous till into the district. This is shown by the trend of striæ on bed-rock underlying the calcareous till and by the fact that the till contains numerous fragments of limestone and other rocks which occur in place in Manitoba, across which the glacier advanced. A pro-glacial lake (Early Lake Agassiz) into which the glacier advanced was ponded to the south by this glacier. In this lake glacio-lacustrine deposits were made which were in part formed in advance of, and later overridden by, the ice and in part formed as the ice gradually withdrew to the north or melted away.

(4.) The pro-glacial lake, referred to as Early Lake Agassiz, in which the glacio-lacustrine clays of the district were deposited, was at least in part, if not wholly, drained away by the retreat of the Keewatin glacier uncovering outlets of drainage to the north, and an interval ensued during which weathering of the surface took place, stream valleys were eroded, and vegetation to some extent obtained a foothold.

(5.) A last advance, as shown by Tyrrell (16), of a lobe of the Labradorean glacier in the region lying to the north of Rainy River district, was met by a re-advance of the Keewatin glacier, which resulted in the blocking of the drainage to the north and pro-glacial Lake Agassiz came into existence. Beaches were formed during the rising stages of the lake and again during the subsiding stage. Strong beaches were built, while the water level remained nearly stationary for some time during the functioning of certain outlets. Again, the waters rose rapidly as outlets to the north were blocked, or later fell rapidly as lower outlets were uncovered by the retreat of the ice, producing marked intervals between beaches. During the final retreat of the ice-sheets differential elevation of the region took place, so that the shore-lines of Lake Agassiz instead of being horizontal as when formed, or nearly so, are now inclined, the maximum amount of crustal upwarping being in a direction approximately north 35 degrees east. That the upwarping was largely accomplished during the existence of the lake is shown by the facts, as pointed out by Upham (14), that in the northern portion of the basin the beaches split up into series and the lowest beaches of the lake are nearly horizontal.

The evidence for the succession of events as outlined in the last two paragraphs is discussed in the following section.

Genesis of Pro-glacial Lake Agassiz.

Upham found by his investigations in the basin of Lake Agassiz that the lake had for a considerable length of time its outlet to the south by way of Lake Traverse to the Mississippi, that in the northern portion of the lake basin no less than seventeen shore-lines were formed contemporaneously with this southern outlet, and that during later stages when the overflow was to the north fourteen more shore-lines were formed (14). He believed that the lake at first occupied a comparatively small area in the southern portion of the region and grew as fast as the ice-sheet waned, until at its maximum extension it covered a very large area (14).

Tyrrell stated in a paper published in the Journal of Geology in 1896, that he had found evidence in the region lying to the north and east of Lake Winnipeg that the lobe of the Keewatin glacier which had advanced far south in Red River valley had retreated well towards its source before it was met by an ice lobe advancing from the northeast, and that the union of the two caused a ponding of the waters which produced Lake Agassiz. The waters then rose until they overflowed southward into the valley of the Mississippi and, later, gradually declined. More recent investigations by Tyrrell in the region lying south of Hudson bay, near the headwaters of the Albany and Severn rivers, have served to confirm these conclusions. In a recent paper (16) Tyrrell has shown that the last advance of the ice in this region was by a lobe of the Labradorean glacier coming from the northeast. This lobe had its western front near the Hayes River region, where it was met by a re-advance of the Keewatin glacier from the northwest. A great moraine was formed by the lobe of the Labradorean glacier on the high land near the source of the Severn river; but whether or not the Labradorean glacier extended south of this great moraine, Tyrrell states is somewhat uncertain.

The evidence found by the writer in Rainy River district confirms the conclusion that Lake Agassiz first had a rising stage, due to the blocking of the drainage to the north, and that later the waters subsided as outlets to the north were uncovered by the retreat of the ice. The lake was not associated directly with the ice-sheets which deposited the till in the region and throughout the great portion of its existence the ice margin was far to the north, while the lake itself was comparatively free from ice.

The evidence is based largely on the fact that in Rainy River district the sediments deposited in Lake Agassiz rest unconformably on the underlying calcareous till and glacio-lacustrine clays, that is, a period of erosion intervened after the deposition of the till and associated glacio-lacustrine clays and before the lacustrine sediments were laid down.

This is well shown in numerous sections exposed along Rainy river and around the shores of the southern portion of Lake of the Woods. Plate XI illustrates the character of one of these sections which has been exposed by wave erosion on the present shore of Lake of the Woods at its southern side. At the base a small thickness of calcareous till is exposed passing up into stony, laminated, glacio-lacustrine clays, which are overlain unconformably by fluvio-lacustrine Lake Agassiz clays containing freshwater shells. The contact is a wave-cut plain. The wave-cut plain is not in itself evidence of an unconformity, but the character of the sediments above this line shows that the water must have risen a considerable height. This old wave-cut plain, which is evidence of the existence in Lake of the Woods basin of a lake which preceded Lake Agassiz, can be traced for many miles in sections around the shores of the lake, and in the southern portion of the lake to the east of Long point it is practically continuous for several miles. Gravel beach ridges formed at the same time also occur at several places. One of these is well exposed in section on Buffalo point in the southwestern portion of the lake. The lake, of which this old shore-line forms a fossil record, had its level, as shown by the old beaches in the southern portion of Lake of the Woods basin, about 4 feet above the present level of Lake of the Woods, and may represent a lake which was left in the basin after the retreat of the Keewatin glacier, or an incipient stage of Lake Agassiz waters. No records of the lake were found in the northern portion of Lake of the Woods basin, so that the relation of its water plane to that of the present lake is unknown. In the southern portion of the basin the old water plane is practically parallel to the present one in an east and west direction.

Numerous sections exposed in the district also show that considerable weathering and a certain amount of leaching took place before the deposition of Lake Agassiz sediments. This is well shown in sections along Rainy river at various points from 1 to 3 miles below the railway bridge near the town of Rainy River. In some of these sections calcareous till which is overlain unconformably by a thickness of 6 to 10 feet of Lake Agassiz clays is also weathered to a depth of 6 feet and is rusty yellow in colour, whereas the colour of the unweathered till is bluish grey. It was also evident in many of the sections that the weathering or oxidation took place before the deposition of the overlying sediments and is not due to recent weathering. Both the weathered and unweathered till contain pebbles and boulders of the cream coloured magnesium limestone which characterizes much of the till. In the weathered portion leaching has been effective in removing a portion of the finer soluble material. A sample of unweathered till was found to sustain a loss of 27·3 per cent when treated with dilute, cold hydrochloric acid. A sample of the weathered till taken at a depth of 4 to 5 feet below the surface of the till, and 8 to 10 feet below the surface of the ground, was found to lose 19·0 per cent, so that apparently it shows no very great amount of leaching. The till is, however, clayey and very compact in character, and consequently is nearly impervious where unweathered. In some places it was also noted that the yellow colour of the weathered till extends downward for at least a foot below the present level of the ground-water. In several sections for a depth of 1 to 2 feet below the contact with overlying lacustrine clays, the calcareous concretions, which are frequent in the upper portion of the glacio-lacustrine clays, were almost wholly dissolved, leaving only white blotches where they formerly lay; the clays are of sufficient thickness to effectively prohibit recent leaching. That the weathering and leaching in the till and laminated clays took place to some extent in situ and before the deposition of the overlying lacustrine sediments seems to be evident from the uniform character of the occurrence as outlined above. Post-Lake Agassiz leaching has been effective only to a slight depth. Fragile shells occur in loose sand and gravel ridges in places within 1 foot of the surface of the ground and where drainage conditions are good. A sample of calcareous till taken from a depth of only one foot from the surface of the ground was found to contain 26·5 per cent soluble material.

Stream valleys were also developed to some extent in the district during this interval of erosion. Near Fort Frances fossiliferous Lake Agassiz clays fill a portion of the valley of Rainy river to a depth of nearly 25 feet. A section across the valley of a small creek which enters Rainy river 3 miles below Fort Frances shows on one side of the valley calcareous till and on the other side lake sediments, partially filling the valley which was eroded to a depth of at least 20 feet before the deposition of the lake sediments. The recent valley was apparently developed along the contact of the till and the more easily eroded and more permeable lake sands and clays. A similar relation was noted in the case of several other valleys.

There is also evidence that during the interval of erosion vegetation had to some extent obtained a foothold. The upper portion of the clays underlying lake sediments several feet thick is in places slightly blackened. In a section exposed on the south side of Buffalo point on Lake of the Woods peaty bands interbedded with sand occur (Plate XII). The peaty bands contain fragments of wood and water-worn chips partially carbonized. No evidence was noted, however, of arboreal vegetation occurring in situ in the clays below the unconformity at the base of the lacustrine sediments.

Little inference can be drawn as to the duration of the interval of erosion, but it is evident that such an interval did occur and that it was not of short duration. It is also clear that the waters of Lake Agassiz rose through a vertical interval in the district of at least 60 feet above the level of Lake of the Woods; for the lake clays are unconformable on the underlying sediments throughout this vertical interval and probably for a much greater one.

A large part of the lake clays was deposited when the waters of Lake Agassiz stood at the strong shore-line which has been referred to as the Campbell beach. This beach passes over the low divide between Lake of the Woods and Red River valley (19), so that the clays could not have been deposited in a lake which was confined to the district, but in a lake which was widespread not only over Red River valley but over adjoining regions, and this lake must have been the last great proglacial lake of the region, viz., Lake Agassiz.

The rising stage of the water could not be due to drowning of the southern shores of the lake by progressive upwarping of the northern portion of the lake basin, for the outlet of the lake was at the southern end. Rainy River district is 150 miles north of the southern outlet and the beaches in the district, marking stages of the lake during which the lake clays were deposited, are upwarped, and are continuous for a long distance southwesterly (19). The rising stage of the lake was, therefore, due to the blocking of the outlets of drainage to the north. It is not known if the lake rose to the level of the highest shore-lines developed in the region to the south (19) and it is possible, as already stated, that some of these may belong to the early pro-glacial lake referred to as Early Lake Agassiz, in which the glacio-lacustrine clays were deposited.

This lake (Early Lake Agassiz) was in part at least drained away before Lake Agassiz came into existence, as has already been shown by the evidence of an interval of land erosion subsequent to the deposition of glacio-lacustrine clays. There is also a suggestion that the lake was entirely drained away. In Red River valley there is a considerable thickness of sediments which contain in their lower portion freshwater shells and remains of vegetation. Upham regarded these sediments as fluvial in origin and stated regarding them (14, page 253):

"Thus the occurrence of shells, rushes, and sedges in these alluvial beds at McCauleyville, Minn., 32 and 45 feet below the surface or about 7 and 20 feet below the level of Red river, of sheets of turf, many fragments of decaying wood and a log a foot in diameter at Gllyndon, Minn., 13 to 35 feet below the surface, and numerous other observations of vegetation elsewhere along the Red River valley in these beds, demonstrate that Lake Agassiz had been drained away, and that the valley was a land surface subject to overflow by the river at its stages of flood when these remains were deposited."

It is evident that a land surface existed in Red River valley before these sediments were laid down; but it is by no means certain that the sediments are entirely fluvial in origin and were deposited on the flood-plain of Red river after the disappearance of Lake Agassiz, as Upham concluded. It is possible that they are mainly lacustrine sediments which were deposited in Lake Agassiz either during its rising stage or later during the subsiding stage, and this appears to be borne out by the character of the sediments. Dawson in describing the section across Red River valley near the International Boundary stated that the valley is floored with a fine silty deposit, a portion of the upper layers of which may have been formed by the overflow of the river itself. He described the typical deposit as of great thickness and consisting of a fine yellowish marly and arenaceous clay, holding considerable calcareous matter, and effervescing freely with an acid (9, pages 248-249). The high calcareous content and great thickness of the clays would seem to show that these are not fluvial in character. The shells and vegetation also occur at the *base* of the clays. At least it is possible that these clays are in greater part lacustrine in origin and that the surface beneath them existed as a land surface partially clothed with vegetation before glacial-marginal Lake Agassiz came into existence.

Earth Crustal Warping.

It is known that the beaches of Lake Agassiz are not now horizontal, but rise differentially, showing a maximum amount of upwarping in a direction approximately north 35 degrees east. It is also known that the uplift of the northern portion of the region which warped the shore-lines took place largely during the existence of Lake Agassiz; for here, beaches which are single fork out into several and the lowest beaches are nearly horizontal (14).

It is believed by many geologists that the crustal upwarping was due to isostatic readjustment following the removal of the burden of the ice-sheets. If this was so it is evident that uplift lagged behind the removal of the great mass of the ice, for it seems clear that during the greater portion of the life of the lake the ice-sheets were far removed toward the north and uplift did not start until the beginning of the final withdrawal of the ice from the region.

RECENT EPOCH.

Recent or post-glacial time began after the disappearance of the ice-sheets from the northern portion of the continent and when sea and land had approximately attained their present relationship. Since the melting away of the ice-sheets and the draining of pro-glacial Lake Agassiz which had covered practically the whole of Rainy River district, stream erosion has developed valleys and transported much of the material eroded to lower levels, depositing the greater portion of it in the basin of Lake of the Woods. Along some portions of the streams deposits have been formed on the low overflow terraces of the streams, but these deposits are relatively small in amount. Most of the material eroded has been laid down as sub-aqueous deposits in Lake of the Woods. Vegetation, largely arboreal in character, has clothed the surface of the greater portion of the region, and extensive deposits of muck and peat have formed in places where natural drainage was lacking or poorly developed.

CHAPTER VII.

ECONOMIC GEOLOGY.

WATER RESOURCES.

The water resources of the district have been investigated to some extent by the Department of Public Works, Canada. On the Minnesota side, the United States Geological Survey, also, has collected data regarding the water supply. These data are of value for purposes of power development, navigation, control of run-off, and for agricultural purposes. The Canadian Department of Public Works has also investigated Rainy river with a view to improving navigation. The following data were derived from Water Supply papers 285 and 339 of the United States Geological Survey and from information gathered during the prosecution of field work in the district.

LAKES AND RIVERS.

Rainy lake, which lies at the eastern side of the district, forms a collecting basin for the drainage waters of a large area to the east. The height of the water in the lake is largely controlled by the Minnesota and Ontario Power Company's dam at Fort Frances and International Falls. The area of Rainy lake is approximately 310 square miles, which, with a range in stage of somewhat over 8 feet, provides for storing about 69,000,000,000 cubic feet of water. The storage is entirely used for power. The elevation of the lake is kept as high as possible until the beginning of the winter and the storage water is then drawn on as soon as the natural flow of the river begins to decrease as a result of low temperature (22, page 24). Above Fort Frances, Rainy river drains an area of approximately 14,600 square miles, and at Lake of the Woods inlet, 20,800 square miles (23, page 76). The discharge of Rainy river below the dam at Fort Frances was found to be 11,400 cubic feet per second on April 6, 1910, and 10,600 cubic feet per second on June 23 (23, page 80).

The period of maximum discharge in some years occurs at times when the melting of the snow coincides with heavy rainfall during April and May; in other years high water occurs in June or July. Destructive floods do not occur because of the timber over much of the area, which tends to produce gradual run-off, and because of the slight gradients and relatively deep valleys of the streams. The lakes and streams are generally frozen from the middle of November until the latter part of March. During the winter months thaws rarely occur and ground-water forms the source of supply for the streams. Hence the flow is regular during the winter, but decreases gradually and is generally least in January or February. The amount of winter flow also depends largely on the amount of precipitation during the preceding summer, which goes to make up the supply of ground-water. During the summer months, the run-off is partly controlled by ground-water, as much of the rainfall sinks into the ground because of the poorly drained character of the surface, and is delivered to the streams largely by springs and seepage. The year 1910 was exceptionally dry, but it is stated that during the greater part of the year Lake of the Woods was maintained at a high level and in the following year was considerably lower although the rainfall was much greater. This was apparently due to the fact that the ground-water supply was deficient during the winter of 1910-1911 and a portion of the following summer.

GROUND-WATER.

In all humid climates the earth below a certain level is saturated with water, and the upper surface of the water-filled soil or rock is called the ground-water level or water-table. Above this water-table the soil contains only capillary water. The level of water in wells and, generally, the level of the water in swamps and marshes, mark the ground-water level. In some cases a "crested" ground-water level occurs where the water-saturated soil near the surface is underlain by an impervious stratum which is not saturated.

In Rainy River district the ground-water level is generally near the surface. In the areas of very low relief underlain by lacustrine sediments it is frequently, except in the immediate neighbourhood of stream valleys, within 10 feet of the surface and over much of the swampy areas is generally within 2 to 3 feet of the surface. It is farthest from the surface in areas of slightly greater relief underlain by till. At some places the level of the water in the swamps marks a crested water-table. This is well shown in the case of the peat bog near Fort Frances, where a portion of the water from the bog drains into the gravel pit 1½ miles west of the town. The level of the water in the gravel pit, marking the true ground-water level, is nearly 30 feet below the level of the water in the bog, only a short distance away. The nearness to the surface of the ground-water level over much of the district serves to check the headward growth of streams, for much of the water issues as springs or as seepage along the sides of the valleys. This is especially noticeable in the case of the lacustrine clays, as they frequently have inter-bedded gravelly layers along which the ground-water percolates and issues as springs and seepage.

The nearness to the surface of the ground-water level facilitates greatly the growth of arboreal vegetation and is also favourable to the growth of crops in seasons of scanty rainfall, but renders a large portion of the area unsuitable for agriculture until artificially drained.

WELLS AND SPRINGS.

Well water is generally obtained in shallow wells. In some areas the calcareous till forms a nearly impervious mass 50 to 100 feet thick, which it is necessary to penetrate in order to obtain well water. The till is commonly underlain by sand and gravel which nearly always hold supplies of water. Flowing wells have been obtained by boring at a number of places in Crozier, Devlin, Carpenter, and Mather townships. In these localities artesian conditions are furnished by the relatively impervious calcareous till and underlying water-bearing sands and gravels. The water enters the water-bearing stratum up in the northeastern portion of the district where the calcareous till is absent, and percolates slowly beneath the till down the slope towards the southwest. The flowing wells are located on the southwestern slope and generally near the base of low till ridges. In most of the borings a thickness of 50 to 75 feet of till was penetrated before reaching the sand and gravel. The water generally rises only a few feet above the surface, but it is of good quality and the flow uniform. As already stated conditions for the obtaining of flowing wells are most favourable on the southwestern slope and near the base of the till ridges, which trend in a northwesterly direction; but much of the western portion of the district is unfavourable owing to the general slight relief and because the till frequently rests on bed-rock.

Springs most commonly occur along the sides of stream valleys and, in places, issue from the calcareous till. They are sometimes chalybeate in character as is the spring 2 miles north of Stratton village. Here a cone of ochreous ferric hydroxide has been built up at the surface where the spring water issues. The waters which come from the calcareous till contain considerable quantities of carbonates in solution and are consequently "hard" waters, but are rendered "soft" by boiling.

WATER-POWERS.

The only developed water-power in the district is that on Rainy river at Fort Frances and International Falls, where 12,000 horse-power, it is stated, is developed on the United States side and 8,000 on the Canadian side. The power is largely used in operating the paper mills.

The only other water-power of importance in the district is that at Long Sault rapids on Rainy river, which is undeveloped.

CLAYS.

The lacustrine and fluvio-lacustrine clays of the district furnish material for the manufacture of common building brick and field drain tile. The distribution of the clays is shown on the map which accompanies this report. The only brick-yard in the district found to be operating is located on the bank of Rainy river, 1½ miles below Fort Frances.

The clays differ somewhat in general character in different sections and sometimes in different parts of the same section, owing to diverse modes of formation. In some sections, as in the case of the clays exposed on the bank of Rainy river below the dam at Fort Frances, thin beds and lenses of gravel and sand occur interbedded with the silty clay layers. Such deposits were largely formed by the deposition in relatively shallow water of material derived from wave erosion of the shores during the rising stage of the lake which formerly covered the district. The gravel in these deposits is largely limestone, which renders much of these clays unsuitable for the manufacture of brick or tile unless the gravel is removed in the process of manufacture.

The greater part of the clays is, however, fluvio-lacustrine in origin, that is the material was derived from land erosion and transported by streams, of gradient too slight to transport gravel, to be deposited either as delta deposits in lakes or as valley-fill along some of the flooded valleys. These clays are generally free from pebbles and are less sandy in character. The deposit which occurs at the brick-yard 1½ miles below Fort Frances is of this character. The clay is fairly uniform in character, extends to a maximum depth of 14 feet, and is underlain by sand. The clay burns to form a brick of uniform reddish colour.

Clay deposits of similar character occur at numerous other places in the district. Near the town of Rainy River clay deposits occur along the bank of the river both above and below the town. The deposits vary in thickness from 2 to 10 feet or more and extend back from the river for some distance. They are thickest near the river and gradually thin out away from the river. Sections exposing the clays occur along the river, one-half to 3 miles below the railway bridge near the town. In places, the clays are overlain by a thickness of 1 to 3 feet of sand and are underlain by stony till or boulder clay. Samples of the clays from the vicinity of the town of Rainy River were collected by the writer and were examined by Mr. J. Keele of the Department of Mines. Mr. Keele's report is as follows:

"*Lab. No. 276.*—Yellowish-grey clay from 1 to 4 feet below the surface, about half a mile below the railway bridge at Rainy river.

"This sample was free from pebbles but contained a small amount of coarse grit particles. It requires 23 per cent of water to bring it to a good working consistency. The clay is rather sticky when wet, but has fairly good working properties, and flowed smoothly through a die for making drain pipe. As the drying qualities of this clay are not good, it must be dried slowly after moulding to avoid cracking. The drying shrinkage is about 7 per cent. The following results were obtained in burning:

Cone	Fire shrinkage %	Absorption %	Colour
010	0	18	Light red.
06	0	15	Salmon.
03	0	14	Mottled.
1	2	7·5	Buff.

"This clay is suitable only for the manufacture of common building brick or field drain tile, a good hard product of reddish colour being obtained even at as low a temperature as cone 010 (1742 degrees F.). On burning to higher temperatures the red colour gradually disappears and a harder, denser product of buff colour results at cone 03 to cone 1 (2000 degrees to 2100 degrees F.). There is no fire shrinkage until the latter temperature is reached.

"The drying and working qualities might be improved by the addition of a small amount of sand, say 15 per cent. This clay resembles the brick clays of the Red River valley in Manitoba, and like them appears to be derived largely from dolomite; but the percentage of lime is much lower in the Rainy River clay, as the latter does not effervesce with acid.

"The Red River brick clays and the Rainy River clay stand up at a higher temperature without softening than most surface clays, probably due to a fairly large amount of magnesia in their composition.

"The development of a buff colour in burning the Red River brick clays is due to the large amount of lime that they

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)

1.0 4.5 2.8 2.5
5.0 3.2 2.2
5.6
6.3 3.6
7.1
8.0 4.0 2.0
1.1
1.8
1.25 1.4 1.6

contain, but the buff colour and low fire shrinkage of the Rainy River clay was unexpected in a clay that does not effervesce with acid.

"*Lab. No. 277.* A yellow rusty gritty clay, containing numerous rock fragments and some pebbles. It underlies clay No. 276 at Rainy River. This clay has all the characteristics of one with a high lime content, as it burns to a buff or cream colour, with a slight expansion after firing, instead of shrinkage. Some of the pebbles in this clay are limestone or dolomite. These pebbles burn to the oxide, then swell on taking up moisture from the air, and invariably burst the brick that contain them. This material is useless for the manufacture of clay products. It is probable that the greater part of clay No. 276 is derived from the erosion and washing of this under clay."

SANDS AND GRAVELS.

Sands and gravels useful for structural purposes and for road material occur at many places in the district, usually in the form of ancient littoral or beach deposits. The localities where the beach sands and gravels occur are shown on the accompanying map. The beach deposits in places contain more sand than gravel, and this renders much of the beach material of poor quality for road metal unless it is screened. Much of the gravel also is limestone; the fragments are small and are not well waterworn. The limestone crushes easily and is soluble to some extent in rainwater, so that it is not very durable. Gravel deposits of fluvio-glacial origin also occur occasionally in the district. A deposit of this character, from which large quantities of material for ballast and road metal have been obtained, occurs 1½ miles west of Fort Frances and is connected with the main line of the Canadian Northern railway by a spur line. In this deposit the gravel is of quite a different character. It is free from limestone and consists for the most part of well waterworn gravel derived from the crystalline rocks, and is, hence, more durable and more satisfactory for purposes of road construction than the beach material. No other large deposits of these gravels are known to occur at the surface in the district. They are older than the calcareous till and hence are generally concealed by it.

Solid rock outcrops occur at numerous places throughout the district and would furnish material for crushed stone of more satisfactory character for road metal than the gravels.

PEAT.

The peat deposits of the district have been investigated to some extent by the Mines Branch of the Department of Mines. The peat bog near Fort Frances and another in Crozier township were examined by Mr. A. Anrep of the Department of Mines. The results of his investigations were published in Bulletin No. 8, of the Mines Branch of the Department of Mines, 1910-11.

SOILS.

The soil consists of the uppermost stratum of the earth, which has been rendered available for the growth of plant life by processes of weathering, by the gradual accumulation in this stratum of animal and vegetable matter, and by the effect produced by organic agencies upon the material comprising the soil. The soil is largely derived from the immediately underlying substrata, but differs from the substrata in that it is weathered. It contains varying amounts of organic matter and has been acted upon by life in some form, so that it is productive. It is often the case, especially in humid climates and when the substratum is composed of glacial till or boulder clay, that material taken from a depth of only 1 foot from the surface is found to be unproductive for several years after exposure on the surface. The presence of a certain amount of organic material in the soil is necessary for productiveness and its accumulation requires considerable time; hence there is a vital necessity for the preservation of the soil from the destructive effects of forest fires and from erosion. The soil may be considered as including the surface soil, or the soil proper, and the sub-soil; the surface soil consists of the uppermost portion a few inches in thickness, which is generally distinguished from the sub-soil by a darker colour. The sub-soil contains less organic matter and has been acted upon by organic agencies to a less extent than the surface soil. It passes downward without any sharp demarcation into the substrata which may consist either of unconsolidated or solid rocks.

On the map which accompanies this report the distribution of the various surface formations from which the soils are derived is shown by different colours. The colours also represent the soils derived from the surface formations or unconsolidated rocks. The descriptive names of the soils, e.g., fine sandy loam, are based on the texture of the soils as shown by mechanical analyses, following the classification of soil material as adopted by the United States Bureau of Soils. Only the most characteristic soils of the district are shown on the map and the boundaries are approximate. In some portions no differentiation of the soils was attempted on account of the densely wooded and inaccessible character of those portions.

In this memoir the mode of origin and general physical character of the soils are discussed; but no attempt is made to consider the crop adaptations of the soils or soil management in general, for the discussion of such matters belongs rather to the scientific agriculturist.

GENERAL CHARACTER OF THE SOILS.

The mode of origin and lithological character of the various unconsolidated rocks or surface formations from which the different soils have been mainly derived, have already been described in the chapter on "General Geology."

The soils of the district have for the most part been derived from glacial deposits which are highly calcareous in character, and from lacustrine sediments which were largely derived from erosion of the till; hence as a whole they are calcareous, especially in the sub-soil portions. The surface soil is usually sufficiently leached to eliminate most of the carbonate material; but where the calcareous till forms the sub-soil it sometimes contains sufficient calcium carbonate to cause the material at less than one foot from the surface to effervesce freely in acid. In general, the sub-soils contain a high percentage of soluble material, a characteristic of soils known to have lasting fertility. The calcareous character of the soils, especially in the case of those that are heavy or clayey, promotes tilth and prevents acidity. In some places in the district the swamp muck and peat soils are acid in character; but this is the case only where these deposits are thick.

In general, the soils of the district have the light colour characteristic of the soils of most timbered regions and lack the black colour characteristic of the prairie soils. The muck and peat soils are brown to black in colour, the dark shade being more pronounced in the muck soils, in which the organic matter is more decomposed, but becoming lighter in colour after cultivation. The alluvial soils are generally dark coloured also, owing to their poorly drained character and to the presence of abundant organic material. The soils of the areas which are naturally drained are generally greyish to brown in colour, the top 2 to 3 inches being of a deeper shade but rarely black. They are not, however, deficient in organic material, except in places where severe burning has taken place, either during the process of clearing the land or from the effects of repeated forest fires.

The only "light" soils of importance in the district are the gravelly sandy loam soil of the old beach ridges and the lacustrine fine sand soils. The sandy ridge soils are generally excessively drained and droughty in dry seasons because of the relief of the ridges and low ground-water level, especially after drainage of the adjacent low-lying lands. The lacustrine fine sand areas have slight relief and the water-table is generally near the surface; these conditions tend to prevent excessive drainage. However, the light soils are not so productive, especially in dry seasons, as the heavier soils.

A striking feature of the soils of the great portion of the district is their clayey character in the sub-soil portions. This clayey character tends to produce swampy conditions on the surface where adequate drainage is not supplied, but is also of great value in producing lasting fertility of the soils and in retaining the moisture and supplying it to the surface during seasons of scanty rainfall.

DISTRIBUTION OF SOILS.

The following table gives the areal distribution of the different soils mapped in the district.

	Square miles
Muck and peat	240
Dune sand and beach sand (recent deposits)	1
Silty clay loam of stream alluvium	12
Gravelly sandy loam of old lake beaches	10
Fine sand of lacustrine deposits	32
Clay loam and clay of lacustrine deposits	88
Gravelly loam and gravelly clay loam of glacio-lacustrine clay (wave-washed)	117
Gravelly fine sandy loam of calcareous till (wave-washed)	176
Gravelly loam of calcareous till (wave-washed)	14
Red drift soils, undifferentiated	38
Bed-rock outcrops with little or no soil	27
Total area	755

DESCRIPTION OF SOILS.

Muck and Peat.

The muck and peat soils consist largely of organic material in various stages of decomposition, and vary in depth from 1 to 20 feet or more. The muck differs from the peat in that it contains a greater amount of mineral soil and the organic material which comprises a considerable part of it is more decomposed. The soils occupy swampy areas which are deficient in drainage and require to be artificially drained before they can be utilized. The swampy areas are generally well-timbered, except in their central and deeper portions, which are usually treeless peat bogs. The peaty material contains comparatively little mineral soil and the organic matter is only partially decomposed. This is especially the case in the uppermost 1 to 3 feet, where the fibrous and woody character of the material is still preserved. The undecomposed character of the raw peat is due to the presence of the ground-water near the surface. Drainage, by lowering the water level, brings about atmospheric oxidation and decomposition and tends to produce a mucky soil. In areas covered by 1 to 2 feet of peaty material it has been found that after drainage the peat largely disappears; for the bulk of the peat is greatly reduced by oxidation, and can be worked into the sub-soil. Near the borders of the swampy areas the soil is generally mucky in character and merely requires drainage to make it productive. The average thickness of the peat and muck in the swampy areas does not greatly exceed 3 feet, and it is probable that a considerable portion of these areas will eventually be drained and be rendered available for agricultural purposes. Up to the present, little effort has been made to utilize the swamp areas. In some places in the district, however, small areas were seen to be under cultivation and to be producing good crops of timothy and clover.

The sub-soil beneath the muck and peat is frequently a calcareous clay loam and sandy sub-soils also occur. Where there are sandy sub-soils and where the peat or muck is thin, the surface is generally clothed with cedar, birch, and spruce. The deeper portions of the bogs are either sparsely timbered with tamarack or spruce, or are treeless and clothed with grasses and mosses. The calcareous character of much of the sub-soil tends to counteract the acidity of the peat and muck, but where the peat is thick its acid character is frequently indicated by the coffee-coloured water.

In attempting to utilize the peat or muck soils where the material is thick, it is important to consider the effect of too much drainage. Soils which are largely organic in character have little power of capillarity and hence in order to be productive require the presence of ground-water not far from the surface. Too complete drainage would probably also result in danger from fires.

It also appears to be true that peaty soils which consist very largely of organic matter require the addition of at least a small amount of mineral soil in order to make them productive for agricultural purposes.

Dune Sand and Beach Sand.

The dune sand and beach sand deposits of recent origin occupy only small areas along the bars and islands near the mouth of Rainy river and along the main shore of the lake for some distance northeast of the mouth of the river. They form soils which are of no value for agricultural purposes.

Silty Clay Loam of Stream Alluvium.

The surface soil consists of brown to black silty clay loam, to a depth of 6 to 8 inches, and contains considerable organic material. The sub-soil is usually somewhat lighter in colour but has nearly the same texture. The soil is developed in narrow strips on the low overflow terraces of the streams and has for the most part poor surface drainage.

Gravelly Sandy Loam of Old Lake Beaches.

The surface soil consists of yellow to brown, gravelly sandy loam from 6 to 10 inches deep, and is underlain by yellowish gravelly sand. The soil is generally excessively drained, and poorly productive in dry seasons. It occupies the surface of relatively long and narrow ridges which were formerly clothed with pine. At present the timber growth consists largely of birch and aspen with scattered trees of white pine and Banksian pine. In some places the beach soils were the first to be cultivated as the land was easily cleared and was higher and drier than the surrounding lands; but after clearing and draining of the adjacent lands, it was found that the ridge lands were excessively drained because of their relief and the lowering of the water level by drainage.

Fine Sand of Lacustrine De[illegible]

The surface soil consists of grey to [illegible] fine sand 6 to 8 inches deep, with the top 1 to 3 inche[illegible]d by organic matter. The sub-soil consists of grey or yellow fine sand to fine sandy loam and clay loam and rarely contains any stones or boulders. The clay loam sub-soil occurs in areas along the stream valleys. The areas occupied by the lacustrine fine sand are well timbered with a growth of aspen and balsam poplar, balsam fir, and birch, with a dense undergrowth of shrubs, wild pea-vine, etc. White and Norway pine was formerly abundant, but has been largely removed or destroyed by forest fires.

In the poorly drained areas the spruces and firs are more abundant and "mixed timber" is the rule. The fine sand areas are of low relief and, because of the nearness to the surface of the water-table, are usually not excessively drained. In some of the poorly drained areas the surface is covered by muck, peat, or forest litter to a depth of a few inches to one foot; this will largely disappear or become mixed with the soil after clearing and drainage of the land.

The following table shows the mechanical composition in percentages of the surface soil of the lacustrine fine sand.

	Description.	Fine gravel. 2—1 mm.	Coarse sand. 1—0·5 mm.	Medium sand. 0·5—0·25 mm.	Fine sand. 0·25—0·1 mm.	Very fine sand. 0·1—0·05 mm.	Silt. 0·05—0·005 mm.	Clay. 0·005 mm.—
No. 10..	Surface soil	0·0	0·4	0·5	50·2	37·1	5·4	6·4

Clay Loam and Clay of Lacustrine Deposits.

The surface soil consists of brown to black loam or clay, 6 to 8 inches deep, underlain by sub-soils generally of nearly similar texture but lighter in colour. The heavier clay soil occupies restricted areas in some of the valley fill deposits and in places forms a sticky "gumbo" soil difficult to work when wet. The clay loam soil is more widespread and is less tenacious and more easily worked, because of the greater proportion of sand which it contains. This soil very rarely contains any stones or boulders. In places the sub-soil contains thin layers of fine gravel, which aid in underdrainage. The areas occupied by these soils have very low relief and the drainage, except in areas near the streams, is usually poor on this account and because of the heavy character of the sub-soil. Swampy conditions prevail in places and the surface is frequently covered with peat or muck a few inches in thickness. Poplar and balm of Gilead, which are often of large size, are the most abundant trees of the clay loam and clay areas. In the poorly drained areas the spruce and fir trees also occur. Along the streams, where drainage is well established, oak and elm are the most characteristic trees, together with a dense undergrowth of shrubs and vines which often form a nearly impenetrable mass of vegetation.

The clay loam and clay soils have been developed and utilized to a considerable extent for farm purposes in areas along the streams where natural drainage is well developed. Large undeveloped areas also occur, especially where surface drainage is poor. These areas are generally densely timbered.

The following table gives the results in percentages of mechanical analyses of surface soil and sub-soil of the lacustrine clay loam soil.

	Description.	Fine gravel. 2—1 mm.	Coarse sand. 1—0·5 mm.	Medium sand. 0·5—0·25 mm.	Fine sand. 0·25—0·1 mm.	Very fine sand. 0·1—0·05 mm.	Silt. 0·05—0·005 mm.	Clay. 0·005 mm. —
No. 11..	Surface soil	0·9	2·3	3·9	7·9	18·2	46·6	20·2
No. 12..	Sub-soil	1·3	1·6	1·7	5·7	19·8	38·1	3[illegible]·8

Gravelly Loam and Gravelly Clay Loam of Glacio-lacustrine Deposits (Wave-washed).

The surface soil of these deposits consists of greyish-brown to black loam, or clay loam, with occasional boulders and pebbles, and is 5 to 6 inches deep. The sub-soil consists of yellow to bluish-grey clay of a dense sticky character and containing in places scattered pebbles and partially disintegrated limestone concretions. The loamy character of the surface soil is largely due to the presence at the surface of fine sand and silt, generally from 1 to 3 inches in thickness, spread as a thin blanket over the surface by wave wash during the life of the great lake which once covered the region. The clay loam or heavy phase occurs only in small areas and where the relief is slight. The surface of the gravelly loam areas is gently rolling and to a great extent naturally drained. The sub-soil is frequently heavy clay which, because of its nearly impervious character, tends to prevent free seepage of water from the surface, thus affecting the working qualities of the surface soil when wet. Small areas where surface drainage is poor also produce sticky "gumbo" soils. Where drainage is well established the dense character of the sub-soil promotes the retention of moisture, which is of great value during seasons of drought.

The vegetation is similar to that of the areas occupied by the lacustrine soils, except that deciduous trees such as the aspen or poplar are more abundant. The areas occupied by the glacio-lacustrine soils have also been burnt over more frequently, because of their greater relief and drier character, and much of the timber is only from 4 to 20 years old; hence the land is more easily cleared.

Portions of these soils have been under cultivation for some time, but large areas are still virgin.

The following table shows the result in percentages of mechanical analyses of surface soil and sub-soil of the glacio-lacustrine loam soil.

	Description.	Fine gravel. 2—1 mm.	Coarse sand. 1—0·5 mm.	Medium sand. 0·5—0·25 mm.	Fine sand. 0·25—0·1 mm.	Very fine sand 0·1—0·05 mm.	Silt. 0·05—0·005 mm.	Clay. 0·005 mm.—
No. 13..	Surface soil	5·0	8·5	6·5	13·5	1[illegible]·0	35·7	16·8
No. 14..	Sub-soil	1·6	3·1	5·1	15·2	13·4	30·5	31·1

Gravelly Fine Sandy Loam of Calcareous Till (Wave-washed).

The surface soil of this deposit consists of grey to brown fine sandy loam and is 5 to 6 inches deep. The upper 1 to 3 inches is generally darkened by inclusion of organic matter.

The sub-soil consists of yellow or grey loam or clay. Gravel and stones occasionally occur in both the surface soil and sub-soil and are generally more abundant on the surface, but rarely in sufficient numbers to interfere with cultivation. The surface soil contains considerable fine sand and silt, a thin wave-wash, lake deposit, which is only slightly plastic or sticky when wet, and crumbles readily when dry, producing a soil that is easily worked and does not readily bake or form into clods. The topography is usually gently rolling and the areas in most cases are naturally drained. The deep sub-soil is nearly impervious to water because of its stiff clay character; this causes the water to lie on the surface and swampy conditions to prevail in some of the flatter portions of the area. In these portions the surface is generally covered with muck or peat to a depth of several inches.

The fine sandy loam areas have been in large part burnt over several times. The last extensive forest fires occurred during the exceptionally dry summer of 1910. Destructive forest fires are reported to have occurred also in 1886 and 1896. The extensive swamps in the district have, however, served to localize the fires to some extent, but in most cases the naturally drained areas show the effects of the fires. Areas were noted in the district where dense stands of young poplar, in some cases only 4 years old and in other places nearly 20 years old, covered ground which had apparently been almost completely bared of forest growth by destructive fires.

The fine sandy loam soil is the most extensively cultivated in the district and is one of the most productive soils. On this ground have been grown some of the remarkable crops of wheat already referred to. Only a small part is under cultivation, however, and large areas of virgin soil, generally timbered with deciduous trees such as poplar, balm of Gilead, and birch, still remain unimproved.

The following table gives the results in percentages of mechanical analyses of the surface soil and sub-soil of the fine sandy loam of the wave-washed calcareous till.

	Description.	Fine gravel. 2—1 mm.	Coarse sand. 1—0·5 mm.	Medium sand. 0·5—0·25 mm.	Fine sand. 0·25—0·1 mm.	Very fine sand. 0·1—0·05 mm.	Silt. 0·05—0·005 mm.	Clay. 0·005 mm.—
No. 15..	Surface soil	0·9	1·8	2·1	14·1	48·2	25·1	7·8
No. 16..	Sub-soil	1·5	1·8	2·9	12·9	14·1	35·8	31·0

Gravelly Loam of Calcareous Till (Wave-washed).

The surface soil consists of grey to brown loam 5 to 6 inches deep, the upper 1 to 3 inches being generally of a somewhat darker colour. The sub-soil consists of yellow or grey clay. Scattered stones and boulders occur, but not abundantly. The soil in general resembles the fine sandy loam soil, but contains less fine sand and silt in its upper portion. In small areas the surface soil is a clay loam, and in general differs from the fine sandy loam in being heavier and more difficult to work, especially when wet. It occupies comparatively small areas, in which the general relief is slight.

The following table gives the results in percentages of mechanical analyses of the loam soil of the wave-washed calcareous till.

	Description.	Fine gravel. 2—1 mm.	Coarse sand. 1—0·5 mm.	Medium sand. 0·5—0·25 mm.	Fine sand. 0·25—0·1 mm.	Very fine sand. 0·1—0·05 mm.	Silt. 0·05—0·005 mm.	Clay. 0·005 mm.—
No. 17..	Surface soil	3·2	4·6	4·6	16·1	21·2	38·2	13·1
No. 18..	Sub-soil	2·4	2·7	2·5	7·9	10·3	34·8	39·4

Red Drift Soils.

The soils of the "red drift" which occupies areas in the northern portion of the district generally consist of gravelly sand

and gravelly sandy loam. They are sandier in general than those of the southern portion of the district and are not so calcareous in character, for the material was largely derived from erosion of the crystalline rocks. The forest trees in these areas are more commonly coniferous than those in the southern portions. The sandy and rocky areas were formerly clothed with white and Norway pine and in some portions considerable stands of young pine still occur. Banksian pine occurs more abundantly, however, together with birch, spruce, and balsam fir. The soils of this portion of the district have not been differentiated.

Bed-rock Outcrops with Little or No Soil.

Small areas of rock outcrop throughout the district and in the northern portion large areas of bare rocks have been denuded of forest trees by repeated fires. These areas were at one time well timbered, as is evidenced by the charred and blackened stumps which still remain. The result of protection from forest fires is well illustrated in the case of many of the islands of the northern portion of Lake of the Woods. The islands are densely timbered almost to the water's edge, although they are rocky and have only a very thin covering of mineral soil. The effect of the fires in the northern portion of the region has been not only to destroy the timber, but also to remove the thin covering of soil which was the result of a long period of weathering, and to prohibit the growth of forest trees for many years to come.

DRAINAGE OF SWAMP LANDS.

One of the most important problems in connexion with the agricultural development of the district is the matter of drainage. The large swamp areas can only be utilized after they have been drained. Portions of the district which have only slight relief would be greatly benefitted by drainage ditches, as natural drainage is deficient. Swampy conditions in places are largely due to the presence of a dense vegetation, and the clearing of the land alone has effected marked changes in many areas. Many of the swamps are due to the fact that the old beach ridges act as dams and hold back the water. This is illustrated by the long narrow sand and gravel ridge which extends northeast from Gameland, and many other cases might be cited. By cutting through these ridges many of the swamps can be at least partially drained. Some of the swampy areas were found to have an appreciable slope, amounting in some cases to as much as 10 and 20 feet per mile; so that it is evident in such cases that drainage is possible. The treeless bogs generally occupy basin-shaped depressions and would probably be much more difficult to drain completely, if such is possible. The ease with which some of the swampy areas may be drained is well illustrated by the peat bog near Fort Frances. The greater portion of the bog and swampy area surrounding it is from 10 to 20 feet above Rainy lake and 40 to 50 feet above the level of Rainy river below the dam at Fort Frances, and in places the bog approaches to within one-quarter mile of the river. It is also probable that the ground-water level, near the surface in the bog, is not the true ground-water level, for the bog partially drains into the gravel pit 1½ miles west of Fort Frances, which is within a short distance of the edge of the bog, and the water level in the pit is nearly 30 feet below the level of the water in the peat bog.

During the past three years considerable advance has been made in ditching in connexion with the construction of colonization roads, undertaken by the Provincial government.

In connexion with the improvement of drainage, one of the most important points which demands attention is the removal of obstructions from the stream channels. At numerous places the streams tributary to Rainy river are partially blocked by accumulations of drift-wood, and in places by rocky barriers. The dense growth of the timber along the banks of the streams greatly favours the accumulation of drift-wood dams, for the streams are in places constantly undermining the banks. The rocky barriers also prevent the streams from cutting down their channels and the streams have consequently little power of erosion in their upper portions and are incapable of carrying off rapidly the flood water, which is especially disastrous to agriculture since periods of high water frequently occur late in spring or sometimes even in early summer.

The fact that the average annual precipitation for the district is small, as compared with that of more humid eastern regions, is favourable to the production of adequate drainage by ditching and to the improvement of natural drainage, in spite of the general slight relief and present widespread swampy character of a considerable portion of the district.

CHAPTER VIII.

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PLATE II.

New road cutting in Wild Land Reserve; showing dense character of forest growth. (See page 15.)

PLATE III.

Glaciated rock surfaces with little or no soil covering, formerly timbered, but now barren as result of forest fi.es; west side of Rainy lake. (See page 33.)

PLATE IV.

Glaciated rock surface. West side of Rainy lake. (See page 33.)

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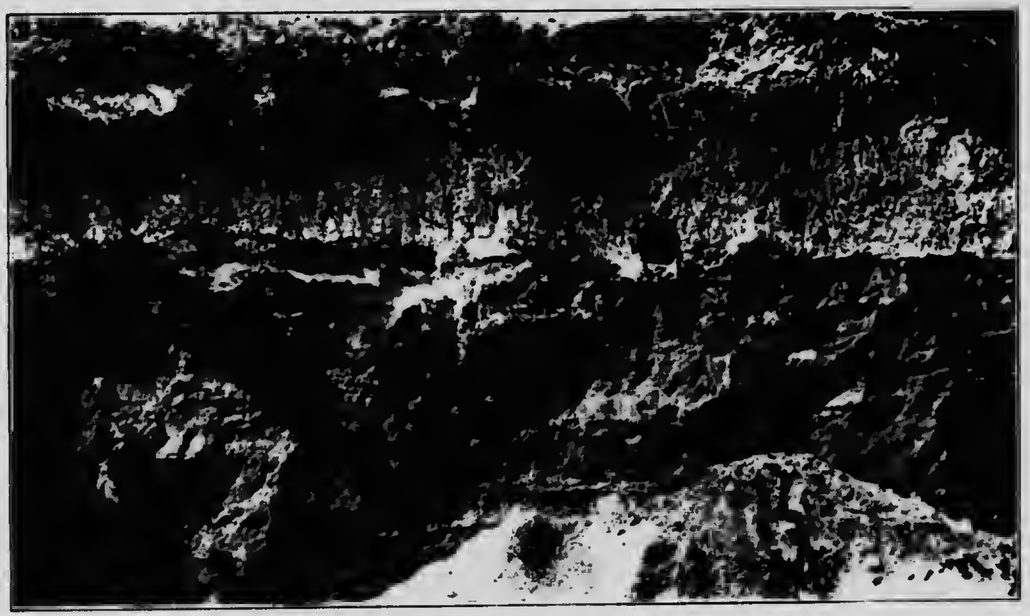
PLATE V.

New road and ditch across muskeg, sparsely timbered with spruce and tamarack. (See page 32.)

PLATE VI.



Section in gravel pit 1½ miles west of Fort Frances, showing calcareous till overlying stratified sand. (See page 43.)

PLATE VII.

Section in gravel pit 1½ miles west of Fort Frances, showing, at the bottom, stratified and ripple-marked sand passing upwards into laminated clay, and, at the top, calcareous till. (See page 46.)

PLATE VIII.

Section in gravel pit 1½ miles west of Fort Frances, showing stratified sand minutely folded and overthrust by overriding of ice-sheet; till occurs in the upper right hand portion of the section. The rule in the middle distance is 7 inches long. (See page 43.)

PLATE IX.

Section exposed on bank of Rainy river, below the dam at Fort Frances, showing character of sandy and gravelly, fossiliferous, lacustrine clays of pro-glacial Lake Agassiz. (See page 53.)

PLATE X.

Section showing a thickness of 12 feet of stratified and cross-bedded sand and gravel (containing fresh-water shells) in beach deposit of pro-glacial Lake Agassiz; near north bank of Rainy river, 8 miles below Fort Frances. (See page 56)

PLATE XI.

Section exposed on south shore of Lake of the Woods, showing at the bottom calcareous till passing upward into glacio-lacustrine, laminated, stony clays unconformably overlain by fluvio-lacustrine clays. The contact is a wave-cut plain. (See page 66.)

PLATE XII.

Section exposed on south side of Buffalo point, Lake of the Woods, showing thin peaty bands interbedded with stratified sand. The peaty bands are one-half to 1 inch thick. (See page 68.)

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LIST OF RECENT REPORTS OF THE GEOLOGICAL SURVEY

Since 1910, reports issued by the Geological Survey have been called memoirs and have been numbered Memoir 1, Memoir 2, etc. Owing to delays incidental to the publishing of reports and their accompanying maps, not all of the reports have been called memoirs, and the memoirs have not been issued in the order of their assigned numbers and, therefore, the following list has been prepared to prevent any misconceptions arising on this account. The titles of all other important publications of the Geological Survey are incorporated in this list.

Memoirs and Reports Published During 1910.

REPORTS.

Report on a geological reconnaissance of the region traversed by the National Transcontinental railway between Lake Nipigon and Clay lake, Ont.—by W. H. Collins. No. 1059.

Report on the geological position and characteristics of the oil-shale deposits of Canada—by R. W. Ells. No. 1107.

A reconnaissance across the Mackenzie mountains on the Pelly, Ross, and Gravel rivers, Yukon and North West Territories—by Joseph Keele. No. 1097.

Summary Report for the calendar year 1909. No. 1120.

MEMOIRS—GEOLOGICAL SERIES.

MEMOIR 1. *No. 1, Geological Series.* Geology of the Nipigon basin, Ontario—by Alfred W. G. Wilson.

MEMOIR 2. *No. 2, Geological Series.* Geology and ore deposits of Hedley mining district, British Columbia—by Charles Camsell.

MEMOIR 3. *No. 3, Geological Series.* Palæoniscid fishes from the Albert shales of new Brunswick—by Lawrence M. Lambe.

MEMOIR 5. *No. 4, Geological Series.* Preliminary memoir on the Lewes and Nordenskiöld Rivers coal district, Yukon Territory—by D. D. Cairnes.

MEMOIR 6. *No. 5, Geological Series.* Geology of the Haliburton and Bancroft areas, Province of Ontario—by Frank D. Adams and Alfred E. Barlow.

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MEMOIR 11. *No. 1, Topographical Series.* Triangulation and spirit levelling of Vancouver island, B.C., 1909—by R. H. Chapman.

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REPORTS.

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MEMOIR 9. *No. 9, Geological Series.* Bighorn coal basin, Alberta—by G. S. Malloch.

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MEMOIR 15. *No. 12, Geological Series.* On a Trenton Echinoderm fauna at Kirkfield, Ontario—by Frank Springer.

MEMOIR 16. *No. 13, Geological Series.* The clay and shale deposits of Nova Scotia and portions of New Brunswick—by Heinrich Ries assisted by Joseph Keele.

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MEMOIR 14. *No. 1, Biological Series.* New species of shells collected by Mr. John Macoun at Barkley sound, Vancouver island, British Columbia—by William H. Dall and Paul Bartsch.

Memoirs and Reports Published During 1912.

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Summary Report for the calendar year 1911. No. 1218.

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MEMOIR 13. *No. 14, Geological Series.* Southern Vancouver island—by Charles H. Clapp.

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LEGEND

Unconsolidated rocks (upon which the soils are developed) — **Soils**

QUATERNARY

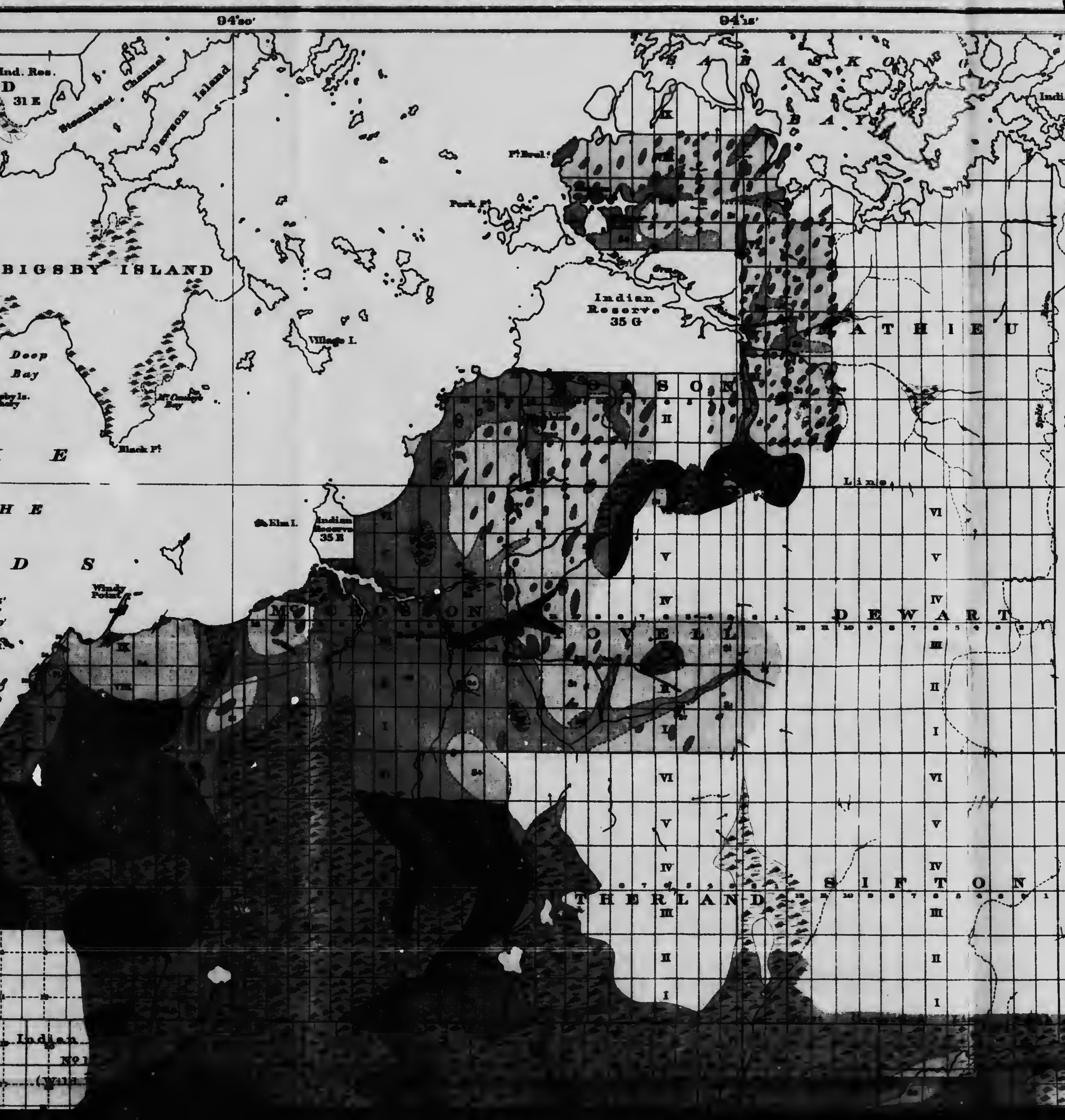
RECENT

- **Muck and peat** *(swamp deposits)*
  - **Muck and peat** *(chiefly organic material; areas generally wooded with cedar, spruce and tamarack)*
- **Dune-sand and beach-sand** *(chiefly wind-blown deposits)*
  - S9 **Dune-sand and beach-sand** *(chiefly fine to coarse sand, of no agricultural value)*
- **Alluvial sand, silt and clay** *(flood-plain deposits of present streams)*
  - S8 **Silty clay-loam** *(brown to black, silty clay-loam, 6 to 8 inches deep, underlain by clay-loam or clay; areas generally poorly drained)*

PLEISTOCENE OR GLACIAL

- **Beach-sand and gravel** *(...eral deposits of pro-glacial Lake Agassiz)*
  - **Gravelly sandy loam** *(yellow to brown gravelly sandy loam, 6 to 10 inches deep, underlain by sand and gravel; areas generally excessively drained; forest trees, birch, poplar and Banksian pine)*
- **Fluvio-lacustrine and lacustrine sand, silt and clay** *(stratified valley-fill, delta and lake-bed deposits of pro-glacial Lake Agassiz)*
  - **Fine sand** *(gray to light brown, fine sand, 6 to 8 inches deep, underlain by gray or yellow calcareous, fine sand to clay-loam, surface nearly level and well-drained only along stream valleys; forest trees, poplar, birch, spruce, and elm, with some pine)*
  - **Clay-loam and clay** *(brown to black clay-loam or clay, 6 to 8 inches deep, underlain by gray calcareous clay-loam or clay; surface nearly level and well drained only along stream valleys; forest trees, poplar, balm of Gilead, spruce, elm, ash, and ash-leafed maple)*
- **Glacio-lacustrine clay** (wave-washed) *(laminated lake-bed deposits of proglacial, Lake Agassiz)*
  - S4 **Gravelly loam and gravelly clay-loam** *(grayish-brown to black loam or clay-loam, 5 to 6 inches deep, underlain by yellowish or bluish-gray calcareous clay, dense, sticky, with some gravel and boulders; surface generally naturally drained; most abundant forest trees, poplar, and balm of Gilead)*
- **Glacial till** (calcareous) **or boulder-clay** (wave-washed) *(unstratified deposits of Keewatin glacier, Wisconsin stage of glaciation)*
  - **Gravelly, fine, sandy loam** *(gray to brown fine sandy loam, 5 to 6 inches deep, underlain by yellow to gray calcareous loam or clay, with some gravel and boulders; surface generally naturally drained; most abundant forest trees, poplar, and balm of Gilead)*
  - Gravelly loam

SOILS



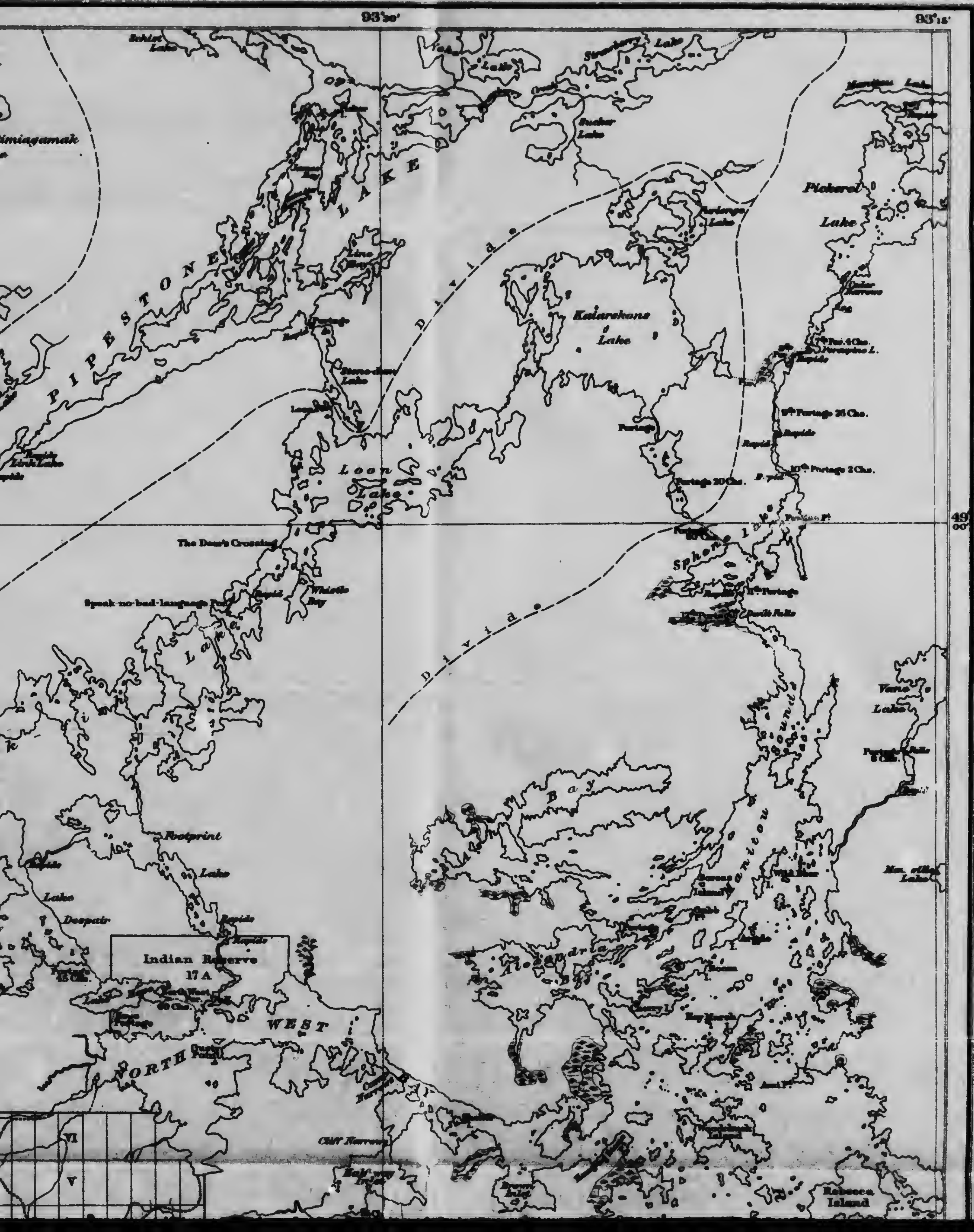
94°20'
94°15'
Ind. Res.
D
31 E
Steamboat Channel
Dawson Island
BIGSBY ISLAND
Deep
Bay
Black Pt
Village I.
Indian
Reserve
35 G
Indian
Reserve
35 E
Windy
Point
MATHIEU
DEWART
LOVELL
SIFTON
THERLAND
Line
Indian

Canada
Department of Mines

HON. MARTIN BURRELL, MINISTER: R.G. M^C CONNELL, DEPUTY MINISTER.

GEOLOGICAL SURVEY

WILLIAM M^C INNES, DIRECTING GEOLOGIST



93°30'
93°15'
49°
00'
PIPESTONE LAKE
Lake
Pickerel Lake
Kaiarskons Lake
Loon Lake
Divide
Divide
Stonechaser Lake
The Deer's Crossing
Whistle Bay
Speak-no-bad-language Pt.
Portage
Rapids
Portage 20 Chs.
9th Portage 25 Chs.
10th Portage 2 Chs.
Devil's Falls
Vane Lake
Footprint
Lake
Lake
Despair
Indian Reserve
17 A
NORTH WEST BAY
Cliff Narrows
Alexandra Bay
Rebecca Island
Boom
VI
V

generally naturally drained; most abundant forest trees, poplar, and balm of Gilead)

Glacial till (calcareous) **or boulder clay** (wave washed)
(unstratified deposits of Keewatin glacier, Wisconsin stage of glaciation)

Gravelly loam
(gray to brown loam, 3 to 6 inches deep, underlain by yellow or bluish gray, calcareous clay, with some gravel and boulders; surface generally of slight relief; and in places poorly drained)

Red drift
(including glacial till and associated fluvio-glacial sand and gravel deposits of Labradorean glacier, Wisconsin stage of glaciation)

S1

Gravelly sand and gravelly sandy loam
(generally yellow sand or sandy loam, underlain by sand or sandy loam, with gravel and boulders; forest trees, poplar, birch, cedar, spruce, and Banksian pine with some Norway pine)

Bedrock outcrop
(Pre-cambrian)

Terminal morainic areas

Symbols

Glacial striae

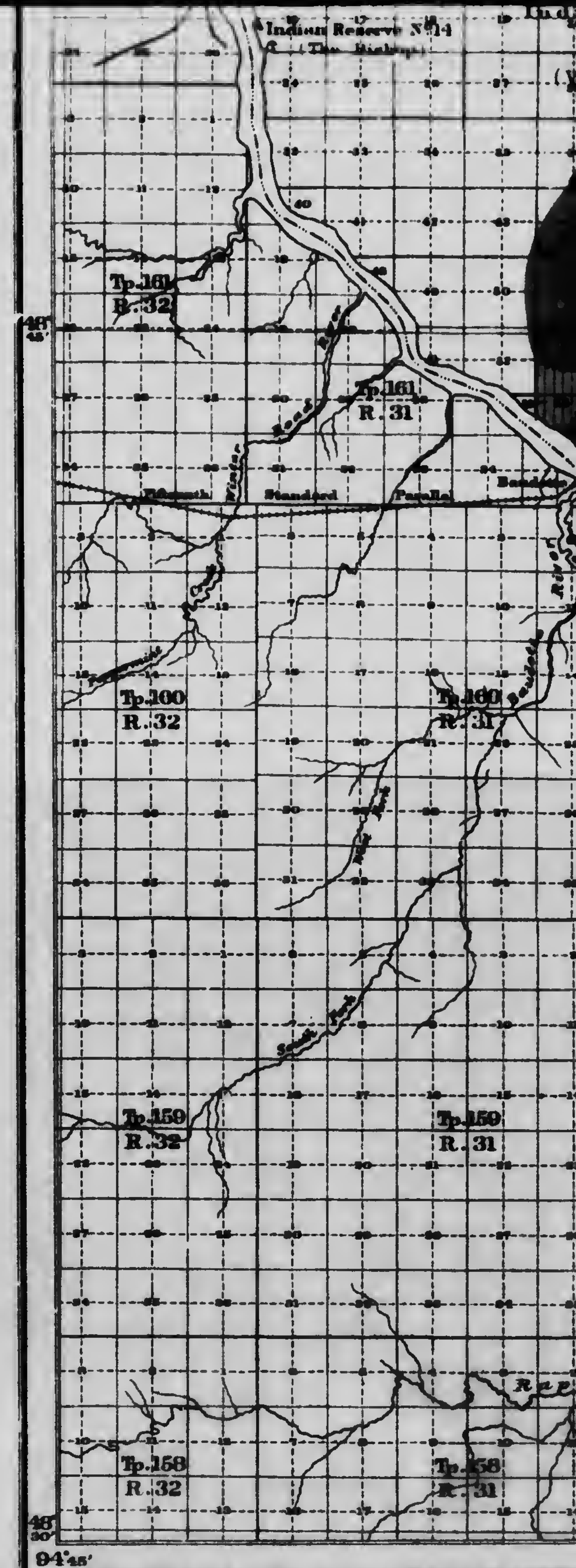
Swampy areas

Soil boundary
(approximate)

Note

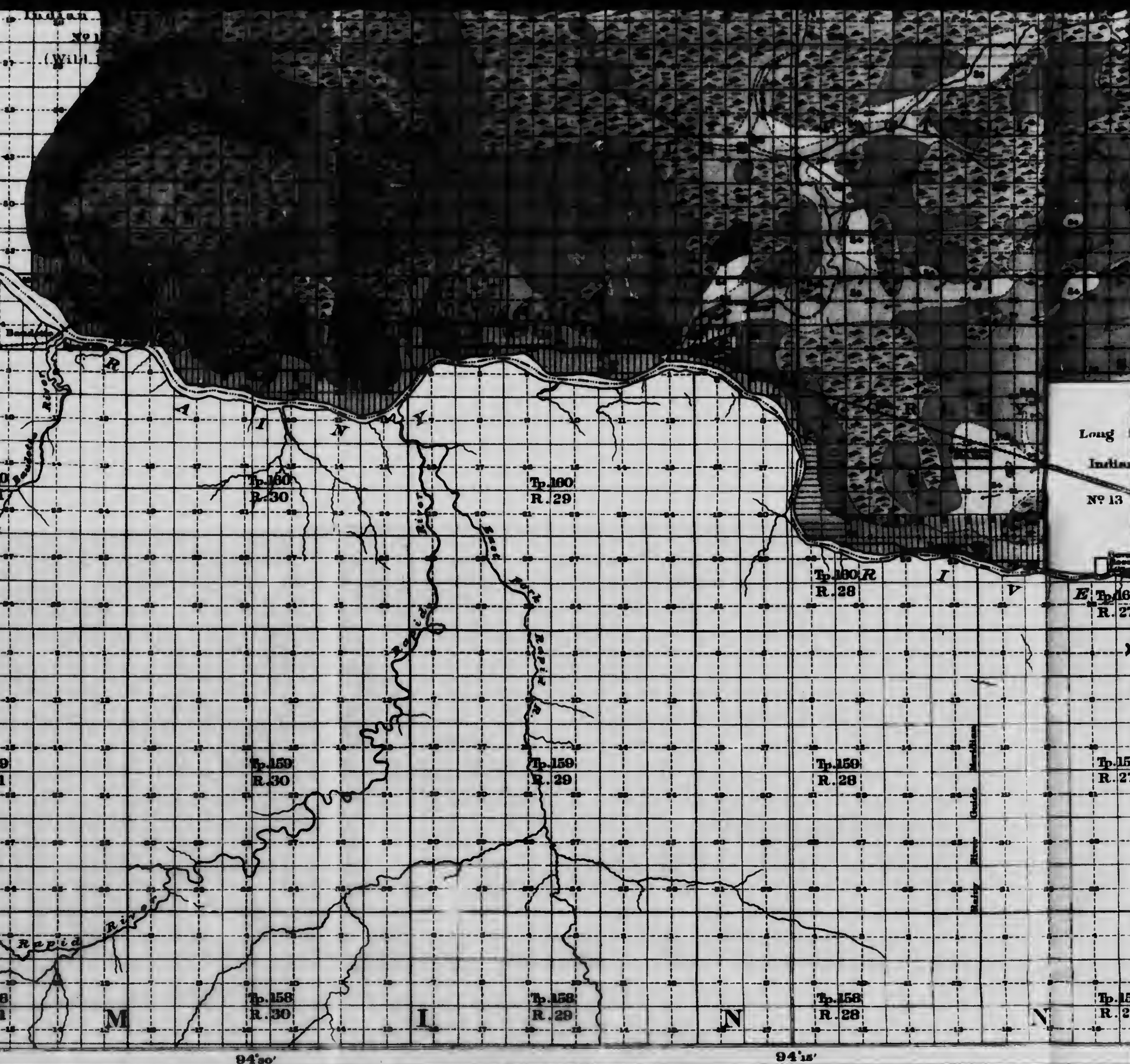
Sand and gravel for structural purposes and gravel for road material, occur in the beach sand and gravel deposits; clay for brickmaking in the lacustrine, and fluvio-lacustrine deposits; peat for fuel in the deeper portions of some of the swamp deposits.

Average magnetic declination 8°35' East



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

To accompany Memoir by W.A. Johnston



Long
Indian
Nº 13
Tp. 160
R. 30
Tp. 160
R. 29
Tp. 160
R. 28
R I V E
R A I N Y
Tp. 160
R. 27
Tp. 159
R. 30
Tp. 159
R. 29
Tp. 159
R. 28
Tp. 159
R. 27
Rainy River Guide Meridian
Rapid River
Tp. 158
R. 30
Tp. 158
R. 29
Tp. 158
R. 28
Tp. 158
R. 27
M I N N
94°30'
94°15'

R

MAP 132 A

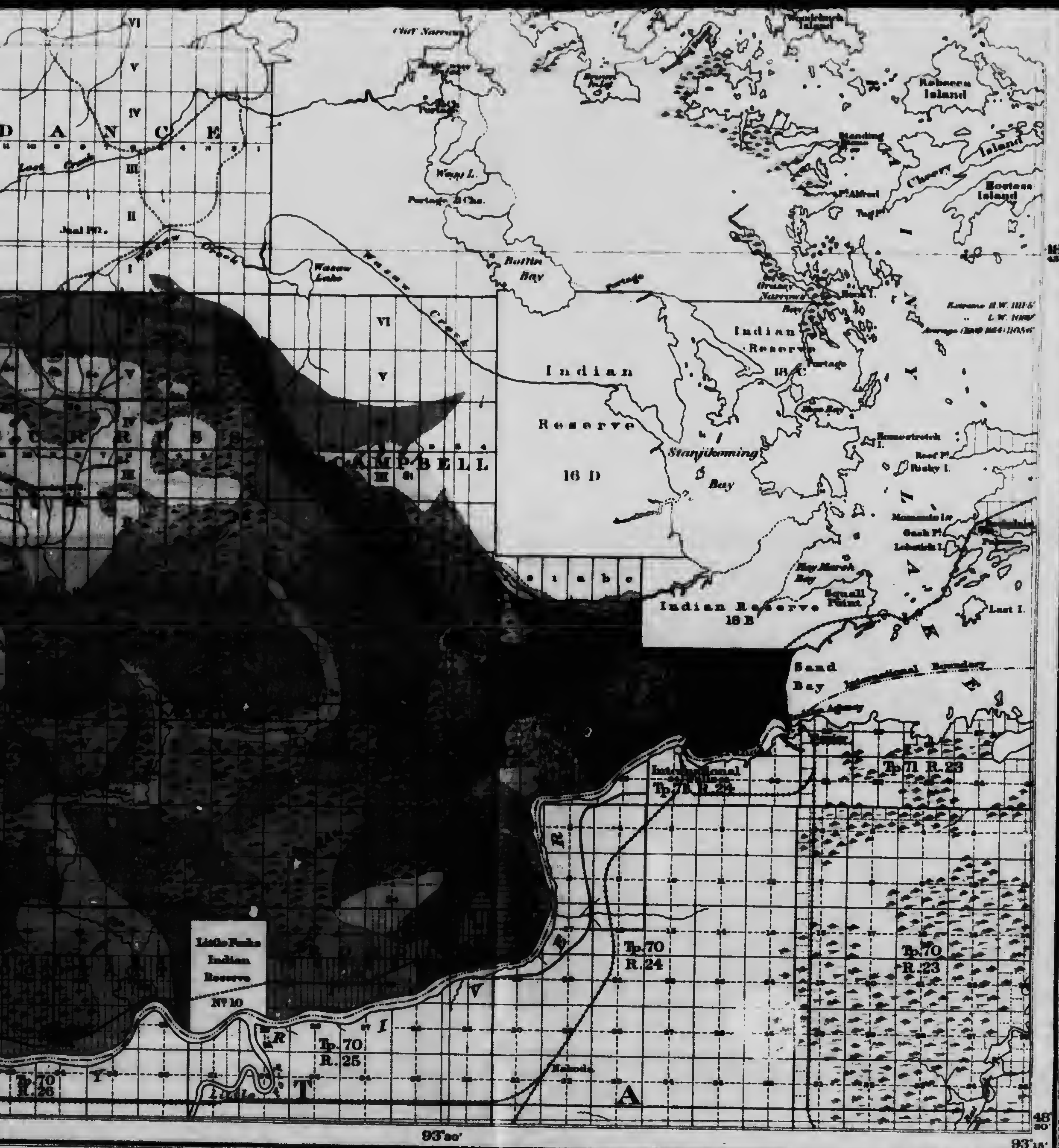
Southwestern Portion of
RAINY RIVER DISTRICT
ONTARIO

Scale, $\frac{1}{126,720}$

Miles

Kilometres

2 MILES TO 1 INCH



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