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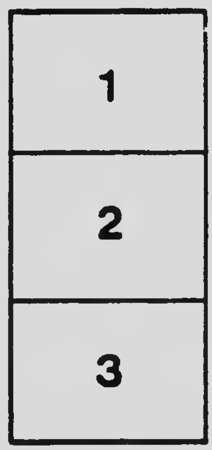
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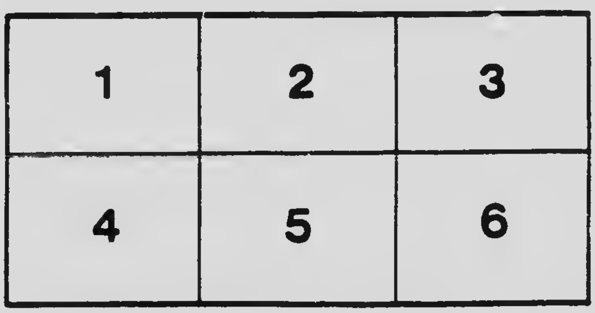
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CANADA
DEPARTMENT OF MINES
HON. MARTIN BURRELL, MINISTER; R. G. MCCONNELL, DEPUTY MINISTER.

GEOLOGICAL SURVEY
WILLIAM MCINNES, DIRECTING GEOLOGIST.

MEMOIR 105

No. 87, GEOLOGICAL SERIES

Amisk-Athapapuskow Lake District

BY
E. L. Bruce

OTTAWA
GOVERNMENT PRINTING BUREAU
1918

No. 1716

PLATE I

Banded ore from Mandy mine. (Page 62.)

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CHAPTER I.

INTRODUCTION.

Following the discovery of the gold deposits of northern Ontario, in basic rocks of Pre-Cambrian age, the attention of prospectors turned to areas of similar rocks in other parts of northern Canada. Several of these were known to exist in the territories lately added to Saskatchewan and Manitoba, and in August, 1913, investigations resulted in the discovery of free gold veins occurring at Amisk lake just west of the boundary line between the provinces. The report which follows is preliminary, mainly economic in character, and for the sake of brevity microscopical descriptions and discussions of origins and other theoretical matter have been purposely omitted.

FIELD WORK AND ACKNOWLEDGMENTS.

In the summer of 1914, geological mapping of the country in the vicinity of Amisk lake was begun and extended eastward along the edge of the Palæozoic rocks towards the Hudson Bay railway. Details were filled in during the field seasons of 1915 and 1916 and the map accompanying this report is a compilation covering a part of the country examined in these three seasons. A new geographical map of this area was necessary to form a base for geological work of a more detailed character than that of the early explorations and to show the large number of waterways navigable by canoes. The mapping was done by means of the Rochon micrometer telescope and prismatic compass with the 2nd meridian as control. Closed traverses were made wherever possible and the closing errors adjusted. Inland traverses to fix geological boundaries were made by pace-and-compass methods, and small lakes encountered in these traverses were sketched by taking compass bearings on prominent points and estimating the distances. It was impossible to map all the lakes in the district, but most of those that are of any size and practically all that are used as canoe routes were traversed or sketched in connexion with the inland work. Plans of surveyed claims and the positions of lakes crossed by the 2nd meridian have been obtained from the Topographical Surveys branch of the Department of the Interior. The map of Flinflon lake is from a stadia traverse by F. H. Kitto, D.L.S., of that department.

The scale upon which the work has been done has made it impossible to delimit varieties of rock in the same formation; and rocks which show marked differences from the type to which they have been assigned may be grouped under the same formational name. It must be borne in mind, therefore, that in all the geological units there has been considerable generalization. It will be found also that some of the smaller outcrops have not been outlined, but it is believed that the larger areas are fairly accurately delimited.

LOCATION AND AREA.

The map-area covered by this report lies between the south boundary of township 61 and an east-west line through the middle of township 68. The western boundary is 20 miles west of the 2nd meridian and the eastern approximately 50 miles east of it. The approximate area is about 3,300 square miles. The boundary line between the provinces of Manitoba and Saskatchewan has not yet been run through the map-area, but its position was fixed relative to the 2nd meridian near Flinflon lake. More than one-quarter of the map-area lies in Saskatchewan, the remainder in Manitoba.

MEANS OF ACCESS.

The area is reached most easily from The Pas, Manitoba, where the Hudson Bay railway crosses the Saskatchewan river. From The Pas during the summer months steamboats ascend the river to Cumberland House and cross Cumberland and Namew lakes to Shining bay and to the mouth of Sturgeon-weir river. From Shining bay a team road leads to Amisk lake, which can also be reached by way of the Sturgeon-weir river. The river, however, is so interrupted by rapids that it was given the name "Maligne" by the voyageurs of the early explorers and it is usually avoided. If, however, a tributary that enters it about 4 miles above Namew lake is ascended, a fairly easy route leads through Goose lake to Athapapuskow lake in the central part of the map-area. Canoe routes also connect Amisk and Athapapuskow lakes, but these entail much portaging. Eastward a good canoe route leads by way of Grass river to the Hudson Bay railway east of Setting lake. There are only two long portages on this route; one, 1¼ miles long leading from Athapapuskow to the first Cranberry lake and another about a mile long leading from Setting lake to the railway at mile 137 north of The Pas. The portage to the railway can be avoided during high water by ascending a stream at the south end of Setting lake to the point where the railway crosses it.

HISTORY.

The great river and lake systems of this district were the routes used by the early explorers of northwestern America in their travels. Before Canada became a British possession, the La Verendryes had explored the Saskatchewan. Following the cession of the colonies to Great Britain, fur traders from the St. Lawrence followed the same route and worked northward from the Saskatchewan towards the Athabaska.

Meanwhile the Hudson's Bay Company several times undertook to make explorations of the country to the northwest. One of their officials, the famous Samuel Hearne, did really penetrate the interior, travelling across country from Fort Churchill to the Arctic ocean. After his return he was sent inland to establish a post to compete with the St. Lawrence traders for the furs of the Athabaska-Saskatchewan country which, with the arrival of these competitors from the south, were no longer being brought down to Hudson bay. He built the first permanent post at Cumberland House in 1774. In 1772 Joseph Frobisher and his brother, fur traders from the St. Lawrence, had built a temporary establishment there while on a journey to the Churchill River basin. The year following the building of Cumberland House by Hearne, the Frobishers were again in the country and they joined forces with another fur trader, Alexander Henry. These three men went up the Maligne (Sturgeon-weir) river to Amisk (Beaver) lake arriving on November 1, 1775, just before the ice began to form. Here, they built winter quarters consisting of five buildings, but on what part of the lake Henry does not say. The following extract from his journal, however, shows that it certainly was not at the outlet of the lake:

"On the first of January, 1776, I left our fort on Beaver lake. At night we made our first encampment at the head of the Maligne where one of our parties was fishing but with indifferent success."

The most likely place for men going to the Churchill country, as the Frobishers and Henry intended doing, would be the inlet of the lake. This, however, is only 12 miles from the outlet—a very short day's journey. The north end of the lake would be a day's journey from the outlet but would be a most unlikely place for an establishment. On the northern mainland, just north of what is known as Vick[illegible] land, there are traces of old houses. Only three buildings have b[illegible]und. In the largest house there was a fire-place of flat stones at the middle of the north wall. In the house to the east, the fire-place was in the corner of the room. The third building was probably a store-house. The walls of the houses are now merely low mounds of earth in which are embedded some rotten timber. Over what appears to have been the floor there is a layer of a foot or more of clay. Upon the clay and debris about the fire-place of the largest building a clump of birches is growing in suc a position that they could have sprung up only after the house hac fallen almost completely into ruins. The largest tree measured ove 3 inches in diameter 2 feet from the bottom and has over fifty growth rings. Allowing another twenty-five years for occupation anc destruction, these houses must have been built at least more than seventy-five years ago. That they are those built by Henry in 1775 is very improbable. In his description of the lake he writes as follows:

"Lake aux Castors or Beaver lake is seven leagues in length and from three to five in breadth. It has several islands, of which the largest does not exceed a mile in circumference."

The length given by Henry corresponds fairly closely to the length of Amisk lake from north to south, but if his houses were at the north end of the lake he must have known of the existence of Missi island, which is 6 miles in diameter. His estimates of distances seem to be somewhat inaccurate, for without considering Missi island, which was long believed to be the northern mainland, the large limestone island on the direct route from inlet to outlet is more than a mile in diameter instead of a mile in circumference as he estimated. The greatest width of the lake is less than 12 miles, approximately Henry's estimate. It may then be considered that the north end of the lake was unknown to Henry and that his winter quarters were in the southern part. On an undated map by Fidler three houses are shown—one on the east side of the outlet, one south of Sucker creek on the east side of the lake, and one just south of the inlet. If one of these was the original winter quarters of Alexander Henry and the Frobishers, it seems most likely both from Henry's description and from the standpoint of convenience, to have been the one near the inlet.

Pond's map, dated 1785, shows Beaver lake, Goose lake, and Grass river marked as the "Middle road to Hudson's Bay." This map is, however, very crude. Mackenzie's map, published in 1801, showing the results of his travels in the years 1789 and 1790, is more accurate, but what is really the south shore of Missi island is mapped as the north side of the lake. Mackenzie's journal shows that he did not pretend to make an exploration of the lakes he crossed. Concerning this area, he says: "In latitude 54° 16′ north the Sturgeon-weir river discharges itself into this lake (Namew) and its bed appears to be of the same kind of rock and is almost a continual rapid. Its direct course is about west by north and with its windings is about 30 miles. It takes its waters into (from?) the Beaver lake, the southwest side of which consists of the same rock lying in thin strata; the route then proceeds from island to island for about 12 miles and along the north shore for 4 miles more, the whole being a northwest course to the entrance of a river in latitude

54° 32′ north. The lake for this distance is about 4 or 5 miles wide and abounds with the fish common to the country. The part of it upon the right of that which has been described appears more considerable."

Harmon's map, 1808, is very similar to that of Mackenzie. He mentions the fact that he arrived at Beaver (Amisk) lake on Sunday, August 14, 1808, but gives no details except a reference to the troublesome nature of the rapids which he had ascended.

In 1794, the area was first visited, and the beginning of fairly accurate mapping made by David Thompson whose name figures so prominently in the history of the exploration of much of the northwestern part of the continent. His route followed Goose river to Athapapuskow lake, thence across the portage to the Cranberry lakes and down Grass river to Reed lake, which lies just east of this sheet. From Reed lake he turned northward by way of Methy and File lakes to Burntwood river. In 1798, he left Cumberland House on August 19 for lake La Biche, travelling by way of Sturgeon-weir river and Amisk lake. In 1804, he followed his route of 1794 through the district, leaving some men to build a trading post at the narrows on Cranberry lake. In 1805, a return journey was made over this route to Cumberland House, where he stayed less than a week and then went back to his post on Cranberry lake, arriving there June 27. He left on July 25 for Reindeer lake by way of Athapapuskow lake, Goose lake and river, Sturgeon-weir river, and Amisk lake. On September 10 of the same year, he again set out from Cumberland House and travelled by Cranberry portage and Grass river to Reed lake, where he had wintered on his first journey through the area. In June, 1806, he left this post and returned to Cumberland House. In the years following, his well known surveys were made in the country farther west.[1]

The various journeys of these men were undertaken solely for the purpose of securing the Indian trade and the delineation of the geographic features was with most of the early explorers a secondary matter. Thompson was a notable exception. He was so deeply interested in his astronomical and geographical work that there was sometimes friction between him and the directors of the fur companies by which he was employed. The maps of the fur traders were simply those of the trade routes and were sufficiently accurate for the purpose for which they were intended. The early maps were very little altered until comparatively recent times, for as long as the Hudson's Bay Company had a monopoly of the country their policy of secrecy as to its resources discouraged an accurate outlining of its physical features.

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[1]From Thompson's narrative of his explorations in western America. Tyrrell, J. B., Champlain Society.

Following the acquisition of the North West Territories by th
Dominion of Canada in 1868, a second period of exploration begar
made by men whose work it was to map and describe the country throug
which they passed, with a view to making known its natural resource
With this end in view, much of the area here dealt with has been mappe
in more or less detail by members of the Geological Survey of Canada
In 1896, J. B. Tyrrell made a track survey by way of Namew lake
Goose lake, and Grass river to Wekusko lake. In 1899, D. B. Dowling
went by way of Goose lake, Athapapuskow lake, and Pineroot river to
Cold (Kississing) lake and in 1909 W. McInnes made a track survey of
Amisk lake. The results of these traverses, combined on one large
sheet covering the explored routes of the Churchill-Nelson basins,
accompanied Memoir 30 of the Geological Survey publications. The
Department of the Interior has also published sketch maps of a strip
of country a few miles wide on either side of the 2nd meridian.

This brief account of previous explorations has been restricted to those of the area under particular consideration. The results of explorations covering a larger area are summarized in Memoir 30. The third period of exploration of this district is directly connected with the discoveries of minerals of possible economic importance and will be discussed in that connexion.

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CHAPTER II.

SUMMARY AND CONCLUSIONS.

GENERAL CHARACTER OF REGION.

The Amisk-Athapapuskow Lake area is situated 50 miles north
Saskatchewan river and is crossed by the boundary line betwee
Manitoba and Saskatchewan. It lies along the edge of a part of th
Canadian Pre-Cambrian shield and about one-half of it is underlai
by Palæozoic rocks. The general elevation is in the neighbourhood o
1,000 feet above sea-level. The southern part of the district which i
underlain by flat-lying Palæozoic rocks is very level, any irregularitie
that may have existed having been to a great extent obliterated by a fairly thick deposit of lake clays. The northern part of the sheet is free from such deposits and, the Pre-Cambrian rocks being heterogeneous in character, the surface is much more uneven, although the relief is slight and the general level lower than that of the flatter land surface of the southern district. Within the Pre-Cambrian region the granite batholiths form resistant areas which stand above the general level and form the stream divides. The granite areas are marked by small lakes and rapid streams, whereas the areas of basic rocks contain the larger lake basins and the larger waterways.

The winters are cold but not unpleasant and the summers, though short, are hot. The ice in the larger lakes is gone by the end of May and in the smaller lakes and rivers before that time. The freeze-up occurs about November 1, although the larger lakes are open for some time after the smaller streams and shallower lakes are frozen.

The climate is not too severe for agriculture and garden stuff is successfully grown in all parts of the area. The lack of soil over part of the area and the wet character of much of the remainder limit the agricultural possibilities, for the present, to well-drained strips lying along the rivers. In time it may be found possible to drain much of the district underlain by lake clays and thus make large areas of rich soil available for agriculture. So far as the growth of vegetation is concerned, the amount of sunshine in this latitude during the summer months offsets to a great extent the shortness of the season.

The country north of the Saskatchewan has for over a century produced annually large quantities of valuable furs. As prospecting spreads, however, the fur-bearing animals diminish and carelessness with fire very often leads to the destruction of their breeding grounds. The same conditions prevail in regard to game. Fish have recently become a commercial asset of the region and with careful enforcement of proper fishing regulations should prove a continuous source of revenue.

Since this area lies on the divide between three great river systems—the Churchill, the Nelson, and the Saskatchewan—most of the streams are small and with the exception of the Sturgeon-weir not capable of supplying much water-power; and even that river from the variation in its flow would not afford a large, continuous supply. Should a market for electrical power be developed, however, there are water-powers on Churchill and Saskatchewan rivers that could be used as sources of energy at any point in this district.

GENERAL GEOLOGY.

The general geological relations are as follows:

Table of Formations.

Quaternary	Recent Pleistocene	Peat, river alluvials. Lake silts. Till, sand, gravel.
	Unconformity	
Paleozoic	Ordovician	Dolomite.
	Unconformity	
Pre-Cambrian		Kaminis granite. Granite gneiss. Hybrid granitic rocks.
	Intrusive contact	
	Upper Missi series	Arkose. Conglomerate.
	Unconformity (?)	
	Lower Missi series	Slate. Greywacke. Quartzite. Conglomerate.
	Unconformity	
		Cliff Lake granite porphyry.
	Intrusive contact	
	Kisseynew gneisses	Sedimentary and igneous gneisses and schists.
	Amisk series	Lavas, tuffs, agglomerates, and derived schists.

STRUCTURAL GEOLOGY.

Structurally the area consists of very unlike elements. The older rocks form the western limb of a great anticline pitching northwestward at an angle of 45 to 50 degrees. On the flank of this there are remnants of minor synclines of sediments. The anticline has been cut off along its axis by a great intrusion of gneissic granite and massive granite has been intruded into the minor folds. Overlying this complex structure the almost flat-lying Ordovician dolomite forms the southern limb of a great low anticline of Palæozoic rocks whose axis is transverse to that of the Pre-Cambrian anticline. The glacial deposits may be considered as another structural element lying unconformably over both of these.

ECONOMIC GEOLOGY.

The deposits of metalliferous minerals are of two kinds: (1) gold quartz veins and (2) chalcopyrite-sphalerite replacements which carry low gold and silver values. Both these types are believed to be genetically related to the granite batholiths and the difference in their mineralogy to be due to the conditions under which they were deposited—the gold quartz veins being formed under high temperature and pressure at great depths, the sulphide ores under less extreme conditions. Up to the end of 1917, although gold has been found in many of the quartz veins, none of the discoveries has led to actual production. Rich specimens can be obtained but most of the veins are low grade.

Many sulphide bodies are found along the contacts of small granite intrusions with greenstone and greenstone schist. In such lenses the sulphides are chiefly pyrrhotite or pyrite, and none of them have been found to contain enough nickel or copper to make them important. The valuable lenses lie some distance from outcrops of igneous rocks but not too far from actually exposed bodies to make their connexion with the intrusions improbable. The association of sulphides, even though lean, with the granite, makes it reasonable to assume that the richer sulphide bodies are derived from the same source, but that the conditions of somewhat lower temperatures with a later fracturing of the earlier deposited minerals may have caused a greater concentration of copper and zinc.

Where conditions were especially favourable, as in the lens of the Mandy mine, almost unmixed chalcopyrite was deposited in one part of the body and fairly high grade zinc blende in another. Hence, it is possible even under the present adverse circumstances to mine and ship the copper ore, although the zinc blende and leaner copper-bearing rock cannot be handled profitably.

Railway connexions and local smelting facilities would make available a large amount of ore that is now being left in the stopes, but a large tonnage must be assured before a project of such magnitude can be undertaken. Lack of fuel for a local smelter is a serious disadvantage, but is to some degree counterbalanced by the occurrence in the vicinity of quartz veins from which flux containing appreciable amounts of gold could be obtained.

Peat, clay, and non-metallic minerals, including granite and limestone for structural purposes, are possible products of the district if the metal mining industry should prove to be sufficiently important to warrant the construction of a railway.

CHAPTER III.

GENERAL CHARACTER OF THE DISTRICT.

TOPOGRAPHY.

REGIONAL.

General Description.

In his discussion of the general physical geography of the district adjacent to the 49th parallel, Dawson[1] describes the topographic divisions as follows:

"The interior region of the continent slopes gradually eastward from the elevated plains lying at the base of the Rocky mountains to the foot of the Laurentian highlands; and though the inclination is more abrupt on approaching the mountains it is not so much so as to attract special attention. Between the fifty-fourth and forty-ninth degrees of latitude, however, along two lines which are in a general way parallel and hold a northwest and southeast course across the plains, very remarkable step-like rises occur.

"The first or lowest plain level is that of which the southern part lies along the Red river and which northward embraces lake Winnipeg and associated lakes and the flat land surrounding them."

In this area north of lake Winnipeg, however, there are no Laurentian highlands in the sense that is conveyed by Dawson's description, but on the other hand the Pre-Cambrian rocks lie below the level of the Palæozoic which forms an escarpment facing out upon the older terrain. Rose, in his description of the Great Plains and their division into steppes by the escarpment referred to, says:

"The actual decrease of elevation in passing from one steppe to the next lower is small in comparision to the decrease due to the general eastward slope of the plains."[2]

This general eastward slope is not terminated in this region at the Laurentian highlands but continues northeastward with the same gentle declivity to Hudson bay. In passing from the Palæozoic to the Pre-Cambrian rocks an escarpment is found, as in passing from the Cretaceous to the Palæozoic, and the escarpment, like those farther west, faces the older rocks; but the change in level is not sufficiently great

[1] "Report on the geology and resources of the region in the vicinity of the 49th parallel"; Montreal, 1875.

[2] Rose, B., "Wood Mountain-Willowbunch coal area, Saskatchewan," Geol. Surv., Can., Mem. 89.

to be of more than local importance, except as a convenient method of dividing the area for purposes of description.

The country lying between the Cretaceous escarpment and Hudson bay, sloping gently down from an elevation of about 1,000 feet to sea-level, naturally falls into three divisions, depending on the underlying geological units. From the bay southwestward there are: (1) A belt of flat, swampy country underlain by Palæozoic limestone and dolomite. (2) A belt of broken hummocky country, the typical Pre-Cambrian plateau. (3) A belt of flat country underlain by Palæozoic. The Cretaceous escarpment showing prominently west of the Canadian Northern railway from Winnipeg to Prince Albert, and called at various places Duck mountain, Riding mountain, and Pasquia hills, rises above this flat country. Northwestward, the western belt of Palæozoic narrows and at Wapawekka lake the escarpment of the Cretaceous, there known as the Wapawekka hills, rises directly from the Pre-Cambrian.

A section southwestward from Hudson bay crosses these belts and from the Pre-Cambrian complex occupying the middle of the section the rocks rise in the time scale northeastward to Hudson bay and southwestward to the Cretaceous escarpment. The general slope of the surface is uniform towards the bay and forms a great plain bevelling a low anticline whose axis lies northwest-southeast. It seems certain that the Ordovician, Silurian, and Devonian were affected by the folding which produced the anticlinal structure, as rocks of these ages are found in similar arrangement on both sides of the Pre-Cambrian core. The erosion to which the district owes its flatness removed the Palæozoic formation and, if the Great Plains slope may be considered as being the same as that which continues to Hudson bay, Cretaceous and Tertiary beds were bevelled to produce it and hence the main period of erosion was late Tertiary. There were, however, earlier erosion periods to which the final result may be largely credited. Later, too, some of the irregularities have been masked by the deposition of lake silts and till during the Glacial period.

Detailed Descriptions.

Surface of the Palæzoic. The character of the land surface, where the underlying rocks are dolomites of Palæozoic age, is quite different from that of the surface where the Pre-Cambrian outcrops. The uniform nature of the rock and the flatness of the strata both assist in giving the surface a smoothness that surfaces in the Pre-Cambrian do not attain. Over considerable areas this flat surface is structural, that is, it is actually the surface of one particular bed. The dip of the formations is so slight that a change from one bed to the next higher is not noticeable in the topography and so, though every where structural, the surface is formed by higher and higher beds as the distance from the Pre-Cambrian increases. Away from drainage channels the flatness of the surface produces extensive muskegs which completely hide the solid rock.

Normal erosion had probably pushed the various cliffs back to approximately their present position before the advent of the Glacial period. The effect of the ice movement in this district was principally the removal of disintegrated material, the deposition of moraines, and, through these means, the disorganization of the previous drainage systems. Over part of this particular map-area, a great thickness of lake clays was deposited at one stage of the existence of the great glacial lake Agassiz.

Present Surface of the Pre-Cambrian. The present surface of the Pre-Cambrian area is similar to that found in other Pre-Cambrian areas in the Canadian shield, but in this district the relief is less than in many other areas. From the edge of the Palæozoic escarpment or from the very rare higher elevations of Pre-Cambrian rocks the mammillated surface, dotted with innumerable lakes, may be seen stretching away to an even, unbroken skyline. Few hills or ridges rise more than 50 or 60 feet above the valley bottoms and since the growth is more luxuriant in the valleys than on the thinner soil of the rocky uplands, the forest cover minimizes to the eye even this small difference. The hill slopes are fairly abrupt and although the difference in elevation is small, the country in detail is rough, excepting in large muskeg areas or where, as in the area east of Cranberry lakes, the rock surface has been thickly mantled by lake sediments and glacial deposits, which have to a great extent masked the unevenness of the rock floor. Where the surface is free of glacial debris it is a continuous succession of narrow, steep-sided ridges or knobs, separated by narrow swampy valleys. The basins of the large lakes are directly connected with differences in the rock structure and rate of erosion. The smaller lakes occupy depressions or blocked valleys in the mammillated surface and the streams joining them are merely spill ways from one basin to the next.

The Pre-Palæozoic Surface. The present surface of the Pre-Cambrian, although locally uneven, does not break the even slope that bevels the Palæozoic resting upon it, and the questions naturally arise as to the amount of smoothing that this surface underwent during the bevelling of the Palæozoic formation and as to the character of the surface upon which the later rocks were deposited. From the levels of the various lakes where Palæozoic and Pre-Cambrian rocks are in contact, it is possible to get an approximate value for the slope of the Pre-Cambrian surface beneath the Palæozoic. The greatest value so obtained is 15 feet per mile almost due south. Taking this greatest value—and the average is probably much less—it is evident that within a distance of 10 miles from the present escarpment there is no pre-Palæozoic hill more than 250 feet in height, for, as far as has been observed, there are no inliers of Pre-Cambrian rocks in the limestone area and the escarpment at its edge is everywhere less than 100 feet in height. In some places the Pre-Cambrian floor has been so recently stripped that it has not been subjected even to Pleistocene glaciation and wherever this condition was observed, the surface has the same low relief and rounded hummocky character that are typical of surfaces exposed both to pre-Glacial and Glacial erosion. It seems certain, therefore, that the general character of the surface is not wholly the result of the late Tertiary erosion period which bevelled the Post-Cambrian formations nor of the action of Pleistocene glaciers, but that this surface was a plain developed before the deposition of the earliest Palæozoic rocks, and was in practically its present condition when covered by these formations. Its coincidence with the slope of the Great Plains is due in only a slight degree to the bevelling by later erosion.

The earlier conception of the Glacial period in northern Canada as a time during which great thicknesses of fresh as well as decayed rocks were planed off the surface has gradually been abandoned by most geologists who have had any broad experience among these older rocks.[1] Occasionally, however, statements are still made that hundreds of feet of rock have been removed by the ice. Besides the general similarity of the Pre-Cambrian surface exposed to Pleistocene glaciation, to that lying directly beneath the Palæozoic cover, there are other proofs of slight attack in many places even where the rocks are grooved and highly polished. The most striking instance seen is at a locality on the south shore of Reed lake just east of this map-area. The tip of a hook-shaped point projecting from the mainland is capped by a small outlier of limestone which is separated from the main escarpment by a long arm of the lake paralleling the main escarpment. This is less than one-quarter of a mile in width. The Pre-Cambrian rocks on the narrow isthmus between the outlier and the main mass are as highly polished as those in any other part of the district. It seems unlikely that ice action would have excavated a narrow, steep-sided trench 60 to 80 feet deep transverse to its line of motion and, therefore, it is believed that the Pre-Cambrian rocks of the isthmus were uncovered at the time of the ice advance. Had much rock been removed by the ice the apparently intensely glaciated Pre-Cambrian surface of the isthmus would stand

[1]Lawson, A. C., Geol. Surv., Can., Bull., vol. I, p. 118.
Adams, F. D., Jour. of Geol., vol. I, p. 338.
Wilson, M. E., Geol. Surv., Can., Mem. 39, pp. 101, 102.
Barlow, A. E., Geol. Surv., Can., Ann. Rept., pt. I, p. 25

at a lower level than that beneath the protecting Palæozoics. Th is no appreciable difference and so it seems evident that near escarpment at any rate, where rocks were not already weathered, amount removed, except by plucking, was not very great.

LOCAL TOPOGRAPHY.

The heterogeneity of rock formations has produced local forr requiring consideration.

Pre-Cambrian Section.

Lakes and Streams. A most striking feature of the Pre-Cambria is the large number of lakes varying in size from mere ponds to thos having areas of 200 to 500 square miles. The smaller lakes occup hollows that seem to bear no relation to the kind of rock in which the lie, but the larger ones are commonly in basins or troughs of thos rocks which are most easily eroded and the streams joining the lake follow zones of such rocks. Such stream-valleys are not th products of normal stream erosion but have been to a very large degre prepared for the stream by other agencies and hence the adjustment of the drainage to the softer and more easily eroded rocks is accidental. Sucker creek is an example of a waterway that has adapted itself to such a channel. Rising 3 miles northeast of Amisk lake it flows eastward, curves back to the west in a wide semicircular course, and finally empties into the east side of Amisk lake. It follows a narrow band of basic rocks between intrusive granites which seldom show along the creek. Grass river between Cranberry lakes and Island lake shows the same adjustment very strikingly. It flows northward to Elbow lake and then doubling back sharply flows southward in a valley parallel to and less than a mile distant from its upper course. The valley between Elbow and Island lakes is close to the western edge of the mass of granite lying north of the latter lake.

The lake basins have apparently resulted from weathering aided to some extent by glacial action in the removal of disintegrated rock. The hollows were formed largely previous to the invasion of the Ordovician sea. Prior to that time the land surface had been undergoing erosion for a period sufficiently long to degrade it to a plain of low relief. No doubt weathering affected the zones of basic rocks more deeply than the granites, since the former were from their original character more easily attacked and since they had already undergone great dynamic alteration during the intrusion of the granite batholiths. Much of the disintegrated material produced during this period of erosion was removed prior to the deposition of the dolomite, the base of which contains only a small amount of thoroughly oxidized foreign material. After the exposure of the Pre-Cambrian by the stripping of the dolomite cover the basins in the zones of softer rocks were further deepened by erosion. This period was much shorter than the previous one and did not affect the surface deeply. It was closed by the ice advance of the Pleistocene, the chief effect of which in this area was the removal of debris leaving the depressions ready for occupation by lakes and rivers.

As a result the larger rivers flow in valleys that are not in proportion to the size of the stream. They have long, narrow, lake-like sections interrupted by short rapids at boulder-dammed constrictions or where a more resistant band of rock or a granite dyke crosses the course of the stream.

Granite Uplands. Between the larger lakes the resistant granitic rocks form areas complementary to the lake basins. In inland sections the granite has been left at a higher level than the more easily weathered basic rocks and forms uplands of considerable area which in many places rise with fairly steep slopes. As a rule the granite hills are thinly soil-covered and the contrast between them and the more deeply soil-covered areas of basic rocks is striking. On the surface of large granite uplands such as that about the headwaters of the Mistik chain of lakes, Separation creek, and Webb creek, the upper lakes lie in very [illegible] irregular basins with low banks and are surrounded by flat muskeg areas through which the streams between the lakes meander sluggishly. Approaching the border of the upland, however, the lakes become smaller and the streams form almost continuous rapids. The elevation of the granite masses above the main drainage systems situated in the troughs of basic rocks makes the descent rapid and the fairly homogeneous nature of the granite does not lend itself to the development of ponded stretches with the descent localized in a few larger rapids or falls. The change in the nature of the streams from the slow meanders of the upper part to the straighter, rapid stretches of the lower part is well shown in the cases of Mistik creek or Separation creek where the number of rapids in the lower parts of these streams is in strong contrast to their almost complete absence in the upper reaches.

Granite Domes. The well-marked jointing of the granite is expressed in the local topography in dome-shaped hills. Striking examples of these occur along the Mistik lakes and there is one especially prominent hill of this type at the outlet of Nisto lake on this chain. The granite at this place has its three joint planes all inclined and hence as blocks split off a pyramidal form is produced and perpetuated. Softening of the outlines produces a dome-like form.

Troughs Formed in the Clastic Rocks. At the opposite extreme fr the granite uplands are certain troughs of clastic rocks most of whi happen to lie in areas of volcanics. These clastics are even less resista than the greenstones and schists and so form broad areas of lower lyi country. One of these areas stretches northwestward from the nort west arm of Schist lake and in it lies the drainage system of Cliff a Ross lakes. From the high hills of greenstone just south of this troug the arkosic rocks can be seen as a terrace along the sides of the gree stone hills which form an upland above them, just as in other places t granite forms an upland above the greenstone.

Rock Ridges. In the quartzite-slate series, the largest area which forms the northwest shore of Amisk lake, the more resistan quartzite beds form low hogsbacks. In the bay a mile north of th Prince Albert camp there are three of these low parallel ridges trendin northward.

In the area of gneiss north of Tartan lake the foliation of th gneissic rocks governs the formation of parallel ridges. The gneisse dip at angles of 20 to 30 degrees northward, and as a result of the struc ture, cuestas with steep southern faces are formed. The lakes lie in th hollows between these parallel ridges, and the different parts of the lake are connected by narrow channels. In many of the hollows not occupied by lakes there are wet muskegs or sluggish streams, which flow through almost impassable swamps.

Glacial Forms. The part of this map-area comprising the Pre-Cambrian province was not an area of much deposition during the Glacial period. Boulders are found over the whole district but moraines are not common. In places where rock protuberances have given protection, small deposits of till have been left but they are not numerous. There are a few areas of sand-plains, evidently the result of outwash from the front of the retreating ice, but during the Glacial period this particular section was one of erosion rather than of deposition.

Palæozoic Section.

Lakes and Streams. In the Palæozoic section the lakes are very different from those of the Pre-Cambrian section. The shore-lines are smoother, islands are lacking or very few in number, the basins are shallow, and the low shores in many places are merely ridges of sand and ice-shoved boulders which inland immediately drop off to muskeg country very little above the lake-level. Streams joining lakes lying at different levels are broad and shallow with numerous flat rapids that make travel very tedious. The Sturgeon-weir, below Amisk lake, with its almost continuous rapid water, is a typical river of this sort.

The rapids are not rough enough to require portaging when the water is sufficiently deep, but in ascending the river it is necessary to pole or track for much of the distance.

Glacial Forms. A large part of the Palæozoic section is covered by clay of varying thickness deposited during submergence of the region by glacial lake Agassiz. In this particular map-area this covering is not so important as farther east, but because of its presence and the flatness due to the Palæozoic structure, parts of the country inland from the drainage systems are covered by large muskegs. Since protecting rock protuberances are not found in the homogeneous Palæozoic formation, as they are in the heterogeneous older formation, deposits of till are almost lacking.

Border Zone.

Where the Pre-Cambrian and Palæozoic topographic districts meet there is a border zone that has some characteristics found in neither the Pre-Cambrian nor the Palæozoic areas. The sapping of the lower and less resistant beds of the Ordovician produces cliff faces which rise 50 to 80 feet above the older rocks and form one of the most striking physiographic features to be found in the whole area (Plates II and VI A). Outliers are scattered along the main border, standing out as flat-topped, steep-sided hills. The prominence of these is, however, masked in most places by the much greater height of the trees on the soil-covered lower rocks than on the thin sterile soil covering the dolomite. Many of the larger lakes lie in this border zone, their basins apparently being troughs eroded in lenses of basic rocks with the southern parts of the troughs blocked by the dolomite which forms a sort of retaining wall along that shore. The cliff faces so commonly found along these "glint" lakes are quite different from the low swampy shores of lakes lying completely within the dolomite. The drainage of some of the glint lakes is through openings in the dolomite, others drain by rivers along the doltomite escarpment.

CLIMATE.

The amount of rainfall and snowfall is not large. The total precipitation is 15 to 20 inches per annum as compared with 35 to 40 inches for southern Ontario and Quebec. The snowfall is 30 to 60 inches as compared with 60 to 90 inches for southern Ontario and 90 to 120 inches for a large part of Quebec.[1] The winters are cold and long, the summers short and hot. The large lakes freeze over during the first part of November and are seldom free of ice until the middle of May. Frosts

[1]Atlas of Canada, 1915, Dept. of Int.

occur in early September. A list of temperature observations for this and adjacent areas is found in Memoir 30, Geological Survey, Canada. The shortness of the summer season is to some extent counterbalanced both by the length of daylight, owing to the latitude, and also by the large number of clear days.

AGRICULTURE.

The climate does not prevent the growing of the hardier cereals and vegetables in any part of the area and wherever settlements have been made, small gardens are cultivated with success. The lack of areas of suitable soil is the chief drawback to agricultural development. In the areas of lake clays rainfall remaining on the surface produces immense muskegs which would be difficult of drainage. In much of the northern part of the sheet the areas of arable land are so limited in extent that agriculture will never be an important industry.

FOREST.

Birch, poplar, tamarack, spruce, and jack-pine form a thick forest cover over most of the area. In favourable localities the trees are quite large, but much of the area has been burned during the past fifty years and the second growth trees are all so small that the amount of merchantable timber and pulpwood is not great.

FURS, GAME, AND FISH.

The first explorations of the country west of Hudson bay were made to obtain furs and from that time to the present the fur trade has been the chief support of the scattered population. In the early days the trappers were all Indians, but recently there has been a larger and larger number of white men adopting the life either entirely, or only in the winter months when other employment fails. The shifting of trading centres and the increase and decrease in the number of trappers coincident with fluctuations of the price of furs and the labour conditions outside, prevent any accurate estimate of the average yield of furs from any district or the comparison of present with past production. There seems little doubt, however, that the number of fur-bearing animals is steadily decreasing. It is the custom of the white trapper at least to choose a certain trapping ground which he works so intensively that in two or three years he finds it profitable to abandon his cabin and trapping ground and move to some new place. Even more serious than the depletion of the fur-bearing animals by too much trapping is the destruction of their breeding grounds by forest fires. This danger has been increased by the prospecting that has been going on for the last three years and it is becoming greater each year. The fur-bearing animals of the district are bears, otters, wolves, lynxes, minks, weasels, beavers, fishers, martens, wolverines, muskrats, and foxes.

The larger game animals are moose and woodland caribou. Neither of these is particularly plentiful and both are probably decreasing owing to all-year-round hunting and to the great increase in the number of wolves in the past few years. Ducks and geese are found in large numbers, the latter during their migration in spring and autumn, the former during the summer. The robbing of the nests during the spring is a menace to the preservation of the ducks. For two or three weeks during the nesting season the whole diet of many of the Indians consists of eggs. Grouse are not plentiful, probably on account of the number of weasels as well as on account of unrestricted hunting.

Recently fish have begun to form a valuable part of the products of the district.[1] The larger lakes are well stocked with fish of the finest kind, including lake trout, whitefish, pickerel, and sturgeon. Other species are found, including pike, suckers, goldeyes, and maria, but are not marketable. Some of the lakes recently opened for fishing have been allowed to be depleted of the merchantable fish to too great a degree. This is true of Amisk lake which the fishermen are now voluntarily leaving. A lake in which the whitefish are depleted below a certain minimum and the predatory fish are not taken, reaches a stage in which the increase of whitefish becomes impossible owing to the destruction of spawn and fish by pike and other marauders and in time this valuable fish may become extinct in the lake. Another very serious danger to the whitefish is the very common practice among both Indian and white residents of catching whitefish during the autumn spawning season when these fish struggling up the rapids in the smaller streams are easily caught in great numbers. In this way the Indians in a week or two get enough fish not only for their own winter supply but to feed the large number of dogs that most of them keep. Summer fishing for dog food also accounts for a large number of valuable fish. If only the destructive pike were used for dog food the result would be beneficial, but all varieties are used indiscriminately. It is a conservative estimate to say that a dog team will each year consume a ton of fish and in a great many cases the work return for this is very small.

WATER-POWERS.

On all the streams there are many falls and rapids, but since the district lies on a height of land, with drainage northward to the Churchill, southward to the Saskatchewan, and eastward to the Nelson, the rivers flowing through it are not large. There is also a great variation in flow,

[1]During the year 1916-1917, the total value of the fish taken from Athapapuskow lake was $14,261, Fisheries Branch, Dept. of the Naval Service. 5th Ann. R[illegible], p. 206.

the summer minimum coming late in August, and during the exces
cold of the winter months the flow of some streams is very small.
C. H. Attwood of the Water-powers branch, Department of Inter
has kindly furnished estimates of water-powers which might be availa
for the district. He states that the lack of accurate flow measureme
on the Churchill and Sturgeon-weir rivers makes definite determinati
of the available power impossible, but he considers his estimates of th
conservative. His statement is as follows:

"THE CHURCHILL RIVER.

The closest power site capable of producing large blocks of 24-h
continuous power to the above-mentio l mining district (Flinfl
Schist Lake district) is Bloodstone falls on the Churchill river.
reconnaissance survey was made at this site in September last and
that time the discharge of the river was found to be about 50,000 cu
feet per second. Assuming that the minimum flow of the river is one-h
of this amonnt, 25,000 cubic feet per second, the site is capable
developing 35,000 continuous 24-hour horsepower.

This site is distant about 70 miles in an air line from the Flinfl
mining properties and aside from the costs of transportation the si
lends itself to easy and economical development. Further and mo
detailed investigations may show that for a small additional expenditu
a higher head could be developed and storage secured that would increa
the possible power output of this site to 60,000 horsepower.

THE SASKATCHEWAN RIVER.

Investigations made at Grand Rapids on the Saskatchewan riv
show that at present 35,000 continuous 24-hour horsepower can b
economically developed and that by creating storage or building
steam plant to tide over the low water periods this minimum can b
increased to 70,000 horsepower. This site is distant in an air line abou
150 miles from the mining district referred to above and as there is
possibility of this site being partially developed in the very near futur
to supply power for a proposed pulp industry at the mouth of th
Saskatchewan river, it may prove to be more economical to supply th
mining district with power from this source rather than from the Churchil
river. These two power sites are the largest sources of power available,
but the development of these sites would not be warranted unless the
mining district referred to can consume nearly the whole of the power
developed.

Of the smaller power sites in the district the only ones investigated
by me were Scoop rapids and Birch rapids on the Sturgeon-weir river.
These sites are approximately 35 miles west of Flinflon and are capable
of developing only 500 to 1,000 continuous 24-hour horsepower each."

CHAPTER IV

GENERAL GEOLOGY.

INTRODUCTION.

The relation of the various geological units is shown in the table of formations given on page 9 and their distribution is indicated on the accompanying map. The area lies along the northern border of the Palæozoic and includes part of a remnant of basic Pre-Cambrian rocks. These are entirely isolated by hundreds of miles of granites from similar types that have been studied to the southeast and hence no attempt is made to correlate them either with the Lake Superior or Ontario areas. A comparison of the succession in these areas shows similarities, but at present it is considered wiser to use a local nomenclature.

AMISK VOLCANICS.

The rocks grouped as the Amisk volcanics are a complex of very ancient surface flows, fragmental rocks of volcanic origin such as ash beds and agglomerates, and to a lesser extent intrusive rocks that are probably closely related to the surface types. Most of the rocks were originally of medium basicity, probably dioritic in composition, but they are now altered to rocks consisting almost entirely of secondary minerals, chiefly chlorite, uralite, calcite, serpentine, and iron oxides. Shearing and compression have changed many of the members of this complex into schists.

Massive Greenstones.

The surface flows are now massive greenstones that in places still retain pillow or amygdaloidal structures. The pillow structures are similar to those described in almost every other area of basic Pre-Cambrian rocks. In this district the areas of lavas showing this form are not large. Possibly the flows were of considerable thickness and as the pillows are surface structures they developed in only a small part of the whole mass. Also, the intense metamorphism that much of the volcanic complex has undergone may have in some parts destroyed these original structures. Amygdaloidal lavas have much the same distribution as have the pillow lavas. Under the microscope, massive greenstones whether showing pillow or amygdaloidal structures or not, have much the same appearance. They have passed through severe metamorphism and are usually nothing but a felt of secondary minerals

The amygdaloidal greenstones are much the same in composition as those described. In many places amygdules are found in rocks showing ellipsoidal weathering but one structure commonly occurs without the other. Polygonal jointing of the old lavas occurs on the east shore of the north arm of Athapapuskow lake (Plate III B) and a very striking sheeted structure simulating bedding on an island southeast of Missi island in Amisk lake (Plate IV A).

Autoclastics and Pyroclastics.

At some points on Schist lake and on the north arm of Athapapuskow lake there are certain types of rocks that seem to be the direct result of movements in the lava during the period of its extrusion. The result is a fragmental rock in which the fragments are angular or subangular pieces of lava cemented by the material of which they are composed. The movement has rounded the corners of many of the fragments and the resulting rock may simulate rather closely a true conglomerate. Pyroclastic types are even more difficult to distinguish from true sedimentary rocks. During the period of volcanic activity ejected material, partially or wholly solidified during its passage through the air, was included in the viscous lavas (Plate III A). These masses now show as very dense oval bodies of various sizes. They are harder than the coarse-grained parent material and stand out on eroded surfaces. Sometimes too they are of a slightly different shade of colour. They are, however, all of the same material, which does not appear to differ from the matrix except in texture. Between them and the enclosing rock there is seldom a sharp dividing line as is usually the case in a true conglomerate, but the hard oval mass grades into the somewhat coarser material in which it lies. Although the enclosing rock does not differ from greenstone showing pillow structures this cannot be accepted as undoubted proof of its igneous origin since, under the severe metamorphism to which all the lower series of this district have been subjected, true fragmental rocks, formed mostly from the debris of greenstones, have been reconstituted into dense, dark green rocks distinguished with difficulty from the volcanic rocks.

Near the tip of the long point, east of the mouth of the Pineroot river, there is a striking example of this pyroclastic lava. The rock has been very severely glaciated, the grooving bending around the hard oval masses leaving them in relief. In this exposure there is also a difference in colour, the bombs being a lighter shade of green than the enclosing rock. A microscopic examination indicates that this is an amygdaloidal rock which has been rather severely squeezed. Its condition is in accordance with its supposed history. A small quantity of ejected molten material would naturally tend to assume a somewhat rounded form, the sudden cooling would produce a fine-grained texture, and the opportunity for the escape of gas on all sides would explain the amygdules. After being embedded, the viscosity of the lava in which it was enclosed would allow the transmission of differential stresses to produce the elongated form of the bomb, and the stretching out of amygdules. The absorption of the solidified material by the still hot matrix would form a border resorption zone with a gradation from the fine-grained, suddenly cooled bomb to the somewhat coarser-textured lava in which it is found.

Schists.

Some of the schists belonging to the Amisk volcanics are clearly the result of dynamic forces acting on the rocks previously described. The intense shearing and squeezing to which the very old volcanics have been exposed have produced from the massive forms highly schistose derivatives. During periods of igneous intrusion rock alteration by dynamic forces was no doubt supplemented by the action of solutions under great pressure and at high temperatures. In certain localities the gradation from massive volcanics to schistose greenstone and to chlorite schist seems to be certainly the result of shearing and alteration. In other occurrences massive greenstone and schists are interbanded in such a way and with such definite boundaries that it seems very probable that there was some other factor governing the course of metamorphism. This is shown especially plainly in the unweathered rocks from the diamond drill holes from the Mandy property on Schist lake. On the surface the rocks are interbanded, massive greenstone and fissile chlorite schists, in zones 50 to 100 feet in width. The contact in the drill cores is very sharp, the change from massive to schistose rock showing no gradation. Possibly the presence of clayey or tuffaceous layers between successive lava flows may have localized the shearing and metamorphism almost completely in these less resistant zones producing a fissile chlorite schist in sharp contact with massive rocks.

Relations.

The volcanic rocks and their derivatives by metamorphism form the oldest recognized series, but since they are all surface types there must have been still older rocks upon which they were laid down and which are now entirely covered by younger rocks or are completely engulfed and absorbed by the intrusi[illegible]e masses. The relation of the Amisk group to rocks of later age will be considered when discussing the younger formations.

QUARTZ PORPHYRY.

Distribution.

The rock classed as quartz porphyry is not found in large a
The best exposures occur on the western side of Missi island w
roughly parallel dykes cut the greenstone. In places the dykes
so numerous that there is less greenstone than quartz porphyry.
other parts of the area isolated dykes are found, but these are
large enough to be indicated on the map. In representing the dy
of Missi island the exposures have been to a certain extent generaliz

Lithological Character.

The quartz porphyry weathers white with quartz individu
standing out in relief. It is not very different in appearance from t
weathered surface of quartzite and where the two rocks occur clo
together, as they do at the north end of Amisk lake, it is sometim
difficult to be certain to which rock type an exposure belongs. Ordi
arily, however, faint crenulated bedding planes can be observed in th
quartzite which are absent in the quartz porphyry. The quar
porphyry fractured whereas the quartzite flowed during the foldin
of the formations. On the fresh surface the quartz porphyry is a ligh
grey, fine-grained rock in which small blebs of glassy quartz are visibl
in some specimens.[1] The quartz porphyry is resistant and commonly
stands out above the greenstone into which it is intruded. The silica
content in the two rocks is shown in the following analysis.

	SiO_2
I	72·82½
II	77·82
III	57·65
IV	70·51
V	85·13

Nos. I, II, III, various facies of lower Missi sediments on the west shore of Amisk lake
No. IV, quartz porphyry intruding Amisk volcanics on west shore of Missi island at a point southwest of the Prince Albert Mining Company's camp buildings.
No. V, quartzite from Willow creek, 2 miles above Trout lake.

Relations.

As previously stated this rock is found in dykes cutting the volcanics of the Amisk group. It is believed to be older than the sedimentary series of Missian age because no dykes of it have been recognized in either of the Pre-Cambrian sedimentary formations and because in the conglomerate there are pebbles lithologically similar to some facies of the quartz porphyry. However, the amount of alteration through

[1]Silica content of Missi sediments and quartz porphyry.

which these very old rocks have passed makes identification on lithological grounds a somewhat uncertain process, since rocks possibly of very different origins subjected to intense metamorphism tend to become somewhat similar aggregates of secondary minerals.

KISSEYNEW GNEISSES.

The northern part of the Schist Lake district is underlain by a complex of gneissic rocks, part of which seems to be sedimentary in origin but in which there is a large volume of igneous rocks.

Detailed mapping of this area will show a large number of types, but for the present they are grouped together. The gneisses that are believed to be sedimentary are well-bedded rocks consisting largely of quartz, feldspar, biotite, and garnet. They vary from very dark to light-grey rocks depending on the constituents. The igneous rocks are typical granite gneisses, some of which are also garnetiferous, others are similar to the granite gneisses separately mapped farther south, and with more detailed work should be referred to that type. A characteristic feature of this gneissic group is the large number of pegmatite dykes, some of large size.

The strike of the gneisses in which Kisseynew lake lies is south of west, almost transverse to the dominant structure of the schists of the southern part of the district. Around Mari lake, however, the general northerly strike is again the most common.

Distribution.

The definition of the area occupied by the members of this group depends largely on the fixing of a somewhat arbitrary line of division between gneiss, chiefly of sedimentary origin, schists of purely volcanic origin, and granite gneiss of a much younger period. There is also the possibility that the close folding that has affected the northern end of the Cliff Lake syncline of Missian sediments together with the granitization of these rocks by intrusives may have changed members of the conglomerate series into gneissic rocks. Crossing the strike of the gneissic complex from Weetago bay on Kisseynew lake to Willow creek, typical garnetiferous quartz feldspar biotite gneisses extend southward for three-eighths of a mile. The rock there, without any change in its attitude, grades into a richly hornblendic quartz schist which resembles more nearly the volcanics than it does the gneisses. Assuming that the hornblendic quartz schist belongs to the Amisk group, the area of gneiss extends northward from a line one-half to one mile south of Kisseynew lake and westward beyond Mari lake.

In this area there are several large masses of later intrusive gr and granite gneisses. One of these lying south of Mari lake (eastward to the west side of Weetago bay on Kisseynew lake. A large mass lies between the two arms of Mari lake and there are so masses of smaller size at other points in the district surrou Kisseynew lake.

Lithological Character.

Since the Kisseynew gr[illegible]s is so heterogeneous in origin, as i.. physical character, an almost infinite number of rock types m be described. The gneisses that seem to be undoubtedly of sedimen origin are well foliated rocks ranging from very dark to light g In many places they have a bedded appearance, the beds rangin thickness from 2 inches to 1 foot. The foliation is parallel to bedding.

At the narrows of Kisseynew lake, east of the arm leading no ward to Weasel bay, the rock is definitely bedded. The beds are 8 inches thick and dip northward at angles of 35 to 45 degrees, strike being parallel to the shore. The rock is strongly foliated w light grey and dark grey bands.

Examination under the microscope shows that the whole rock been very completely recrystallized and original sedimentary textu are not recognizable, but the bedded appearance and the apparen abnormal mineral proportions are rather conclusive evidences of su an origin.

In the bay extending southward from the long arm connecti Weasel bay with the main body of the lake, there is a garnetifero gneiss that is undoubtedly of igneous origin since it contains garnetiz fragments of older rocks. It is strongly foliated and carries a larg number of deep red garnets. The surface weathers white but on th fresh fracture it is dark grey and rather dense. Under the microscop the rock shows no foliation but looks like a typical massive granit with closely interlocking quartz, orthoclase, and plagioclase as th principal constituents, and biotite, garnet, and a little muscovite as les important minerals. The orthoclase is only slighlty altered and th plagioclase, which is about andesine in composition, is very fresh.

This granite is intrusive into a dark reddish gneiss that forms th top of the hill just north of the narrow mouth of this bay. The samples described probably represent a part of a granite intrusion somewhat altered by the assimilation of some of the roof of its chamber and th garnets have been formed by the crystallization of the hybrid magna.

The two rocks described may be considered as the end types of the composite Kisseynew group. One of them is believed to be composed mostly of sedimentary materials, possibly metamorphosed by the intrusion of granitic rocks. The other is clearly of igneous origin but is modified by the assimilation of the rocks which it has intruded. There are gradations between these types. Pegmatite dykes and sills form another quite distinct type. Some of them are as much as 100 feet thick and many of the sills are exposed along the lake shores for long distances. The dykes are composed of orthoclase, quartz, and muscovite. None of the rarer minerals so often found in pegmatites were observed.

Structure.

In the vicinity of Kisseynew lake the gneiss strikes approximately north 60 degrees east and dips at angles of 30 to 40 degrees to the northwest. On Mari lake, however, the strike is northward and the dips rather steep to the eastward. Evidently the whole forms a northeasterly pitching syncline. On the southern limb of this syncline the gneisses overlie and dip away from the schists assigned to the Amisk group. The strike of the formations of this arm is, however, transverse to the dominant strike of the schists farther south and it is evident that there was a great fold which bent all formations up to and including the upper Missi sharply westward and then again northward. The Missi sediments are apparently cut off a short distance to the north of Willow creek and it is assumed that an east-west fault is the explanation. In the gneisses of supposed sedimentary origin there is a large amount of igneous material injected as sills. Some of these sills differ from normal granite gneisses only in a slight change of composition produced the dissolving of a certain portion of the adjacent beds. Others are pegmatitic. In both cases the igneous rock is more resistant than the sedimentary and, consequently, in many places forms very thin facings over the gentler northward slopes of the cuestas, the lower parts of the steep south faces of which consist entirely of the more easily eroded sedimentary rock.

Age.

Since it is a complex rather than a simple formation the ages of different portions of the group are very different. The sedimentary part is believed to be younger than the Amisk volcanics since the gneiss appears to overlie the greenstone and schists. There is, however, no trace of any unconformity between the two, the relation being rather that of a gradual transition from the dominantly igneous rock of the Amisk group to the dominantly sedimentary rock of the Kisseynew group, and it may even be found that some of the bands in the latter are merely contact metamorphosed representatives of the former. Hence,

for the present it is assumed that the Kisseynew group is simply th
upper portion of a great formation of which the Amisk group forms th
lower part.

CLIFF LAKE GRANITE PORPHYRY.

Distribution.

The rock to which the name Cliff Lake granite porphyry is applie
forms one small batholith lying between Cliff and Ross lakes on th
west, and Trout and Big Island lakes on the east, but does not outcro
along the lakes on either side. It is roughly pear-shaped in outline, th
small end just crossing the portage from Cliff to Trout lake. On th
preliminary map this area is shown under the same colour as is th
Kaminis granite, but is now believed to be entirely different in age.

Lithological Character.

The Cliff Lake granite porphyry weathers to a pink colour mottle
with lavender-coloured phenocrysts of quartz. On fresh surfaces th
phenocrysts are pale blue.

Relations and Age.

This batholith intrudes massive greenstone and schist of th
Amisk volcanic group, but no dykes of similar rock have been found in th
Missi group. At one place east of Cliff lake, the two rocks are less tha
one-eighth of a mile from each other, but the boundary of the conglom
erate series along Cliff lake is an overthrust fault of the volcanics over th
sediments. Hence, the absence of dykes of the granite in the sediment
has no bearing on the relative ages. The evidence upon which the Clif
Lake granite porphyry is placed unconformably below the Missi sedi
ments rests on the likeness of the graphic intergrowths in the porphyr
of the batholith and that found in pebbles in the conglomerate. In th
greywacke bands there are also tiny grains of bluish quartz very simila
to the quartz phenocrysts of the Cliff Lake rock. The almost complet
chloritization of the basic rock minerals and the alteration of th
orthoclase is corroborative evidence that this rock is somewhat olde
than the Kaminis granite. For these reasons it has been placed in th
table of formations below the Missi group. It must be remembered
however, that its position in the succession rests on the meagre evidenc
given above and that, even if it is older than the upper Missi formation
there is no proof whatever that it is older than the lower Missi slates and
quartzites.

MISSIAN SEDIMENTS.

Since there are two clearly sedimentary Pre-Cambrian rock groups in the area, both of which occur on Missi island, the terms lower and upper Missi have been adopted to designate them.

LOWER MISSI SERIES.

The lower series is found along the west side of Amisk lake on the northwest corner of Missi island and along the west side of the northeast arm of Schist lake. This latter occurrence is somewhat doubtfully assigned to this group, for although lithologically similar to the slates occurring on Amisk lake the structural relations of this belt with the Amisk volcanics and the lack of any observed unconformity between the two types make it seem possible that the Schist Lake belt is merely a slaty zone in the volcanic series rather than a representative of the lower Missi sediments.

The lower Missi consists of conglomerate, quartzite, slate, greywacke, and carbonate rocks in frequent alternations. Quartzite and slate form the greater part of this apparently very thick series. Due to the drag folding of the beds and the faulting to which these old rocks must have been subjected the thickness may be much less than it appears to be. This is especially true in the slates, in which the thickening by drag folding must be very considerable. Although the various rock types will be described under separate headings the formation must be pictured as a unit composed of many interbandings of the various types, the whole so closely folded that the result is practically a complex.

Lithological Character.

Conglomerate. The conglomerate which, from evidence to be given later, is believed to form the base of this series, is not everywhere present, but where found it is a typical conglomerate carrying pebbles of quartz, greenstone, quartzite, and felsite. These are embedded in a matrix much like greenstone in appearance which is probably composed largely of the debris of the greenstone upon which the sediments were laid down, reconstituted by metamorphism to almost its original condition. Strangely enough the pebbles are not squeezed or distorted to nearly the same degree as are those of the conglomerate of the supposedly younger upper Missi series. This is probably due to the softer slates of the lower series having taken up the greater part of the stresses, whereas in the more competent beds of the upper formation, composed of a matrix with a resistance comparable to that of the enclosed pebbles, both pebbles and matrix were distorted.

Slate. The slate member of the lower Missi is typically a s black, fairly fissile rock with the bedding well-marked by variations in colour and, in places, by a variation in the hardness of the beds, wh causes it to weather to a ridged surface. Ordinarily the beds are th averaging one-eighth inch. The intense metamorphism that the wh series has undergone has locally silicified the slate, making it much hard than in the typical exposures. The close folding is expressed in gre numbers of drag folds in the slate (Plate IV B) and, in some beds, by secondary cleavage. Under the microscope thin sections of slate a almost opaque, showing merely a few tiny fragments of quartz a feldspar.

Quartzite. The quartzite is a white weathering rock which, bei more resistant than the slate, forms low hogsbacks. In the field it somewhat difficult to distinguish from the white weathering quar porphyry that is found intruding the greenstone on Missi island. I many exposures, however, the quartzite has a very fine crinkly bandin due to slight differences in composition of different layers. Micro scopically, it shows a distinct banding due both to differences in size o grain and to differences in constituents. It is made up mostly of rounde quartz grains and biotite, the latter arranged parallel to the bedding The beds are comparatively thin, but because of the frequent alternation that occur the total thickness of quartzite in this formation must be great.

Carbonate Rocks. Interbedded with the quartzites and slates are layers of a soft brownish-weathering rock that on the surface has the peculiar pitting found in limestones. The beds are seldom more than 10 to 20 feet in thickness and seem to have been the least competent of the series, since this rock has undergone so much thickening and thinning of the beds that in places the legs of the drag folds are pinched apart and the beds remain as fragments filling the crests and troughs of the folds. A microscopic examination of a specimen of this rock interbedded with quartzite shows it to be a calcareous arkose made up of quartz, plagio- clase, calcite, sericite, pyrite, and hematite. The quartz fragments are somewhat rounded, the plagioclase less so. Calcite is so abundant that the rock effervesces freely with acid. The hematite is no doubt secondary from the pyrite and gives the weathered rock its deep brown colour. Some of the calcite may be of secondary origin but some of it seems to have been deposited with the original sediment. The whole has been recrystallized.

Structure.

Conglomerate is not always found at the base of this series nor was it possible on the scale on which the work was done to use any bed as a reference plane. However, the attitude of drag folds and secondary cleavage give some idea of the positions of the axes of the major folds. On the west shore of Amisk lake opposite the Hudson's Bay Company's store there are two bands of conglomerate striking north. Westward from the western band there are many alternations of quartzite, slate, and carbonate rocks much contorted. The average strike is north 10 degrees east, dip 75 degrees west. On a small point about 400 feet west of the conglomerate are well-marked drag folds pitching northwestward with the western beds dragged up with reference to the eastern beds. Hence the exposure is on the east limb of a syncline whose axis lies farther west and these beds are very probably above the conglomerate layer 400 feet to the east. There is, of course, the possibility of faulting, but in the absence of a fault there does not seem to be space enough for a minor fold to carry the slates and quartzites under the conglomerate; thus the succession is believed to be from the conglomerate at the base up through alternations of slates, quartzites, and carbonate rocks. On similar evidence an anticlinal axis is believed to pass northwestward across the mouth of Backagain bay. The beds on each side of this axis are practically vertical. On the south limb of the syncline, however, the beds are flatter than they are elsewhere, striking north 80 degrees west and dipping 57 degrees north. The sudden change in the trend of the shore-line at this point from nearly south to about west is an expression of the structure, the shore-line following fairly closely the strike of the beds.

Northward from the conglomerate beds referred to, the general strike of the rocks is parallel to the trend of the west shore of the lake but with many minor folds. The deep bays of the west side of Missi island seem to be the physiographic expression of drag folds in the eastern limb of one of the synclines. The slates are soft and easily eroded and where these were drag folded erosion has now excavated two large bays. All the folds pitch steeply to the northwestward at an angle of about 45 degrees and the whole series as mapped on the west side of Amisk lake probably represents one element in the major structure which will be referred to later.

Thickness.

As the folds pitch steeply to the northwestward and have not been traced far from the lake shore no estimate of the total thickness can be made. There are crenulations, especially of the softer beds, which increase the apparent thickness, and faulting also may have duplicated the series. The conglomerate found at the base of the series opposite the Hudson's Bay Company's store has a thickness of approximately

40 feet. A section from the mouth of the Sturgeon-weir river nor east to the opening of Backagain bay, at right angles to the strike of t axis of the southern syncline, shows a thickness of about 4,000 fe of quartzites, slates, and carbonate rocks. This, of course, does n represent nearly the maximum thickness of the formation becau of the westerly plunge of the syncline; bu it is probably considerab greater than the true thickness of beds at that particular place owi to the thickening and reduplication referred to above.

Relations.

The lower Missi series is clearly later than the Amisk volcanic This is shown by the structural relation of the syncline just describe and also by the presence of disk-shaped fragments of greenstone in th conglomerate beds. Pebbles are also found that are lithologicall similar to the quartz porphyry. Quartzite pebbles are found that ma have come from some of the sediments now recrystallized into th gneisses of the Kisseynew formations. The relation of the lower Miss series to younger rocks will be discussed later.

Origin.

All the various types of rocks referred to this series are evidently shore deposits. The thin conglomerate found occasionally as the basal member can be explained as a beach formation. The quartzites represent a rather well sorted sand and the slaty layers are the finer-grained products of rock weathering. Even in the carbonate rocks a large part of the material is clastic and they were probably deposited under somewhat quieter conditions than were the shore facies of the conglomerate or the quartzites, but under conditions unsuitable for the formation of true limestone. That conditions were relatively unstable is shown by the frequent alternations of all these types. In some places there seems to have been decomposition of the older rocks and their reconstitution into the younger series practically in situ. Where this relation is found only an arbitrary line can be drawn between greenstone and slate. Probably the conditions of formation were those of a fairly low land mass from which well decomposed material was obtainable and very slight oscillations of the land mass or slight climatic variations would cause frequent changes in the character of the sedimentation. Transportation lagging behind decomposition made possible the formation of rocks that seem to be gradational from greenstones to slates.

UPPER MISSI SERIES.

Distribution.

The rocks assigned to this series form three fairly large areas and occur as small patches at various places. One of the larger areas lies north of Amisk lake, extending northwestward an undetermined distance, and a second, beginning at the north end of the northwest arm of Schist lake, extends northwestward across Trout creek. The third is a band reaching from the west arm of Athapapuskow lake northward to the north arm. Other areas large enough to be represented on the map are found along the Pineroot river.

Lithological Character.

The greater part of the upper Missi rocks consists of conglomerate and arkose (Plate V), though in places, where they rest upon the Amisk volcanics or where the chief supply of debris came from those rocks, greywacke is found. Nearly all of this formation along the north shore of Amisk lake is fairly acidic in character, consisting of arkose and conglomerate with an arkosic matrix. The pebbles of the conglomerate are disk-shaped fragments of greenstone arranged with their longer axes parallel to the original bedding, together with quartz, jasper, quartzite, and felsite; and, commonly, there is enough iron oxide to give the formation a reddish colour. The arrangement of the pebbles is extremely irregular and in size they vary from coarse sand up to diameters of one foot. In many cases the finer material forms lenses in coarser material. Under the microscope the arkosic beds are seen to consist of angular to subangular quartz fragments sometimes with feldspar in a matrix of quartz and usually a large amount of secondary material. Where there has been shearing practically the whole rock may be altered to sericite.[1]

In the trough in which Ross and Cliff lakes lie there is relatively more greywacke. The rock is usually massive and commonly the bedding is obscure. Towards the base of the formation, however, the beds are thinner and more regular but the basal beds are very severely sheared. A conglomerate with beds striking north 10 degrees west and dipping 30 degrees east is exposed along the east shore of a small lake 2½ miles west of Cliff lake. At the water's edge it contains a large number of pebbles and boulders as large as one foot in diameter, forming 30 to 40 per cent of the rock. The fragments are well rounded and consist of quartz, chert, and granite. The matrix is an impure quartzite or arkose. Eastward toward Cliff lake the pebbles become fewer and the rock passes into a dark massive type much like the matrix of the conglomerate. This grades from a dark grey massive rock to a more schistose variety of a greenish grey colour, but the beds, some of which are as much as 2 feet in thickness, still retain a uniform dip eastward expressed by cuesta-like ridges with a gentle slope of 30 to 35 degrees easterly. On the east side of Cliff lake there is another band of conglomerate with a greenish matrix that resembles greenstone, probably from the inclusion in it of a large amount of greenstone debris.

Structure.

Folding. The indistinct and inconstant bedding of the upper Missi formation makes the unravelling of the structure of the various areas somewhat difficult. Along the north shore of Amisk lake drag folds and secondary cleavage indicate that the beds there are on the south limb of a northwesterly pitching syncline. The northern limb of this has not been found, probably because the intrusions of granite have cut up and very severely metamorphosed this band of sediments. It is possible that a large part of the original fold has been entirely removed or absorbed. The structure of the Cliff-Ross Lake area is more clearly evident. In that area the Missian rocks form a basin on the southwestern side of which the sedimentary rocks dip steeply away from the rocks of the Amisk group, the strike of the lower beds paralleling the line of contact. Apparently here also there is a syncline pitching steeply to the north.

Faulting. The eastern side of the Cliff-Ross Lake syncline is probably bounded by a fault zone of considerable displacement. Northward from the northwest arm of Schist lake the conglomerate is separated from the greenstone by a steep-sided, drift-filled valley. East of Ross lake a small lake separating the two formations lies in a well-marked valley trending northward. On the eastern side of [illegible] lake, McLeod found evidence of a shear zone along the edge of the conglomerate. The greenstone mass to the east has been thrust westward over the conglomerate. At the base of the syncline just north of the northwest arm of Schist lake the basal bed of the conglomerate is an arkose or fine-grained conglomerate which has been granulated by movements parallel to the bedding during the formation of the syncline. The slipping was naturally greatest near the base of the formation where the massive greenstone formation acted as a competent member. As a result the shearing is greatest and at many places almost entirely localized in the basal sedimentary bed.

In the smaller area of conglomerate on Athapapuskow lake the evidences of normal faulting are fairly clear. On both sides of this band the arkose has been altered to sericite schist along the contacts though a short distance away it is fresh and practically unaltered. The convergence of these two fault zones may explain the remarkably straight course of Pineroot river as well as the remnants of conglomerate at Whitefish lake and at the rapids just below it.

Relations to Older Formations.

The relation of the upper Missi rocks to the Amisk volcanics is clear. Greenstone pebbles are always present near the base of the series although on account of their softness they are never very numerous. In many places, also, the Missi rocks lie structurally above the volcanics. The relation to the slate, quartzite, and greywacke that have been placed in the lower Missi series is not so clear. The two series have not been found in contact and the differentiation has been made on the basis of lithological character and the presence in the conglomerate-arkose series of pebbles of quartzite that may have come from the quartzite slate series. A pebble of conglomerate has also been found. Some of the pebbles are comparable to the white weathering quartz porphyry that occurs as dykes cutting greenstone on Missi island.

Besides these pre-upper Missian rocks which have been recognized in place, there are in the upper Missian conglomerate pebbles of some other rocks which have not yet been found to occur in the district. Many outcrops of conglomerate have as their most prominent and in some places their most abundant constituent, pebbles of jasper, some of which are a foot in diameter. In other Pre-Cambrian areas, jasper has been found closely associated with volcanics similar in lithology and history to the rocks of the Amisk group. No jasper beds have been found in this district but the abundance of jasper pebbles in the conglomerate shows that some such formation once existed. Probably here as in other Pre-Cambrian areas the volcanic period ended with the deposition of jaspery sediments which have now been entirely eroded, the only evidence of their existence being the pebbles of the Missi conglomerate.

HORNBLENDE SCHIST.

At various points along the northern border of the conglomerate-arkose area that lies north of Amisk lake and at one point on the lake there are belts of hornblende-bearing schistose rocks that seem to belong to the sedimentary series. The area on Amisk lake forms a triangle on the eastern side of the creek which drains Grassy lake to Amisk lake. Smaller bands are found at various points in the granite gneiss.

Lithological Character.

The hornblende rock east of the creek draining Grassy lake is very striking in appearance. The matrix of the rock is distinctly schistose, whereas hornblende needles, which form a fairly large part of the rock mass, lie in all directions. Many of these needles cut directly across the foliation, the lines of which bend around the hornblende crystal. The hornblende is a clear green variety in well formed, elongated, and flattened forms which lie in a groundmass consisting mostly of quartz. The schistosity is marked by a brown pleochroic mineral arranged with its elongation parallel to the foliation of the rock.

Relations.

The hornblende schist is always found in direct contact with granitic rocks. Small elongated bodies are common in the gneissic granite north of Amisk lake and these grade into the granite gneiss by diminution of the basic minerals. Apparently these patches are remnants of a formation into which the granite was intruded and their preservation is due to the solidification of the intrusive before the remnants could be completely digested. The original rock has been so completely recrystallized that no definite determination of its origin can be made, but, since along the borders of the conglomerate areas deformation, accompanied by granitic intrusions, has produced a rock in which the matrix is very similar to the hornblende schist, it seems at least possible that the lenses of schist represent remnants of the sedimentary series engulfed in the granite batholiths. Elevated temperature, the action of vapours from the invading batholith, and the movements attendant on its intrusion have combined to form a recrystallized foliated rock in which evidences of sedimentary origin have been obliterated. No doubt much igneous material is included in these lenses, the result being a hornblendic rock whose character is more nearly like that of an igneous than of a sedimentary formation.

Ordinarily the recrystallization has been so complete that the microscope shows no definite evidence of sedimentary origin, but a conglomerate found on a small lake 2½ miles west of Cliff lake shows a stage in the change to hornblende schist. The matrix of this rock contains biotite and some well formed crystals of blue-green to yellow-green hornblende very similar in appearance to the hornblende found in typical hornblende schist.

GRANITE GNEISS

Distribution.

Northward, the belt of volcanic and sedimentary rocks is cut off by a great intrusion of somewhat gneissoid granite. Gneiss, with inclusions of hornblende schist, is found both north and south of Annabel lake north of Amisk lake, and typically developed along the north shore of Wabishkok lake. Other masses are found near Mari lake and there are many smaller areas in the vicinity of Kisseynew lake.

Lithological Character.

The granite gneiss is a pink weathering rock with more or less pronounced gneissic structure. On fresh fractures where the banding is not very distinct the colour is grey, but in well banded specimens the colour is pink and black. The feldspars in the lighter-coloured bands are pink and are large enough to show good cleavage faces. The black bands are not regular but interfinger with the lighter-coloured bands. Under the microscope a specimen, from a small lake north of Wabishkok lake, is found to consist of the following minerals, in order of importance, orthoclase, quartz, plagioclase, biotite, amphibole, microcline, and some other minor accessories. An analysis of this rock is given in analysis No. 1 following. Analysis No. 2 is a sample of granite described on page 40.

	No. 1	No. 2
SiO_2	67·72	66·76
Al_2O_3	14·69	15·39
Fe_2O_3	2·07	1·27
FeO	3·72	1·49
MgO	1·00	1·50
CaO	4·94	2·56
Na_2O	3·39	4·47
K_2O	1·28	3·35
$H_2O \pm$	0·25	0·60
TiO_2	0·30	0·15
CO_2		Undet.
	99·36	97·54

Recast to conform with the mineral composition, the analyses give the following proportions:

——	No. 1.	No. 2.
Quartz	30·12	19·20
Orthoclase	5·60	19·50
Plagioclase	41·03	......
Plagioclase albite	...	37·82
Hornblende	16·01	7·16
Magnetite	2·05	1·60
Ilmenite	0·80	0·35
Biotite	2·82	....
Kaolin	1·10	4·28
Anorthosite	..	7·66
	99·53	97·57

Analyst, M. F. Connor, Dept. of Mines, Can.

The chemical composition of No. 1 is somewhat peculiar for a rock having such a mineral assemblage. The alkalis are low; potash especially so. As a result, in calculating the norm, the amount of orthoclase seems to be much smaller than the microscopic examination of the specimen would seem to indicate. It is possible that the untwinned feldspars that look like orthoclase are largely soda-bearing varieties. The fairly basic nature of the feldspars is indicated by the high percentage of lime. With the large amount of plagioclase feldspar shown in the norm this rock should probably be classed as a granodiorite gneiss rather than a granite gneiss. The calculated norm in No. 2 does not, of course, conform to the mineral content of the rock as determined by microscopic examination but it serves to show the relative proportions of the essential minerals.

Relations.

The granite gneiss has been found intrusive into rocks of the upper Missi series and into the Amisk group. Where the gneiss intrudes the volcanics the contact is a zone of shattered and metamorphosed rocks. The intrusion does not seem to have been violent but the fragments were detached by the highly heated magma working in along fractures, joint planes, and foliation of the older rocks.

Where the sedimentary rocks are intruded the action has been somewhat similar and locally the banding in very basic gneiss may be the result of assimilation of greywacke and the solidification of the hybrid rock before sufficient time had elapsed to produce a nomogeneous mixture of the various components. The relations of these rocks have been mentioned before and the reasons given for believing that the lenses and schlieren of hornblende schist found in the granite gneiss are remnants of included bodies of sedimentary rocks.

KAMINIS GRANITE.

Distribution.

Areas of massive granite form the divides between the main waterways. In the western half of the map-sheet a huge, U-shaped mass emerges from beneath the dolomite escarpment between Amisk and Athapapuskow lakes. The western limb of this mass crosses Sucker creek and then divides that stream with its string of lakes from Amisk lake. A northward extension of this mass swings northwestward between Amisk and Annabel lakes. The eastern limb lies between Sch'st lake and the Sucker Creek waters and extends as far north as Phantom lake. A small isolated mass, 3 miles long by 1½ miles wide, lies with its south edge on Athapapuskow east of the narrows between the main lake and the north arm. The Mistik chain of lakes, from Nisto lake northward, lies almost wholly in a great upland of granite which sends two tongues southward, one reaching the east side of the north arm of Athapapuskow lake, and the other crossing Mistik creek at the rapids between Neso and Payuk lakes. Another great area lying between Twin and Athapapuskow lakes touches Cranberry lakes and broadens northward. Thus, with the exception of about 12 square miles at Brunne lake, most of the district between the Mistik lakes and Elbow lake is underlain by granite.

Lithological Character.

Naturally, in a mass of granite of such extent, there are many lithological variations Some of the types may be due to intrusions of granite of entirely different ages but the probability is that they are merely differentiations of the one magma. Locally a change of composition has been produced as the batholith invaded and absorbed more basic formations. Along many of the contacts there are broad zones of this kind but there are also other areas of basic granitic rocks that are at some distance from the present contact of the granite and older rocks and which must be explained either as separate intrusions, as differentiates, or as absorbed roof pendants from the batholith cover.

A specimen of granite unaffected by contact action was taken from the shore of the long bay of Athapapuskow lake into which the Mistik lakes empty. It is a very fresh, bright pink, granitic rock shown by microscopic examination to consist of feldspar, quartz, hornblende, biotite, magnetite, kaolin, sericite, apatite, and zircon. The feldspar is about equally divided between orthoclase and an acid plagioclase near oligoclase in characteristics.[1]

[1]Analysis No. 2, p. 39.

From the fifth lake on Separation creek the rock for the first half mile from the shore is a fresh, pink granite consisting almost entirely of deep pink feldspar and quartz. Farther southwest the type of rock changes to a more basic granite in which the feldspar is white. Quartz is still present, but there is a great increase in the basic minerals which are chiefly hornblende. This rock seems to be as fresh and unaltered as the red granite first encountered. Pink feldspars have also been observed in the hornblendic granites.

The grey hornblendic variety is as fresh as the red variety but contains a larger amount of basic minerals and plagioclase, of about the composition of andesine, is the most abundant mineral present. The predominance of plagioclase over orthoclase makes the rock classifiable as a granodiorite rather than a true granite.

The change of character in the granite does not seem to be explainable on the ground of assimilation of basic material. Both types seem to be fairly homogeneous, but the hornblendic type is cut by stringers and dykes of fine-grained, red granite which no doubt represents offshoots of the mass along Separation creek. Nevertheless, it does not necessarily follow that the two types are of greatly different ages. The red, practically binary granite seems rather to be an acid differentiate intruded into the more normal granite as the final stage of the batholithic invasion.

For a considerable part of its course the stream draining the Mistik chain of lakes flows over granite which is well exposed at many places. It is commonly a fresh, acidic granite of very pleasing light pink colour. Near the point where the east branch of the creek enters, there are prominent north-south trending ridges of granite with well marked jointing which breaks the mass into cubical blocks many of which are 3 feet to the edge.

Relations.

Eastward from the east branch of Mistik creek and westward from Nesosap lake this particular belt of granites is separated from typical greenstones by an unusually broad contact zone of nondescript rocks that are no doubt the result of the action of the granite on the intruded rocks. Westward from the west end of Nesosap lake (twelfth Mistik) the rocks are heterogeneous but gradually grow more and more basic in character as far as a deep, marshy, north-south valley, $1\frac{3}{4}$ miles west of the lake. West of that valley the rock is a dense greenstone and between the valley and Nesosap lake there is a succession of ridges of dioritic, iron-stained rocks, fairly fresh or somewhat gneissoid granites, and very basic red-weathering rocks that could hardly be classed either as true granites or as diorites. Along this contact the assimilation of one rock by the other seems to have gone unusually far. In most regions the contact zone between a granite batholith and the rock which it has invaded is marked by bands and masses of the older rocks floated away from their original places and included in granite. The granite is so little affected by the material included that a few feet from any such mass it is almost normal in composition. Though such a "shatter-zone" may have, as it does in many Pre-Cambrian contacts, a considerable width on the ground, the nature of the zone is never doubtful, and it is only locally that a truly hybrid rock is produced by the engulfing of foreign material. In the district west of the Mistik lakes, however, assimilation has apparently gone so far that the stoped material is not now recognizable as such. It has been almost thoroughly incorporated in a new rock type which differs from both the intruding and intruded rock in texture and in mineralogy. The formation is still heterogeneous but the boundaries of the various types are no longer definite and one grades into the other without any marked change at any point. To produce such a rock there must have been a very gentle intrusion of the granite and a rather slow diffusion of granitic vapours outward into the invaded rocks.

A specimen was taken from a narrow ridge of a basic, red-weathering granite three-quarters of a mile west of Nesosap lake. On the fresh surface this is a grey pepper and salt rock with some cleavage faces of slightly pink feldspar. Under the microscope it is found to consist of amphibole, quartz, orthoclase, biotite, sericite, and a very little plagioclase. Amphibole is the most abundant mineral and forms confused aggregates and radiating or sheaf-like groups.

The contact zone rock is so entirely different from either the granite on the one side or the true greenstone on the other that in many localities it has the appearance of a separate rock type. One area lying south of Tartan lake has been mapped separately since in it little true granite has been observed. The rock is very dark grey in colour and granitic in texture with small shining cleavage faces of hornblende on the fresh fracture. Under the microscope, it is very similar in appearance to the rock described from the contact zone west of Nesosap lake. In the Tartan Lake batholith, however, there are only small dykes of true granite to give a clue as to the possible origin of such a zone of rocks. All the intrusive rocks are of this dark grey to black variety that in the field would be at once classified as diorites or diabases. Only after having observed in many other places the gradation from fresh, red, almost binary granites through dioritic rocks to greenstones was the probable genesis of the Tartan Lake intrusive suspected. The microscopic similarity seems to make the relation almost certain. In this area erosion has not yet gone deep enough to remove the whole contact zone and thus expose the granite core of the intruding mass; and the present surface cuts across the igneous rock so close to the roof of the batholith that only contact rocks are exposed.

The granite is intrusive into the sedimentary rocks as well as into the volcanic series. On Wolverine lake granite and conglomerate are found in contact and a narrow tongue of granite cuts through the upper Missian syncline of conglomerate and arkose north of Amisk lake. Small bosses of granite are found in the lower Missian slates and quartzites west of Amisk lake. At Wolverine lake where the contact is well exposed for observation, the conglomerate is squeezed and contorted and the matrix altered to sericite. The igneous rock near the contact has a porphyriti appearance. Some of the sediment has been absorbed along the edge, but since in this particular locality the matrix of the conglomerate is arkosic and does not differ very greatly from the igneous rock in composition the character of the granite is not much affected. In one or two places a pebble from the conglomerate is preserved in the igneous rock, which has evidently dissolved all the matrix.

ORDOVICIAN.

The massive Kaminis granite is the youngest Pre-Cambrian formation so far observed and is later than all the periods of pre Palaeozoic folding. The formation following it is separated from all the basement complex by a great time interval and the rocks belonging to it are of an entirely different character. In the Pre-Cambrian period carbonate rocks are represented in this area only by the occasional impure, calcareous beds in the lower Missi formation. In contrast to this practically all the rocks of the Ordovician are dolomite.

Distribution.

Dolomite of Ordovician age is found over the whole southern part of the Amisk-Athapapuskow map-area. The major lakes of the district lie along the escarpment of the Palæozoic and are partly in dolomite and partly in rocks of much greater age. At the western edge of the sheet, Sturgeon-weir river above Amisk lake is the northern limit of the dolomite. On the south side just below the first rapids above Amisk lake, cliffs of this rock rise 40 to 50 feet above the river. North of the river the rocks are Pre-Cambrian. From the mouth of the river the contact crosses almost due easterly to the mouth of Sucker creek on the east side of the lake. The approximate line of contact is indicated by the abundance of small islands north of the contact and the lack of islands in the southern part of the lake. North of Sucker creek an outlier of dolomite about one square mile in area is separated from the main mass by the valley of the creek. South of the creek the edge of the Ordovician bends northeastward as far as the point where the contact crosses the 2nd meridian and then it bends eastward to Athapapuskow lake. At the eastern end of Athapapuskow the fairly regular east-west direction of the escarpment is broken by a pronounced southward extending embayment reaching down to the north end of Goose lake. From the east side of Goose lake it runs northward to the first Cranberry lake and then holds an almost due easterly course to the eastern margin of the sheet.

The nature of the lower beds of the Ordovician formation and the way in which these beds are removed by erosion are not favourable to the development of many or large outliers. Besides the small one north of the lower part of Sucker creek, there is a fairly large outlier extending from Kaministikquobskok lake northward nearly to the west arm of Schist lake. It is not more than a mile in width. Other smaller outliers are found between this one and Sucker creek and a prominent though small mass of dolomite is found on the north shore of Athapapuskow lake west of Tin Can narrows. The mass lying north of the First Cranberry narrows can hardly be considered as an outlier although it is separated from the main mass by a narrow fringe of schist along the shore of the waterway connecting the First and Second Cranberry lakes.

Lithological Character.

The rocks of the Ordovician period in this district are nearly all dolomites. They are thick to thin-bedded with only locally some development of sandstone or arenaceous beds at the base. Most of the dolomite is a fine-grained, buff-coloured, semicrystalline rock weathering to a darker buff. Locally, however, there are layers which though still fairly pure have enough oxidized iron in them to give them a brick red colour. Between this extremely deep coloured type and the buff-coloured rock there are many variations but the colour in the intermediate varieties is not evenly distributed. The red colour occurs in patches that fade out into a buff-coloured groundmass and give the rock a blotchy appearance. Thin sections of buff dolomite show small interlocking grains of calcite with a few larger ones due to recrystallization. Blotchy dolomite is not noticeably different from the buff under the microscope, but the deep red variety shows small particles of hematite included in the calcite crystals and filling in between the crystals.

The following table shows the chemical composition of the three types of dolomite:

	I	II	III
$CaCO_3$	52·85	53·21	51·96
$MgCO_3$	44·14	43·14	40·04
Fe_2O_3	1·07	0·80	3·11
Al_2O_3	0·03	0·26	0·39
Insol.	1·80	1·36	3·80
	99·89	98·77	99·30

Analyst, H. A. Leverin, Department of Mines, Canada.
I. Thin-bedded, buff dolomite, south shore of Table lake.
II. Blotchy, variegated dolomite. Amisk lake, east side.
III. Red dolomite, southwest bay of Athapapuskow lake.

In these analyses the iron present is calculated as Fe_2O_3 although this probably is not the form in which it is present. It is noticeable that the amount of iron in the buff-coloured sample is higher than that in the variegated rock. This could hardly be true if all the iron were in the same state of oxidation. It is probable that in the buff-coloured rock most of the iron is in the ferrous state and gives no colour and that in the other rock, although less in amount than in the buff, it is in the oxidized form and acts as a pigment. If this is true it is probable that these rocks have a certain proportion of iron carbonate along with the magnesium lime carbonate that forms their largest constituent.

The thinner beds of the formation show a structure which although present in the thicker beds is less noticeable. There is an irregular thickening of the beds, the centres of the thicker parts being from 1 foot to 2 feet apart. Looked at from the edge there is an alternate pinching and swelling of the bed, the swells of each bed fitting into the pinches of the beds below and above it. On the surface of the beds the swells show as very low. The difference in elevation from the centre to the periphery of such a structure is always less than half an inch. Rocks with this structure have been called by earlier writers "nodular" limestone.

On the surfaces of the more massive beds there are markings that seem undoubtedly to be mud cracks. The depressions are sometimes half an inch across and the same depth. They narrow towards the bottom and the rock below is perfectly solid, showing no trace of either an old or recent crack. The depressions are linear and join to form figures that are commonly pentagons 6 to 8 inches in diameter. The evidence shows that they are not due to cracks after the solidification of the rocks but are practically contemporaneous with the formation of the rocks. Their appearance is exactly that of mud-cracks of the present day and there seems little doubt that they were formed in the same manner.

Thickness.

The very flat character of the Ordovician relieved only by very gentle folds, makes the measurement of a complete section in a district of such low relief an impossibility. At Cormorant lake in the southeast corner of the sheet McInnes[1] records a detailed section of 112 feet of thin to thick-bedded, buff to reddish dolomite with sandstone at the base. This is a greater thickness than is exposed in any of the sections observed along the northern border. At Table lake the following section was measured.

	Feet	Inches
Massive, buff-coloured dolomite beds 1 to 2 feet thick	5	0
Bed of buff dolomite.	5	0
Bed of buff dolomite.	5	0
Massive beds 2 feet thick, buff dolomite	6	0
Massive beds 2 to 2½ feet thick, buff dolomite	8	6
Bed of dark buff dolomite	0	8
Thin beds of dolomite 2 to 3 inches thick	11	0
Talus	45	0
	86	2

Dowling gives a thickness of 270 feet for the Cambro-Silurian (Ordovician) of the Winnipeg basin but states that the beds thin out northward and that the lower beds disappear.[2] As shown when dealing with the topographic development, higher and higher beds are encountered as the distance from the edge of the escarpment increases. Hence the thickness south from any point at the edge of the Ordovician would increase both by the presence of lower beds deposited earlier in the advancing Ordovician sea and by the preservation of younger beds as the present surface bevels higher and higher horizons.

Relations.

The Ordovician rests with a great unconformity upon the clean swept mammillated floor of the Pre-Cambrian. The relation is unmistakable although the two formations have not yet been found actually in contact. The lower beds are less resistant than those higher up, due to their thinner bedding or to less coherent arenaceous basal members. As a result, erosion works into the base of the series sapping the support of the upper beds, large parts of which are then easily split off by frost action or by their own unsupported weight (Plate II). A vertical cliff is thus

[1] Geol. Surv., Can., Mem. 30, p. 59.
[2] Geol. Surv., Can., Sum. Rept., vol. XIII, pt. FF, p. 11.

perpetuated, but along its base a pile of huge blocks obscures the contact of the dolomite with the basement complex (Plate VI A).

The Ordovician is the youngest consolidated formati-n in the district. Since its deposition there have been very slight movements and none of these were accompanied by any intrusion of igneous rock, or at any rate by any intrusion that reached to the horizon of the present surface. Later rocks overlap the Ordovician to the south and probably at one time covered the whole of this area but if present they have since been completely removed. The only materials of later age are the unconsolidated glacial tills, clay, gravel, and sand, the recent alluvium of some of the rivers, and the extensive peat deposits in the muskeg areas.

Conditions of Deposition.

The conditions under which the dolomite was deposited were somewhat unusual. At the beginni g of Ordovician deposition the sea floor was fairly free of coarse clastic material. Local beds of red sandstone or red limestone probably represented the incorporation of some of the debris of the Pre-Cambrian surface in the Palæozoic beds. This gives an indication of the conditions obtaining at the beginning of the period.[1]

Most writers agree that the necessary conditions for production of red sediments are moisture, warmth, aeration to insure complete oxidation of the ferruginous material, and a sufficient length of time. Most of these conditions seem to have been fulfilled in the period just preceding the advance of the middle Ordovician sea. The long period of erosion allowed for the complete decomposition and oxidation of the surface rock and the remnants of the old soil retained in protected positions and included in the basal beds of limestone have locally imparted to them a red colour. The dolomite was evidently formed in salt water since it contains, although somewhat sparingly, a typical marine fauna. There is evidence, however, that it was deposited in shall. water. The mud-cracked surfaces referred to above, seem to be indisp. ble evidence that not merely at one period but at many periods, surfa. s of the dolomite were exposed as great mud flats. Under these conditio: , probably with shallow lagoons, occasionally separated from the open sea and evaporating under abnormal conditions, it is possible that dolomite could be precipitated directly. If the organisms present formed a deposit low in magnesia the action of the concentrated waters in the lagoons might replace part of the lime by magnesia and so form these great thicknesses of dolomitic rock. Nevertheless, the formation of thick beds of dolomite so close to the shore-line of that period, without any alternation of clastics, is certainly a peculiar phenomenon and demands unusual conditions on the continental shelf of the mid-Ordovician land mass.

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[1]Jour. of Geol., vol. XVI, p. 293.
Dept. of Agriculture, New South Wales, Sc. Bull. No. 1, Aug., 1912.

Age.

The fossil evidence as to the age of the dolomite is rather meagre. In many localities life seems not to have been very abundant and the semicrystalline and dolomitic nature of the rocks has not been very suitable for the preservation of even this scanty fauna. The most commonly observed forms are large curved or coiled cephalopods, the body chambers of some of these having diameters of as much as 6 inches. Corals are abundant in some localities and probably formed reef masses. Brachiopods are not common. They are all small forms and so poorly preserved as to be usually unidentifiable. Fucoid stems are frequently the only evidences of life to be found.

The following forms are listed as occurring at Cormorant lake near the southeast corner of the sheet:[1]

Pasceolus (Cyclocrinus) spaskii? Eichwald.
?Zaphrentis affinis Billings. Teste Lambe.
Nyctopora billingsii Nicholson. Teste Lambe.
?Labechia ohioensis Nicholson. Teste Lambe (a fragment).
Rhynchotrema sp.
Strophomena deltoidea (?).
Strophomena trentonensis (?).
Pleurotomaria (?).
Ophileta (?).

A small collection was made from Namew and Amisk lakes in 1915, upon which the following report was made by E. M. Kindle.

"The collection represents a locality on Namew lake and two localities on Amisk lake. The fossils indicate the same general horizon for these three localities and represent the following species:

Receptaculites cf oweni.
Halysites gracilis.
Maclurina manitobensis.

This is a fauna of middle Ordovician age representing probably a Trenton horizon. The dolomite from which this fauna comes is doubtless equivalent to some part of the Lake Winnipeg limestone series which Dowling[2] described and divided into three formations under the names Upper Mottled limestone, Cat Head limestone, and Lower Mottled limestone."

PLEISTOCENE.[3]

The Pleistocene deposits of the area are of two classes: (1) deposits of glacial origin consisting of boulders, till or boulder clay, and outwash sands; (2) lacustrine clays. The lacustrine deposits are restricted

[1]Geol. Surv., Can., Mem. 30, p. 61.
[2]Geol. Surv., Can., Ann. Rept., vol. XI, pt. F, 1898.
[3]The writer is indebted to W. A. Johnston for a criticism of this section of the report.

almost entirely to the southern part of the district and cover the greater part of the area about Goose lake, Simonhouse lake, and the country south of Island lake. The area lying northwest of these lakes has very little drift covering and the deposits which occur there are chiefly of glacial origin. Boulders are scattered abundantly over the whole surface but there is no continuous cover of glacial deposits. The solid rocks are well exposed and still retain on their surfaces the fluting and polishing produced by the scouring of the overriding ice. The efficiency of ice action to erode unweathered rocks is discussed in the chapter on "Physiography." It is probable that in this area the solid unweathered rock was only slightly eroded but that the products of weathering were almost completely removed. In the northern area ice erosion was dominant and little deposition took place. In the southern area glacial till, the unstratified deposit of the ice-sheet, occurs chiefly in the form of ground moraine. No well-marked terminal moraines occur. The till is small in amount and is irregularly distributed. It commonly forms small ridges which tail out from rock knobs on the side opposite to the direction from which the ice advanced. These deposits are seldom more than 100 feet in length, the northward end level with the top of the knob of rock, to the presence of which it owes its deposition, and the southward end tapering out. A low ridge of this character is crossed by the road from Namew lake to Amisk lake 4 miles north of Namew lake. As a rule these deposits are quite unassorted but there are gradations to somewhat sorted material which pass into sand-plains.

The outwash sands forming sand-plains are usually of small extent and have no great thickness. They commonly occur on the south side of rock ridges. It is possible that the rock ridges were in a manner associated with the formation of the sand-plains for the rock ridges probably formed obstructions against which the front of the glacier rested for a time. On the southern side of the ridge the water from the melting ice deposited an outwash plain, the material of which would be to some degree assorted. One of these sand-plains is crossed by the portage from Athapapuskow lake to Cranberry lakes, and there are many others of small size in the district north of Athapapuskow lake between the Pineroot river and Elbow lake.

The lacustrine clays cover the surface of a large part of the southern portion of the area and their presence renders the physical character of the southern part quite unlike that of the northern part. Instead of the bare ridges and narrow swampy valleys of the northern area are found the level or slightly undulating surfaces, few rock exposures, and extensive muskegs of the clay-covered country. Along its northern edge the clay is not very thick and ridges of rock are frequently found projecting through it. Scarped sections of any considerable thickness of the clay do not occur. The clay is a fine, greyish, friable variety, stratified but not prominently so, and containing very few pebbles. Apparently the clays are, as has been pointed out by Tyrrell,[1] Dowling,[2] and McInnes,[3] lacustrine deposits of glacial lake Agassiz. They were formed in a much restricted lake after the water had fallen much below the high level of the old southerly outlet. During the time of deposition of the clays the ice front probably stood just north of Cranberry lakes. The absence of lacustrine deposits in the northern part of the area and the occurrence of outwash sands seem to show that the lake was largely drained at a time when the ice began to retreat from the northern part of the area.

RECENT.

Recent deposits are represented chiefly by peat and in a few places by very local deposits of alluvium along river valleys and by beach deposits along lake shores. At the mouths of some streams deltas are forming, but these are small because practically all the rivers and streams of this area have clear water. In most cases the delta deposits are largely composed of vegetable material and the woody particles obtained from the cutting of peat banks by the streams in flood time. Along lake shores the waves have cut cliffs in the drift and alongshore currents have transported the material removed to form sandspits, usually close to the source of the supply.

Peat is the most important of the recent deposits. It covers to a considerable depth the greater part of the area underlain by the lake clays and is found in the valleys between the rocky ridges of that part of the country which has little drift covering. In poorly drained areas organic matter is preserved from complete decomposition and accumulates year after year as the various swamp plants, mainly sphagnum moss, grow upward and the lower parts die and are added to the mass. These flat bogs are commonly called muskegs[4]. In a practical way muskegs may be classified (1) as those in which the peat rests directly upon the clay subsoil or upon rock and so have a soft but still fairly firm surface and (2) those in which the peat is separated from the solid underlying formation by a greater or less depth of very thin ooze. These latter form the "floating" bogs that make travel across much of the clay-covered district so difficult during the summer months. In muskegs of the latter type the matted roots of the sphagnum moss and other water-loving plants form a surface sufficiently tough to sustain a man's

[1]Geol. Surv., Can., Ann. Rept., N.S., vol. XIII, pt. F.
[2]Geol. Surv., Can., Ann. Rept., N.S., vol. XIII, pt. FF.
[3]Geol. Surv., Can., Mem. 30, p. 126.
[4]From a Chippewa word meaning a grassy bog.

weight, but sometimes flexible enough to move up and down in wave-like undulations under each step and so are given the name of quakingbogs. A slight weight presses down the surface below water-level. The drainage of such area is seldom by means of regular streams but rather by a sort of mass flow of the water without any well-marked channel. Some of these floating bogs seem to be the result of the out-growing of shore bogs in shallow muddy lakes until the open water is completely covered. This probably could only occur after a lake had practically been filled up by vegetable ooze.

On the southeast shore of Simonhouse lake the following section of unconsolidated material, which is probably post glacial, was found resting upon thin-bedded limestone.

[illegible]ry fine sand	[illegible]eet
[illegible] decayed [illegible] layer	2½
[illegible]	½
[illegible]	2½
[illegible]gular pebbles, all smaller than 2 inches in diameter	10

[illegible]obably the lower 10 feet of this particular deposit are beach [illegible] that have been very little disturbed. Over these, fine beach sand [illegible]sited by wind action. A period intervened during which vegetation covered the surface, after which sand was again deposited.

STRUCTURE.

The broad elements of structure of the area may be considered as connected with the larger geological divisions. The Ordovician rocks are fairly simple in structure. From the escarpment marking the edge of the Ordovician element the beds of dolomite dip very gently southward with higher and higher beds forming the surface until the Ordovician is overlapped by the Silurian. Possibly also the base involves lower and lower beds as the distance southward increases, but this is not yet proved. In some localities there are gentle folds locally reversing the general gentle southerly dip, but these do not affect the broad structures. It is probable that these beds are the southern limb of a great anticline whose axis strikes northwest-southeast, and the other limb of which is represented by the similar northeasterly dipping beds of the Palæozoic basin of Hudson bay.

The lithological elements entering the structural complex of the Pre-Cambrian are: (1) Amisk volcanic formation, in itself a complex; (2) Kisseynew gneisses; (3) Missi sedimentary series; (4) intrusive granites and granite gneisses. The volcanics are of such a heterogeneous nature that the solution of their structure has not been attempted. They are, however, involved in the later movements that affected the sedimentary Missi series. The main areas of the Missi rocks are northwesterly pitching synclines along the northwestern edge of the area. A section east and west, north of Amisk lake after crossing the two main troughs of upper Missian rocks, would show a broad band of Amisk greenstones interrupted by areas of intrusive granites. Apparently the troughs of sediments along the western and northwestern margins are the remnants of minor folds on the western limb of a great anticline, of which the eastern limb may be represented by the conglomerate and quartzite formations at Wekusko lake which lies beyond the eastern margin of this sheet[1]. The evidence upon which this assumption rests is the absence of areas of sedimentary rocks in the district between Schist and Wekusko lakes, excepting those which like the Athapapuskow Lake band are explainable as infaulted remnants. Intruded irregularly but exposed where erosion has brought the surface down to them, are the batholiths of granite and granite gneiss which no doubt underlie the whole of this remnant of volcanic and clastic rocks. To the northward the older rocks fray out and are completely cut off by the invading rocks. Very probably the tongues of granite forming the divides between the lake and river systems have been intruded along the axes of the minor folds in the great anticlinal structure postulated. Erosion has since removed the folded rocks which they intruded leaving only the granite areas marking the summits of the anticlines. However, the irregularity of an igneous intrusion, especially in such heterogeneous rocks, makes it impossible to outline any broad structure solely on the basis of the position of granite tongues. The Kisseynew gneiss with its associated granite sills is a cross fold with its axis striking northeast and pitching in that direction.

GEOLOGICAL HISTORY.

The earliest part of the decipherable history of the Amisk-Athapapuskow district reveals a period of intense volcanic activity. The rocks are largely flows of a type believed to be most commonly formed subaqueously. Along with these there are tuffaceous, pyroclastic, and autoclastic rocks formed by the explosive action of the volcano or volcanoes and by the movement of the lava poured out. Possibly there were also, towards the end of the period, some true clastic sediments which are now so highly metamorphosed as to be unrecognizable. Certain rock types are represented only by pebbles in later conglomerates, among which are true quartzites and jasper rocks. The quartzites represent normal erosive action at some time during the early period. The jaspers probably are chemical deposits from water highly charged with silica and iron by the subaqueous volcanic extrusions. Probably accompanying some of the volcanic activity and related to some of the more acidic flows there were intrusions of dykes of quartz porphyry. The first period is dominantly one of volcanic activity

[1]Geol. Surv., Can., Sum. Rept., 1916.

during which there were flows of lava, probably subaqueous, intrusions of fairly acidic rocks, deposition of tuffs, of chemical precipitates, and of true clastic sediments. The surface upon which these diverse types of rocks were laid down is not exposed or if exposed has not been recognized. It may have been entirely absorbed in the later granitic intrusions.

This early, chiefly volcanic period was followed by a period of erosion sufficiently long to uncover the dykes of quartz porphyry and to remove any flows of a corresponding nature which may have been fed by them. The lower Missi series has the character of flood-plain or shallow water deposits with an occasional bed that represents quiet water conditions. The land of that time was yielding fine-textured, thoroughly assorted material and hence was of low relief. Another period of erosion, probably not of great length, is indicated by the presence of pebbles of quartzite and of conglomerate in the upper Missi series. These rocks are of quite different character from the lower Missi slates and quartzites and show by their lack of assortment, irregular bedding, and sudden variations in material the very different conditions under which they were laid down. In at least part of this period the conditions were those of great mechanical erosion without much decomposition. Evidently the material came from high and possibly arid land. The clastic material obtained from it was spread out in outwash plains by rapid, possibly torrential streams.

After the deposition of the arkose of upper Missi times all these formations underwent a great period of mountain-making in which the conglomerates, buried so deeply as to be in the zone of flow for even the most resistant minerals, were compressed into great northwesterly trending folds. Probably this did not take place in one great revolution but in two or even more which accompanied the intrusion of the great granite gneiss and massive granite batholiths. The intensity of these movements is shown by the drag folding of even quartz and granite pebbles in the conglomerate.

No very marked disturbance of any kind seems to have occurred since the intrusion of the granite. During the rest of the Pre-Cambrian and up to the time of the invasion of the Trenton sea, the area was undergoing probably continuous erosion which finally reduced the mountains formed by the post-Missian revolutions to a plain of low relief and hummocky character much like that at present found over the Pre-Cambrian rocks. The advance of the sea upon this plain removed from it most of the soil which must have covered it and in the quiet but shallow waters of the continental sea calcareous and magnesian sediments were deposited. According to palæogeographers there were various retreats and advances of the sea over this area during Palæozoic times. Records of these, however, were not observed in the rocks and the enumeration of these supposed oscillations will be omitted here. It is sufficient to say that following possibly the Cretaceous deposition a slight folding formed the gentle anticline of which the Palæozoic rocks of this district form the southwestern limb. Erosion working from the axis of that anticline stripped back the dolomite beds exposing once more the pre-Palæozoic floor upon which they were laid down. When the Palæozoic and Pre-Cambrian contact had reached nearly its present position the Glacial period intervened and from part of the area the ice removed nearly all the accumulated debris, leaving only local deposits of morainal material in sheltered localities. The close of the Glacial period was marked by the presence of a late stage of glacial lake Agassiz in whose waters fine-grained silts were deposited over the southern portion.

Since the retreat of the ice and the consequent draining of lake Agassiz some removal of glacial material has been effected by the new drainage systems, but this has not proceeded very far. In the hollows, peat has been formed, making the surface of the country still flatter and seriously retarding the drainage.

CHAPTER V.

ECONOMIC GEOLOGY.

HISTORY OF PROSPECTING.

Although from the earliest inland ventures of the Hudson's Bay Company this country has been one of the main travel routes, only in comparatively recent times have any indications of possible mineral wealth been discovered. The early explorers were concerned almost entirely with the fur trade and its possibilities and the other resources of the whole northwestern country were deliberately kept hidden by the fur trading corporations. In later times when prospectors had begun to work their way into the great Pre-Cambrian area around the bay, the rather discouraging history of gold mining in the Rainy River district did not stimulate the investigation of areas farther removed from lines of transportation. The development of Sudbury and Cobalt did not encourage prospecting in this country since the nickel and silver of the Ontario deposits are associated with intrusive rocks which do not occur in northern Manitoba. It was only after the gold quartz veins at Porcupine in northern Ontario had proved their worth and dispelled the generally accepted impression that payable gold deposits did not exist in the Canadian Pre-Cambrian rocks, that really active prospecting began in areas of basic rocks north of Saskatchewan river. It is true that some years ago a certain amount of prospecting was done and some claims were staked but these were never actually developed. A prospector and trapper named Brunne, who for some time made his headquarters northwest of Cranberry lakes, staked some claims the posts of which are found on the high ridge north of the lake bearing his name. There are no prospect pits on these claims nor any evidence that work has ever been done on them. Other claim posts at least ten to fifteen years old are found on the north shore of Cranberry lakes, but what led to the staking of these early locations is not known. The present activity began in 1913. Late in the summer gold was discovered by the Mosher-Creighton party in a quartz vein on the northwest side of Amisk lake and the news of the find led to a promiscuous staking of all the easily reached country about the north end of the lake. The one-line method of staking lends itself to rapid location of ground with very little initial outlay and a large area of the promising formations adjacent to the lake was soon blanketed. In many cases the locators hoped for a "boom", never intending to do any serious prospecting on their claims. Before the time when such claims would again become free ground through failure to comply with the requirements, the period for the completion of the first year's work was extended for one year on account of the war and at the end of that time still another year. Thus many original claims were held three years without the performance of any work whatever. To the blanketing of the country by people who never intended doing work, is added the difficulty of finding what ground actually was located. The location line was seldom well cut out in the first place and along the lake claims were staked by placing posts on prominent points. After a month or so the writing on birch and poplar posts becomes entirely unreadable and a prospector really looking for open country is unable to tell where a staked claim lies with respect to a location line. Naturally under such conditions prospectors went into new districts in preference to doing any thorough prospecting in the district about Amisk lake. A few of the original holders did some development work, but the number of claims upon which any real prospecting has been done is very small in proportion to the number recorded.

During the summer of 1914 a few parties were working farther east and Messrs. Hackett and Woosey staked claims and found several gold showings in veins on the east shore of Wekusko (Herb) lake. This shifted the main interest outside of this area for a time. In 1915, Messrs. Creighton, Mosher, Dion, and their associates, who had meantime discovered and stripped a large but low grade quartz vein near Wolverine lake, were shown some pieces of sulphides by an Indian named Collins, whose hunting territory lay about the north arm of Athapapuskow lake. They recognized the possibilities of mineral such as he showed them and guided by him they found and located the sulphide bodies at Flinflon lake. The news of the discovery was kept quiet until enough trenching had been done to make sure of its extent. It was not until very close to freezeup that the claims were recorded. The usual rush to stake any piece of land in the neighbourhood regardless of its probable value, followed. No more discoveries were made until very late in the season when Messrs. Jackson and Reynolds prospecting on Schist lake noticed a trace of copper carbonates on the rocks near the mouth of Phantom creek and on investigating found the deposit upon which the Mandy claim was staked. In 1916 most of the prospectors working in this section were searching for sulphide bodies, but no others were located that seem to give any promise of producing ore. In 1917 a few small bodies of sulphides were opened up, but nothing at all comparable to the two original deposits has since been discovered.

GOLD-QUARTZ VEINS.

Gold-quartz veins are found in the older formations of Pre-Cambrian age in this district—the Amisk volcanics and both the lower and upper

Missi series. In all these they have much the same irregular lenticular nature and the mineralization is similar in all varieties of country rock.

Fissuring.

The fissuring in the sedimentary rocks is controlled largely by the behaviour of the various beds during folding. In some places shearing almost parallel to the bedding planes has produced the common type of irregular, lenticular openings. The vein at the original discovery on the Prince Albert claims is of this kind. In somewhat more resistant rocks, such as those of the upper Missi series, the folding of beds of various competence has resulted in the dragging of softer or thinner beds between those of a more resistant nature. This has prepared openings for large irregular masses of quartz, apparently filling the crests and troughs in drag folds, which pitch steeply with the formation. In such occurrences the length and width may be almost the same. The outlines are usually extremely irregular and such bodies will no doubt be broken by many faults. In greenstones the fissuring is commonly related to the axes of the regional folding and so parallels the schistosity.

The fissures may be very different in age. Many of them are later than the formation of the upper Missi arkose and conglomerate, but two other periods during which there was some deformation have been recognized, one separating the lower Missian from the Amisk volcanics and another following the lower Missian and preceding the upper Missian arkose and conglomerate deposition. It is very probable that both these foldings produced fissures in the rocks affected. A quartz-filled fissure of one of these earlier deformations might be physically similar to a fissure of later age but be barren or much leaner than later ones. There is also the probability that older veins were refractured and values introduced during later fracturing. This may to some extent explain the erratic distribution of the gold. From a mechanical standpoint, the close foldin· that followed the deposition of the latest sediments of Pre-Cambrian age was intense enough to produce most of the fissuring. This folding was closely associated with the various granitic intrusions and it may be assumed that the ore-bearing fissures belong to approximately the same age as the granites, but, since these may themselves belong to different magmas that may be of widely different ages, the fixing of a definite age for the fissuring is impossible.

Fissure-fillings.

The gangue mineral of the veins is principally quartz. Brecciated wall-rock included in the veins has been altered to secondary min· als around the edges. Some foils of muscovite are present and in some · in-there is a little tourmaline. Calcite also occurs, sericite has developed where the veins have been crushed, and along tiny cracks a yellow or red micaceous material is found which seems to consist of very thin films of iron oxide. Some of these films have very nearly the appearance of thin leaves of native copper. The ore minerals in the veins are native gold, gold-bearing arsenopyrite and gold-bearing pyrite, a little chalcopyrite, and molybdenite. Native gold is found as small flakes along tiny cracks or in apparently solid quartz, but most commonly along definite slip planes which are usually coated with the iron oxide films mentioned. It is also found along dark lines along which there was some slight movement. Where tourmaline is present the gold may be found embedded in the massive mineral or in nests of tiny radiating needles. Arsenopyrite occurring in or near quartz veins is nearly always auriferous. It is found in two forms. In the altered wall-rock or in fragments of wall-rock enclosed in the vein, it occurs as well-formed crystals, up to one-eighth inch in diameter, of the common form assumed by this mineral. Where found in quartz, it is massive and granular, very rarely showing its crystal form. Pyrite is found mostly in the quartz as the massive mineral although, occasionally, cubes of pyrite are found in the wall-rock of the vein. Small amounts of chalcopyrite are present and the quartz is in places stained with copper carbonates. Rarely, molybdenite, galena, and stibnite occur. Tellurides of gold have been found in similar veins east of this area at Wekusko lake and search will no doubt show them to be present here.

The values are carried chiefly as visible gold. Assays from quartz samples in which no flakes are to be seen rarely carry more than traces. The sulphides and arsenosulphides are always auriferous but the values in them are not very high. This patchy disposition of gold values makes the sampling of a vein difficult and the result uncertain. Picked samples may show high assay values whereas other samples from the same channel may show only traces. The only satisfactory test of such a vein is a mill-run on a fairly large quantity. In general, up to the present time average values from veins of fair size, say 4 feet and over, are not encouraging, but the values in small veins, 1 foot to 18 inches in width, are quite commonly high.

Genesis of Ores.

The presence of muscovite and tourmaline in the quartz veins is evidence of a close connexion between the vein-filling and granitic intrusions. It is very likely that the whole belt of basic rocks is underlain at no great depth by intrusive granites and it may be that these are the parent bodies of the veins. The surface distance of any point in the areas of volcanics or Pre-Cambrian sediments from granite outcrops is not great and the distance underground may be even less than on the surface.

The connexion of gold-quartz deposits of Pre-Cambrian age with granitic intrusions has been assumed for many other deposits of this character. In Ontario, the gold-quartz deposits of Porcupine are believed to be the final effects of granite invasions[1] which do not reach the surface. At Swastika and Kirkland lakes, also in northern Ontario, the ore is believed to owe its origin to intrusions of granite, syenite, and feldspar porphyry.[2] In the lake of the Woods district the relation is with granite, quartz porphyry, or andesite porphyry[3]. In the Rice Lake district of Manitoba the origin of the gold-quartz veins is referred to granite intrusive into older rocks[4]. These examples are cited not because the relations have been in all cases thoroughly worked out but because the occurrences are comparable in the types of rock involved, the age relations of the various members, and the structure and mineralogy of the veins themselves.

The character of the quartz and the presence of tourmaline show that the veins are high temperature deposits. They were probably formed at very considerable depths under great pressures and fairly near to the heat supplying body of the parent granites. The gold was no doubt in some sort of chemical combination with potassium, whose presence in the original solutions is indicated by the muscovite noted in the quartz. Other somewhat rare elements were also present in the materials from which the veins were formed. Among these are boron now in the tourmaline, the tellurium of the gold tellurides, and possibly others that have not been recognized. These rare and volatile substances aided in the formation of a solution which could remain fluid at a temperature much below the fusion point of quartz. Hence these narrow and irregular veins could be injected through possibly many hundred feet of overlying rocks and quartz stringers could find their way into the tiniest crevices along the margins of larger bodies.

SULPHIDE DEPOSITS.

The sulphide deposits may be classed as (1) those which consist of pyrite-chalcopyrite-sphalerite-galena mixtures and (2) those that are largely pyrrhotite. The important discoveries are all of the former type. These deposits are almost solid masses of sulphides differing only in the

[1] Burrows, A. G., "Porcupine gold area," Ann. Rept., Ont. Bureau of Mines, vol. XXI, pt. I p. 225.

[2] Burrows A. G., and Hopkins, P. E., "Kirkland lake and Swastika gold areas," Rept. Ont. Bureau of Mines, vol. XXIII, pt. 2, 1914, p. 18.

Bruce, E. L., "Swastika gold area," Ont. Bureau of Mines, vol. XXI, pt. I, 1911, p. 264.

[3] Parsons, A. L., "Gold fields of lake of the Woods, Manitou and Dryden," Rept. Ont. Bureau of Mines, vol. XXI, pt. I, 1912, p. 169.

[4] Moore, E. S., Geol. Surv., Can., Sum. Rept., 1912, p. 269.

amounts and arrangement of the various minerals present. All those yet found are in rocks of the Amisk volcanic series.

Openings.

The openings occupied by sulphide bodies have been produced by forces similar to those which have opened up the channels for the gold quartz solutions. Some occurrences occupy shear zones in massive greenstones or in schists. Others are probably explainable as the drag folding of schistose zones between more competent bands of massive greenstones. In both types the brecciation and shearing of the country rock has given room for solutions to penetrate. The variation in the size of the friction breccia and original differences in the character of the wall-rocks and in the amount of alteration that they had previously undergone, conditioned a different amount and different kind of substitution by the incoming solutions. The sulphide deposits differ from the quartz veins in that they represent a considerable replacement of original rock by sulphides, whereas the gold-quartz veins occupy practically only the original fissures.

Mineralogy of the Sulphide Bodies.

The list of minerals found in sulphide bodies is not very long nor are many of the specimens well crystallized. Practically all are of a fine-grained, massive character.

Gold. Gold occurs in small quantities in all the sulphides but has not been found in visible quantities except in the oxidation products above the ore.

Silver. No native silver was observed. It probably occurs in some chemical combination with the sulphides of the other metals.

Quartz. Quartz occurs sparingly in the more massive sulphides and in large quantities along the edges where they are more disseminated in character. At the surface white, porous, friable masses of quartz are sometimes found, evidently the result of the leaching of a mixture of quartz and sulphides. Underneath the clay at the north end of the Mandy sulphide lens, small quantities were found of a compact, hard, but very light mineral which corresponds to the variety of quartz called floatstone. It has so low a specific gravity that it floats on water.

Iron Oxide. Both yellow and red iron oxides are formed by the oxidation of the surface of the sulphide zones. The red variety is found where there is good drainage and aeration. It probably is not hematite but one of the red hydrated varieties.

Pyrite. Pyrite occurs in two forms. A massive and granular variety interbanded with other sulphides forms a large part of most of the sulphide lenses. In the somewhat altered wall-rocks of lenses crystals up to one-fourth of an inch in diameter are often found. The form is always the unmodified cube.

Pyrrhotite. Some lenses of sulphides are practically entirely pyrrhotite. This sulphide does not occur in quantity with the other sulphides excepting pyrite. Its presence shows a scarcity of sulphur in the depositing solutions and hence somewhat different conditions from those under which the bodies of mixed sulphides were deposited. The pyrrhotite is a massive variety. It carries some nickel, assays up to one-half of one per cent being reported.

Galena. Some massive galena occurs among the other sulphides.

Sphalerite. Sphalerite is found abundantly interbanded with chalcopyrite and pyrite (Plate I). It is a very fine-grained, black variety with submetallic lustre. Some bands of ore in the Mandy lens are 70 per cent zinc sulphide.

Chalcopyrite. Chalcopyrite occurs in massive bands and in small grains scattered through pyrite or sphalerite bands. In picked samples from some of the bands of the Mandy deposit the chalcopyrite forms as much as 84 per cent of the ore.

Malachite. The surface of the ore is very fresh, but in some places a little copper carbonate, of the variety malachite, has been formed by weathering.

Chalcanthite. Copper sulphate has been formed, as small botryoidal crusts of a greenish-blue colour, along openings where water carrying copper leached from chalcopyrite bands has trickled in and deposited part of its load.

Paragenesis of the Ores.

Apparently homogeneous chalcopyrite such as that in the high grade lens of the Mandy is somewhat lighter in colour than typical chalcopyrite and an analysis gives a copper content of only 28·96 per cent. A polished specimen (Plate VII B) shows the cause of the lower percentage of copper to be small inclusions of altered country rock, considerable pyrite, and intergrowths with zinc blende. Particles of country rock included in the ore ... very thoroughly impregnated with pyrite. The edges of some such n... ...s are fractured or granulated and recemented by chalcopyrite. Pyri... is clearly the earliest of the sulphides; fragments of it are embedded in both chalcopyrite and zinc blende and some of it is replaced by the later sulphides. Some of the pyrite particles have a square outline as if the fracturing of the original sulphide had been controlled by cleavage directions or by crystal form.

Sphalerite and chalcopyrite are in intimate intergrowths showing the relations of simultaneous crystallizations. In the bands, which are largely chalcopyrite, the zinc blende is included in small angular particles in the copper mineral and this relationship is reversed in the sphalerite bands. Along the boundary between bands the two minerals interfinger so intricately that there seems to be no avoiding the conclusion that they are contemporaneous in crystallization. Pyrite was the first sulphide filling of the zone of rock brecciation, replacing the material of the rock and filling openings. A later fracturing allowed the introduction of chalcopyrite and sphalerite-bearing solutions, from which those minerals crystallized together, but with some segregations due to local conditions. Relations in the Flinflon ore are much the same as far as order of crystallization is concerned, but sphalerite occurs in the pyrite in more definitely vein-like masses than it does in the Mandy ore.

Origin of the Sulphide Ores.

The sulphide bodies like the gold-quartz veins are believed to be related to granitic intrusions. At the Flinflon deposit a small dyke of granite porphyry is in close proximity to the ore-body. The Mandy lens at Schist lake has no igneous body in the immediate vicinity, but the distance to tongues of granite is not great on the surface even if there were not the possibility of unexposed intrusions. The clearest evidence of the origin is the occurrence of the small bodies of sulphides which are strung out along the borders of dykes and small bosses of granite. Sulphides do not seem to be found close to the main granite masses but only at some little distance from their actual contact with older rocks or along the borders of small intrusions. Evidently there were conditions present near the smaller masses that permitted sulphides to be deposited, whereas close to the larger batholiths deposition was not favoured. This explains the apparent anomaly of attributing two types of deposits, gold-quartz veins and sulphide replacements, apparently so unlike in character, to the same intrusive.

In the ore-bodies occurring in intensely metamorphosed rocks such as those of the Amisk volcanic series, it is difficult to decide to what degree the rock alterations are dependent upon the effects accompanying the introduction of the ores and to what extent the enclosing formation may already have been changed to masses of secondary minerals before being subjected to the action of mineral-bearing solutions. Without definite quantitative data conclusions must be merely tentative.

In general the schists of the Amisk series consist chiefly of plagioclase feldspar, altered to kaolin and sericite, chlorite in large amounts, epidote, zoisite, and magnetite in smaller quantlties. Calcite is nearly always quite abundant and secondary quartz is not uncommon. In thin sections from both foot and hanging-wall of the Mandy lens, there is no plagioclase recognizable. Quartz is the most abundant mineral and calcite is very abundant both as a network following the foliation of the schists and as impregnations. In the foot-wall rock there is a great deal of disseminated pyrite and sericite is more abundant than in the rock from the hanging-wall side. The presence of so much calcite would indicate the action of hydrothermal solutions, but it is not evident that these were definitely related to the ore since the schist on the island south of the Mandy contains more calcite than the wall-rocks of the ore. Intense shearing of this latter rock has, however, produced conditions favourable to more than ordinarily intense alteration and may even have been related to the ore period. Inclusions of wall-rock in the sulphides consist almost entirely of chlorite with a much smaller amount of sericite. All of the minerals associated with the ores are those characteristic of hydrothermal action and, although there is the possibility that most of the alteration may have been previous to and quite independent of the introduction of the ore, the apparently greater quantity of calcite, secondary quartz, and sericite in these rocks than in those farther from ore-bodies makes it probable that the ore solutions were hydrothermal in nature

Relations to Intrusives.

Sulphide ores have been found to be produced in zones where the temperatures though elevated are not those of true high temperature deposits as the quartz veins of this district have been shown to be. Hence sulphide bodies would not be expected close to the main mass of granite where the temperature must have been high and the pressure intense. They would form some little distance from the big batholiths where more moderate conditions prevailed or along the edges of the smaller bodies where less extreme temperatures and pressures would be found. In the high temperature deposits formed close to the main batholiths or at great depths, quartz, gold, and arsenides with small amount of sulphides are the minerals deposited. At lower temperatures and so farther from the big masses or at higher levels, the deposits consist chiefly of gold and sulphides. As a direct corollary of this deposits may be expected, if followed to sufficient depth, to change from sulphides to arsenides, so that whereas upper levels may be chiefly pyritiferous the lower levels will have chiefly arsenopyrite with likely a decrease in the amount of chalcopyrite present. There is also a further reason for the clustering of ore-bodies about small batholiths, since they are merely the projecting domes from the greater batholith lying beneath and the mineralizing vapours being more volatile rose into them carrying up the ore minerals and depositing them in the batholith roof.

Age.

The age of the deposits is indicated by their origin. As in the case of the gold-quartz veins the sulphide deposits were formed during the closing period of the granitic intrusions and the changes since their formation have been negligible. The products of any secondary concentration have been almost entirely removed and fresh sulphides are found practically at the surface or covered by only a comparatively thin gossan (Plate VII A).

DEPOSITS OF NON-METALLIC MINERALS.

Up to the present prospecting has been confined entirely to metallic minerals. There are, however, certain deposits that might with good transportation facilities and the opening of a market be handled profitably.

Dolomite.

The Palæozoic dolomite occurs in beds that could be quarried in blocks ot almost any size and thickness. The buff-coloured rock would make a very pleasing building stone and it is possible that the variegated varieties could also be found in sufficient quantities to be used. The local deposits of red dolomite would probably produce enough for ornamental purposes. At many points along the escarpment at the northern edge of the Ordovician 80-foot faces of rock with little overburden are to be found, but a part of this 80 feet would be useless on account of its thin bedding. In the sections given by the cliffs on the south side of Table lake the upper 20 feet would produce large blocks 2 to 3 feet in thickness.

Granite.

At many places massive granite of a very pleasing light pink colour is obtainable. On the Mistik lakes at various places there are exposures of very fresh massive rock that is jointed into blocks 3 feet or more in each direction. The amount of overburden is small but the face that could be exposed is not more than 30 feet in height. This particular locality, situated as it is in a granite area on one of the smaller waterways, is hopelessly distant from any possible transportation route. It has been mentioned to show the type of material that no doubt can be obtained at other more accessible points of the area if a railway is ever built into this district.

Clay.

The fine lacustrine clay of the area south of Cranberry lakes is suitable for the manufacture of common brick. Tests of samples of clay of very similar composition have been made, the details of which are given in Memoir 30, page 137.

Peat.

If the briquetting of peat becomes a commercial possibility the great peat bogs of this country should be valuable fuel resources. No careful estimate of the average thickness of peat over the clay subsoil has been made, but in some places it is considerable.

DESCRIPTION OF INDIVIDUAL CLAIMS.

GOLD-QUARTZ CLAIMS.

Prince Albert Group.

This group of claims, which lies on the west side of Amisk lake towards the north end, was the first staked in this district. The vein is in a much altered and contorted rock that is believed to belong to the lower Missi slate series. The metamorphism has been so intense that the resulting rock might be the product of the shearing of a member of the Amisk volcanic group, but, since this vein lies directly along the strike of the contorted slates found at the camp buildings, the country rock is placed tentatively with the sedimentary series.

The main vein lies in a sheared zone. It strikes northerly and dips 60 degrees to the west paralleling the shearing. As in all veins of this class it is lenticular. This particular lens has been traced 150 feet, the width of quartz varying from 2 feet to 9 feet with stringers paralleling the main mass. At the place where the shaft has been sunk, a smaller vein 20 inches in width lies a few feet east of the main vein and as it dips to the west less steeply than the main vein, the two unite at a depth of 20 feet. At the junction the width of quartz showing in the shaft is 9 feet. Stringers from the large fissure work out into the enclosing rock but they follow to a great degree the structure of the country rock. As a result, alteration has not proceeded far from the vein.

The gangue of this vein is entirely a bluish, pinkish, or mottled brown quartz with a little muscovite. A little calcite has been found.

The vein has been slightly squeezed since formation, which has produced strain shadows in the quartz, tiny shear zones in which sericite has formed, and dark greenish planes parallel to the walls. Metallic minerals form only a very small part of the vein filling. Gold is, of course, the most important economically although the least abundant. It occurs commonly along the slip planes coated with yellowish micaceous material, and along the greenish lines of fracture but in places in solid quartz. Arsenopyrite is the most abundant of the metallic minerals present. It occurs as a massive variety in the quartz and in crystals in the wall rock. It is nearly always auriferous. Chalcopyrite, pyrite, molybdenite, galena, and possibly stibnite are present in small amounts. Practically all the gold except the small amounts held by arsenopyrite, pyrite, or other suphides is in flakes large enough to be visible. On this account the values obtained by assay are variable and a fair estimate of the average gold content could be made only by means of a mill run on a fairly large quantity of the quartz. However, the assays obtained indicate that this vein at best would produce only low grade ore.

Most of the development work has been done on the original discovery. The vein has been stripped for a distance of about 150 feet. During the season of 1914 an inclined shaft was sunk to a depth of 70 feet and during the following winter a boiler, compressor, hoist, and other mining machinery were brought in. These have not been installed and no work was done on the claims during 1915, 1916, or 191[illegible].

Freetown Claim.

The Freetown claim lies at the north end of the [illegible] west of the Prince Albert group. A mass of quartz 8 [illegible] in a well banded slate at the base of a high ridge of [illegible] As far as can be seen from the stripping done, the [illegible] the slate and is cut off or pinched out at the base of the [illegible] was seen in this vein.

Kent Claim.

The Kent claim lies on the west side of a small lake one mile west of the north end of Amisk lake. The country rock is a green schist that has been placed provisionally in the lower Missi series. The vein outcrops at the foot of a high ridge of this rock which forms the eastern wall of the vein. The western wall is concealed beneath a swamp. The vein is 6 to 7 feet wide, strikes north and south, and dips westerly at a steep angle. It differs from the other veins of the district in having quartz of a distinctly blue colour. Gold has been found in this vein. It has been stripped for a length of 100 feet along the base of the hill and a shallow test pit has been sunk at one point on the vein.

Graham Claims.

The Graham claims are situated three-quarters of a mile north of Amisk lake and west of Magdalen lake. The country rock is conglomerate of the upper Missi series. The close folding of these sediments opened spaces between the bedding planes as the layers crumpled and along the axes of the folds quartz has been introduced, forming irregular masses not of great surface extent but probably following the folds as they pitch downward. These quartz saddles carry some visible gold. Pyrite is present but no arsenopyrite was observed. Considerable stripping has been done on these deposits and some test pits sunk.

Waverley Claim.

The Waverley claim, situated on an island between Missi island and the western mainland, shows a network of stringers of white and mottled brownish quartz with some sulphides. No gold was seen. The zone trends north parallel to the general strike of the crumpled slaty rocks. The vein has been stripped at the south end and a shallow test pit sunk.

Nagle Claims.

This group of claims lies near Magdalen lake north of Amisk lake. They are in rocks of the upper Missi group. Work on them was done in 1916 and some veins exposed but the claims were not visited after the beginning of development.

Wolverine Claims.

Wolverine lake lies 2 miles north of the northeast bay of Amisk lake draining into a long, narrow bay by a stream only a few hundred feet in length. Robinson creek enters at the north end of Wolverine lake and a few chains up this creek a trail leads northwesterly to a group of claims staked and developed by the Creighton-Mosher-Dion party in the winter of 1914-1915. The vein lies partly in conglomerate and arkose of upper Missi age and partly in greenstone. Granite intrusions are found only a short distance from the vein. The strike is northwest parallel to the structure of the enclosing rock. The vein is lenticular and more irregular in the conglomerate than in the greenstone. At places there is 8 feet of quartz, but in many places the vein breaks into a network of quartz stringers. The quartz is white to brownish mottled from the presence of iron oxides. There is considerable arsenopyrite present from the decomposition of which the soil overlying the vein is very heavily iron stained. The vein has been traced by cross trenching for a distance of 2,000 feet and part of it has been completely stripped. No work has been done since the spring of 1915.

Hassett Claim, Lake Athapapuskow.

West of Bakers narrows in the north arm of lake Athapapuskow a claim has been staked on a vein in the upper Missi conglomerate and arkose. The quartz is in irregular lenses dipping westward. Some of these are 2 feet in width and the zone in which they occur is 10 to 12 feet wide. The quartz is a milky white variety containing granular pyrite and chalcopyrite. Blebs of calcite and some arsenopyrite are found in some lenses. Pyrite occurs as cubes as large as one-third of an inch in diameter in the wall-rock which is chiefly a sericite schist produced by the shearing of the arkose. An open-cut 30 feet in length, 10 to 20 feet deep, and 10 feet in width was made in the quartz-bearing zone, but the gold values not proving encouraging work was discontinued.

Island Lake Claim.

During the summer of 1915 some pieces of schist with stringers of quartz carrying large grains of gold were picked up on the beaches of Island lake. Claims were staked on the narrow fringe of greenstone on the south shore and some trenching done, but no vein with quartz similar to the samples has yet been uncovered.

SULPHIDE CLAIMS.

Flinflon Lake Claims.

The first discovery of large bodies of sulphides was made on the east shore of Flinflon lake, now the Apex and Unique claims. The mineral outcrops at the water's edge and the whole point where sulphides are found, is so near lake-level that trenching is difficult. The amount of surface work yet done is not very great and the following description of the body must be considered as subject to correction.

The Flinflon sulphide body lies in a shear zone in Amisk volcanic rocks of the ellipsoidal greenstone type. On the hill just east of the deposit and on the portage south from Flinflon lake the ellipsoidal structure is well shown. Westward towards Douglas lake the rock is a massive greenstone. A microscopic examination of the country rock just east of the vein shows little but secondary minerals—chlorite, calcite, sericite, considerable quartz, and some remnants of feldspar individuals. On the east side of the sulphide body at the most northerly trench there is a narrow dyke of acidic rock of very fine grain. This is a granite porphyry showing under the microscope a few large crystals of quartz, plagioclase, and orthoclase in a very fine-grained groundmass of the same minerals. A lamprophyric dyke outcrops in the bay west of the portage at the south end of the lake, and there is a similar dyke, probably the continuation of this one, in the bay north of the cabins. This would place it 100 feet or more in the foot wall of the ore-body. It is a soft, greenish black, coarse-grained rock consisting almost entirely of faintly green hornblende and its alteration products. Of these, serpentine is the most abundant.

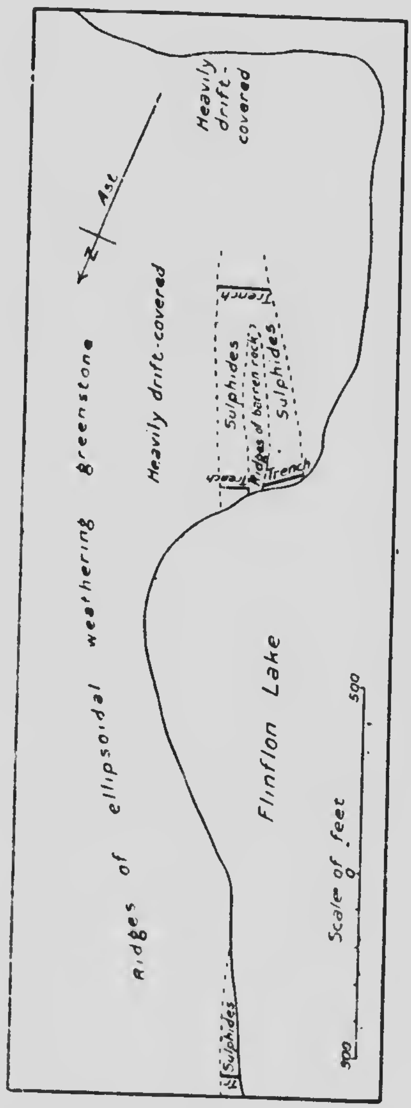


Figure 1. Plan of the Flinflon sulphide deposit.

A series of trenches across the strike of the ore zone on the north side of the broad point upon which the ore outcrops, shows 55 feet of sulphides, 40 feet of barren rock, and then 30 feet more of sulphides (Figure 1). Four hundred feet south of these trenches the sulphide band is unbroken and is 75 feet in width. Some disseminated material is found on the borders of the main mass of ore. Eight hundred feet to the north of the main trenches, ore has again been found but at this place the lens is much narrower. On the south shore of the lake no ore has been found but drilling was being carried on there in the autumn of 1917 in the hopes of finding it under cover. Assuming that the ore found in the most northerly trench belongs to the same lens as that in the southern drill holes, the deposit is more than 2,500 feet in length. It may be found to be not one simple lens but several. It is probable that the lenses include horses of barren rock, as indicated by the exposures, and the actual distribution of sulphide may be very irregular. The dip is somewhat variable but may be assumed to be between 60 and 70 degrees on the average and is always northeasterly.

The ore is very definitely banded, consisting mostly of pyrite with narrow bands of chalcopyrite, and zinc blende. This banding no doubt is in a general way parallel to the wall but at the one place where it could be definitely measured it has a dip of 45 degrees northeasterly. The banding is probably due to differential precipitation during the replacement of material in the shear zone. The foot-wall side of the lens at Flinflon is mostly massive, granular pyrite. Eastward, bands of fine-grained, black sphalerite and a little galena begin to appear. Towards the eastern margin of the vein, chalcopyrite band are present. Some chalcopyrite is also disseminated through the pyrite. All of the sulphides carry some gold and silver. Along the edges of the lens and on the margins of horses of country rock there are disseminated sulphides; and weathering, removing the sulphide content from these disseminations, leaves nothing but a porous mass of quartz. Alteration of the sulphide has not proceeded to great depth, being arrested by the ground-water level which is here very close to the surface. Where the drainage and aeration have been sufficient a thin coating of soil, stained deep red by iron oxides, is found. On the low muskeg area under which the eastern edge of the deposit is buried, the uppermost material is red, but beneath that there is a greenish pyritiferous mud resting upon the solid sulphides. Gold can be panned from the oxidized soil.

Between the time of finding the mineral late in the summer of 1915 and the freezeup in November the locators of the original group of claims trenched across the ore in two places and opened a few pits down through the overburden where the cover was deep. A short trench was also opened north of the main outcrop. Since the sulphides are easily eroded and hence form hollows very close to the water-level of the lake, the work of outlining the extent of the ore by trenching was difficult and unsatisfactory. Enough was shown, however, to make it apparent that there was a large amount of mineral, and during the winter Boston and New York mining men were interested in the claims. Between March, 1916, and the middle of July of that year two diamond drills were working continuously on the properties. The drilling is said to have indicated a very large body of ore but work was suspended in July. Early in 1917 drilling was again begun to locate the southward extension of the body and was continued throughout the year. Comfortable camps are being erected and plans made for a thorough exploration of the deposit.

There seems no doubt from the surface extent and the reported extension in depth that the body is sufficiently large to make it important under favourable conditions if the average value is found to be sufficiently high. The ore is not of very high grade and the constituents are so intimately associated that it would probably be found impossible to separate the copper and zinc minerals from the pyrite which forms the bulk of the ore. Hence the concentration of the ore and the shipping of high grade concentrates during the winter months is not feasible. Present transportation facilities prohibit the handling of a low grade smelting ore and the deposit will not be workable unless it is found that the value of this and neighbouring deposits is sufficiently great to warrant the building of a railway.

Mandy Mine.

The group of claims to which the Mandy mine belongs is situated just north of the mouth of Phantom creek, 2 miles from the north end of the northwest arm of Schist lake. The deposit is on the narrow point separating the bay into which Phantom creek empties from the main arm of the lake. It was discovered late in the autumn of 1915 and almost immediately after the claims were recorded was optioned to the Tonopah Mining Company, whose geologist Mr. J. E. Spurr was making an examination of some other northern Manitoba deposits at that time. During the winter a diamond drill was installed and surface trenching undertaken.

The country rock is massive greenstone and chlorite schist in relatively narrow bands which strike parallel to the shore of the lake. Pyroclastic rocks, containing bombs up to 2 or 3 inches in length, are found along the shore to the north and still farther north the volcanic rocks are overlain by a closely folded syncline of conglomerate and arkose, the tip of which rests on the north end of this arm of Schist lake. Dykes of granite are found rather commonly east of the lake and westward a tongue of the main granite batholith extends as far north as Phantom lake. The succession of rocks across the point from west to east, is greenstone, schist, greenstone, schist, greenstone. The ore lens lies in the western zone of schist protected from erosion by the massive greenstone on either side of it and so preserved above the lake-level to which no doubt it would have been reduced if undefended by resistant rocks. The greenstone and schist are so very different in character

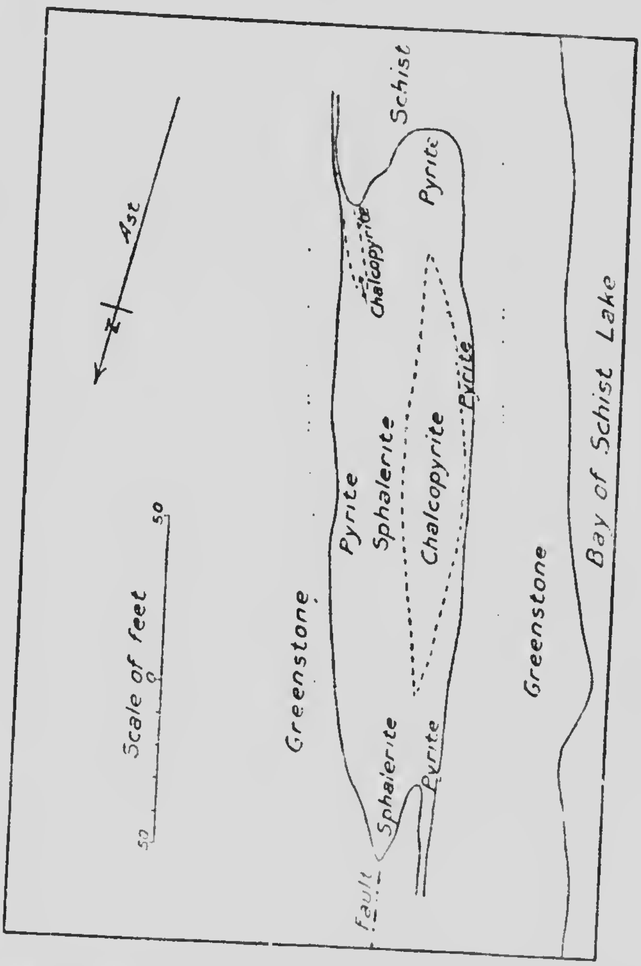


Figure 2 Plan of the Mandy sulphide deposit

that although classed together they may very well be quite different in origin. The schist may represent somewhat more clayey layers separating flows of volcanic material. Subsequent movements during the periods of close folding would naturally be localized along these layers and would produce in them the well-marked fissility which they exhibit, whereas the more competent greenstone layers might escape any marked deformation. Either from some difference in composition or from the very marked difference in physical character, mineralization is confined to the schistose zones, the massive greenstone being almost free of sulphides.

The lens of sulphides (Figure 2) is 225 feet in length by 40 feet in maximum width. At the northwest side a 2-foot vein continues northward following the strike of the schist. At the southeast side there

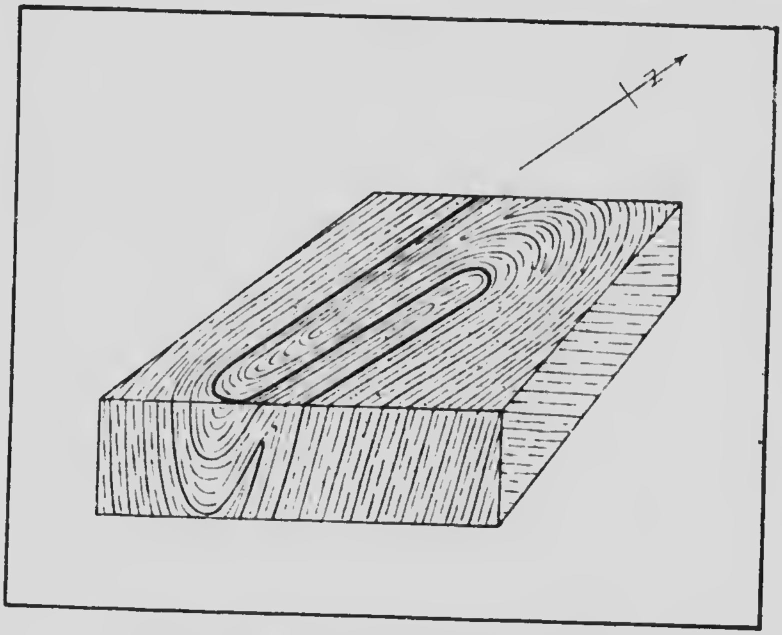


Figure 3. Diagram of a drag fold in banded rocks

is a similar vein. The elongation of the lens follows the general strike of the schist and greenstone bands. At the north end of the lens the ore pitches beneath barren schist, but a fault continues northward following the general trend of the body. At the southern end the actual extremity of the sulphides has not been stripped, its outline in the diagram being generalized from two trenches of which the northern shows a width of 20 feet of ore, the southern one barren country rock. Drilling has shown that the lens dips steeply to the east. The shape of the body and its relation to the massive zones of greenstone are explainable under the theory that the opening or replaceable zone owes its origin to a drag folding of the less competent schistose band between the massive greenstone bands that lie on either side of it (Figure 3). No conclusive evidence of such an origin can be adduced but the shape of the deposit resembles closely a structure of that type (Figure 4). Furthermore, its position with regard to the larger elements of structure and its attitude correspond with the theoretical attitude and position that minor folds should have, since, a short distance to the north, there is the closely folded syncline of Missi rocks, the axis of which lies somewhere northeast of the Mandy claim striking north and pitching at an angle of 15 to 50 degrees to the north.

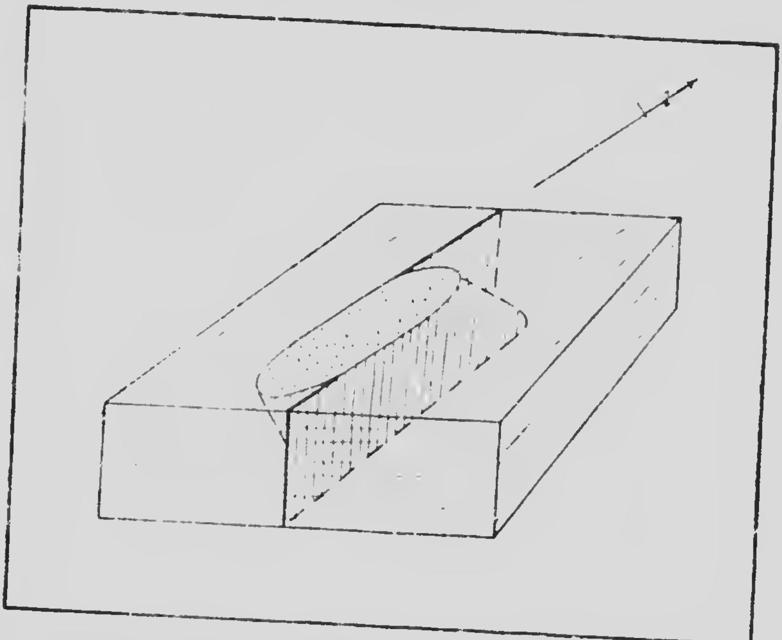


Figure 4. Diagram to show the possible mineralization of a fold of the form shown in Figure 3 to produce an ore body similar to that at the Mandy mine.

The folding which produced this pitching trough of sediments must also have affected the rocks below the sedimentary series. Hence the Amisk volcanics, in which the ore is found, are probably on the western limb of the syncline. A soft layer of rock between more competent bands would be dragged by the upward and northward movement of the eastern zone with reference to the western. A drag fold pitching to the northward would have in plan the outline of the ore-body. The main mass of the ore would represent the brecciated and sheared rock replaced by sulphides. The strike fault observed at the northern tip of the lens would be expected in such close folding at exactly that place.

The ore has much the same composition as that of the Flinflon Lake deposit. The vein to the northwest is mostly pyrite, that to the southeast mostly chalcopyrite. A section across the middle of the lens shows 12 feet of pyrite on the foot-wall, 12 feet of high grade chalcopyrite, 8 feet of sphalerite, and about the same width of pyrite on the hanging-wall side. The northern end of the lens is mostly sphalerite. The chalcopyrite does not run through from end to end but tapers out both north and south, thus forming a lens of chalcopyrite within the other sulphides but not absolutely parallel to the main lens. The zones of the various sulphides are not as distinct as the diagram and description indicate, but grade into each other by an intimate interbanding of the varieties. As at Flinflon the banding is believed to be due to successive periods of mineralization and to selective precipitation due to either physical or chemical influence or to a combination of them. The body owes its value chiefly to the rich chalcopyrite in the middle of the lens. All the sulphides carry gold and silver but the value of these minerals present is not high enough to warrant shipping for them alone. However, the segregation of this high grade copper ore makes it possible to mine and ship that much of the lens even though it must bear the excessive cost of hauling by teams 35 miles to Sturgeon lake, stocking until the opening of navigation, loading into scows, shipping to The Pas, and then transhipping to the railway for a long haul to a smelter. Only the phenomenally rich part of the deposit will be able to bear this expense, the poorer material will necessarily be unworkable and after the removal of the richer zones the lens may be so impoverished that the much larger amount of low grade ore may never be recovered.

The Mandy Mining Company, a subsidiary of the Tonopah Mining Company of Arizona, have been actively mining their ore lens during the year 1917. During the winter high grade chalcopyrite was taken from an open-cut (Plate VI B), hauled on sleighs to the mouth of Sturgeon-weir river, and there stocked to await the opening of navigation on Saskatchewan river. Two carloads were taken through to The Pas. During the summer of 1917, this ore was taken by boat to The Pas and shipped to the Trail smelter. After the winter roads became impassable the Mandy Company began the installation of a mining plant that had been brought in on the ice. Their equipment now consists of a 125-horsepower boiler, a seven-drill compressor, a hoist; they also have a portable sawmill for cutting lumber for the mine buildings. Four 40-ton barges and a small stern-wheel steamer to handle them were built for use on Schist and Athapapuskow lakes. During the winter a 60-ton tug was brought across the winter road from Sturgeon lake to Athapapuskow lake to be used to carry freight from the end of the road to the mouth of Schist creek. A lock is being built in Schist creek to overcome shallow places and allow barges to be brought from the mine directly to the south end of lake Athapapuskow without unloading. This will make the sleigh haul in half.

After the installation of the plant, underground mining was begun. A vertical shaft was sunk to 100 feet, a crosscut driven to the ore body, and a drift and raise made in the chalcopyrite lens. The ore was loaded directly from the shaft head by a tramway to barges and these were towed to the foot of Schist lake. At the close of navigation 2,400 tons of ore were stocked at that place. The shaft is being sunk to 200 feet and it is planned to ship out by sleighs at least 7,500 tons during the winter. The ore already sent to the smelter averaged 17 per cent copper with a little gold and it is probable that the product now being mined will be equally high grade.

Dion Claim

On the point immediately south of the Mandy, a little stripping and blasting away of rusty rock has exposed a zone of chalcopyrite stringers. The present showing is valuable only as indicating the possibility of a lens of ore at depth.

Sunbeam Group.

A group of claims lying close to the west shore of Hook lake is located on a vertical shear zone near a small boss of granite. In this zone there are a number of small stringers of chalcopyrite, the total width of the band of rock and sulphide veinlets being 30 inches. Shallow test pits have traced the mineral for a distance of 75 feet, but this deposit, like the Dion claim, is as yet merely a possibility.

Chica Claim.

Considerable trenching and stripping has been done on a claim on the west side of Pineroot river near its mouth. In an open cut 35 feet long by 10 feet deep at the deepest point a shear zone has been exposed, consisting of serpentinized rock impregnated by pyrite and a little chalcopyrite.

Bailey Durond Group.

This group of claims lies between the first and second lakes east of Tartan lake. Near the most westerly lake three deep trenches have been dug showing heavily iron-stained gossan. Near the eastern lakes a series of four trenches expose a 6 to 8-foot vein of pyrrhotite with

*In the spring of 1918 it was estimated that 9,000 tons were stocked at Sturgeon lake.

a little chalcopyrite. The pyrrhotite carries very small values in nickel and so far as exposed the chalcopyrite forms a very small percentage of the sulphide.

Pyrrhotite Claims East of Ross Lake

From the east side of Ross lake a trail leads across the belt of conglomerate and arkose to a small lake lying on the contact of these rocks with the volcanics to the east. On the high ridge of the latter rocks forming the eastern shore of the small lake, two or three shallow pits have been sunk on almost massive pyrrhotite. So far as the pits show these deposits are not large and the nickel content in the samples taken is too low to make them workable even if they were large enough.

Claims on Webb Creek, North of Elbow Lake.

In 1916 some claims were staked on the west side of Webb creek which enters the west side of Elbow lake. These claims are practically on the contact of the granite and green stone series. The sulphide is a mixture of pyrite and pyrrhotite, the latter predominating. Gold, silver and nickel values are all very low. Very little work has been done on any of these claims as most of them are in low places. In a wet season, such as the summer of 1916, trenching is impossible. The values obtained from the grab samples of the sulphides exposed are not encouraging.

Claims Near Brunne Lake

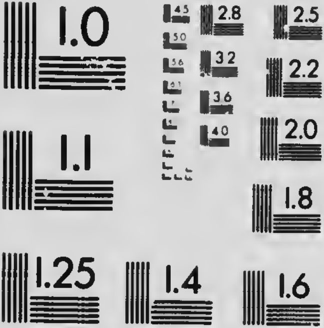
Some sulphide claims were located on a small lake lying west of Brunne lake, but there also the values present appeared to be too low to make the prospects worth development.

Plate II

[illegible] dolomite [illegible]

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



APPLIED IMAGE Inc
1653 East Main Street
Rochester, New York 14609 USA
(716) 482 - 0300 - Phone
(716) 288 - 5989 - Fax

A. Pyroclastic rocks of Amisk series, east shore of north arm, Athapapuskow lake. (Page 24.)

B. Jointing in lavas of Amisk group, east shore of north arm, Athapapuskow lake. (Page 24.)

PLATE IV.

A. Jointing in greenstone, island southeast of Missi island, Amisk lake. (Page 24.)

B. Contorted slates of lower Missi formation, west shore of Amisk lake. (Page 32.)

Contorted conglomerate, Graham claims, north of Amisk lake. (Page 35.)

PLATE VI

A. Joint crack in dolomite, lake Athapapuskow. Page 48.

B. Open-cut at Mandy mine, 1917. Page 76.

PLATE VII.

A. Weathered surface of sulphide-impregnated rock, Phantom lake. (Page 65.)

B. Microphotograph of polished surface of ore from the Mandy mine, magnified 185 diameters. White areas are pyrite; light grey, chalcopyrite; dark grey, sphalerite; black, included country rock. (Page 62.)

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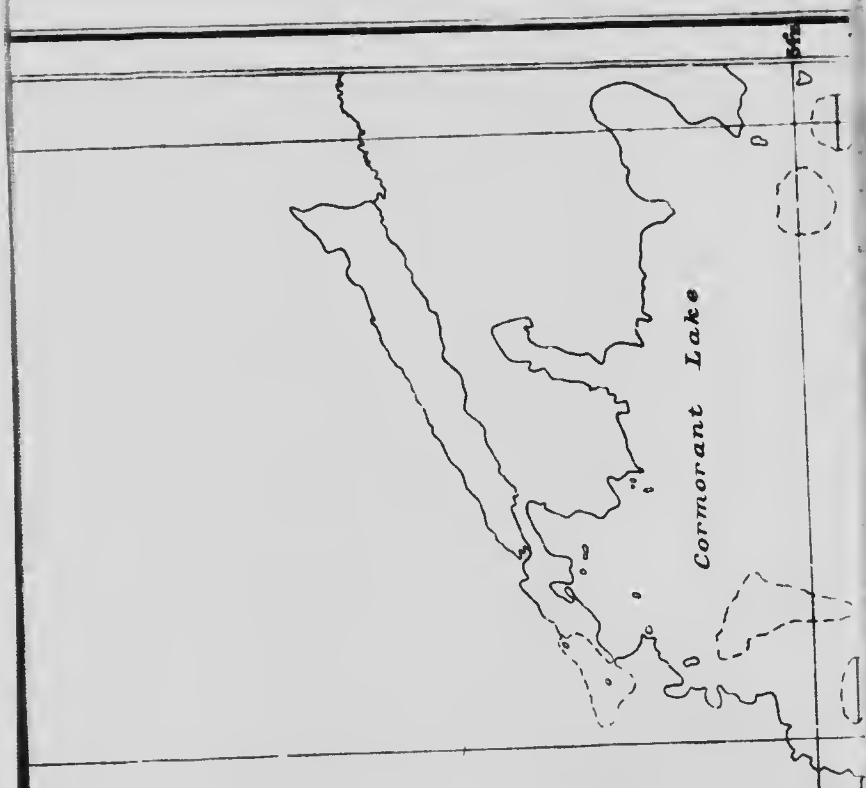
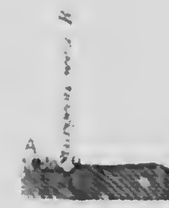

Cormorant Lake



LEGEND

RECENT AND GLACIAL

Q

Peat, river silts lake clays, till, gravel, sand

ORDOVICIAN

O

Dolomite

Unconformity

PRE-CAMBRIAN

A10

Kaminis granite

A9

Granite gneiss

A8

Hybrid granite rocks

Intrusive contact

A7

Upper Missi series (altered *(hornblende schist)*

MISSI GROUP

A6

Missi series
(conglomerate and arkose)

Unconformity

A5

Lower Missi series
(conglomerate quartzite and slate

Unconformity?

A4

Cliff Lake granite porphyry

A3

Quartz porphyry

Intrusive contact(?)

Canada
Department of Mines

GEOLOGICAL SURVEY

Issued 1919

Ideal sections showing rock relations

Canada
partment of Mines

GEOLOGICAL SURVEY

Issued 1919

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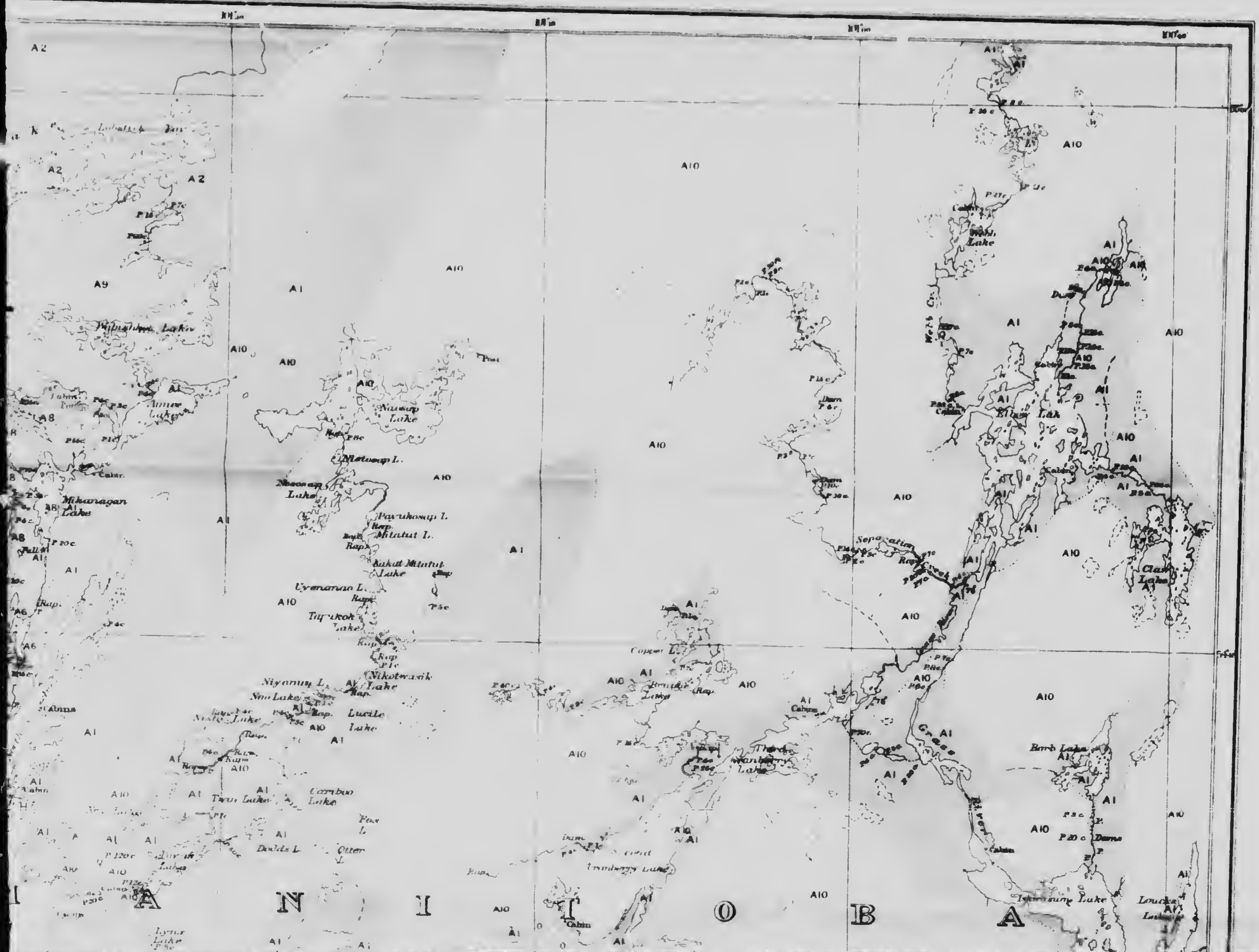


A 2

A 1

Symbols

Geological boundary

Geological boundary

Fault

Fault

Dip and strike

Vertical strata

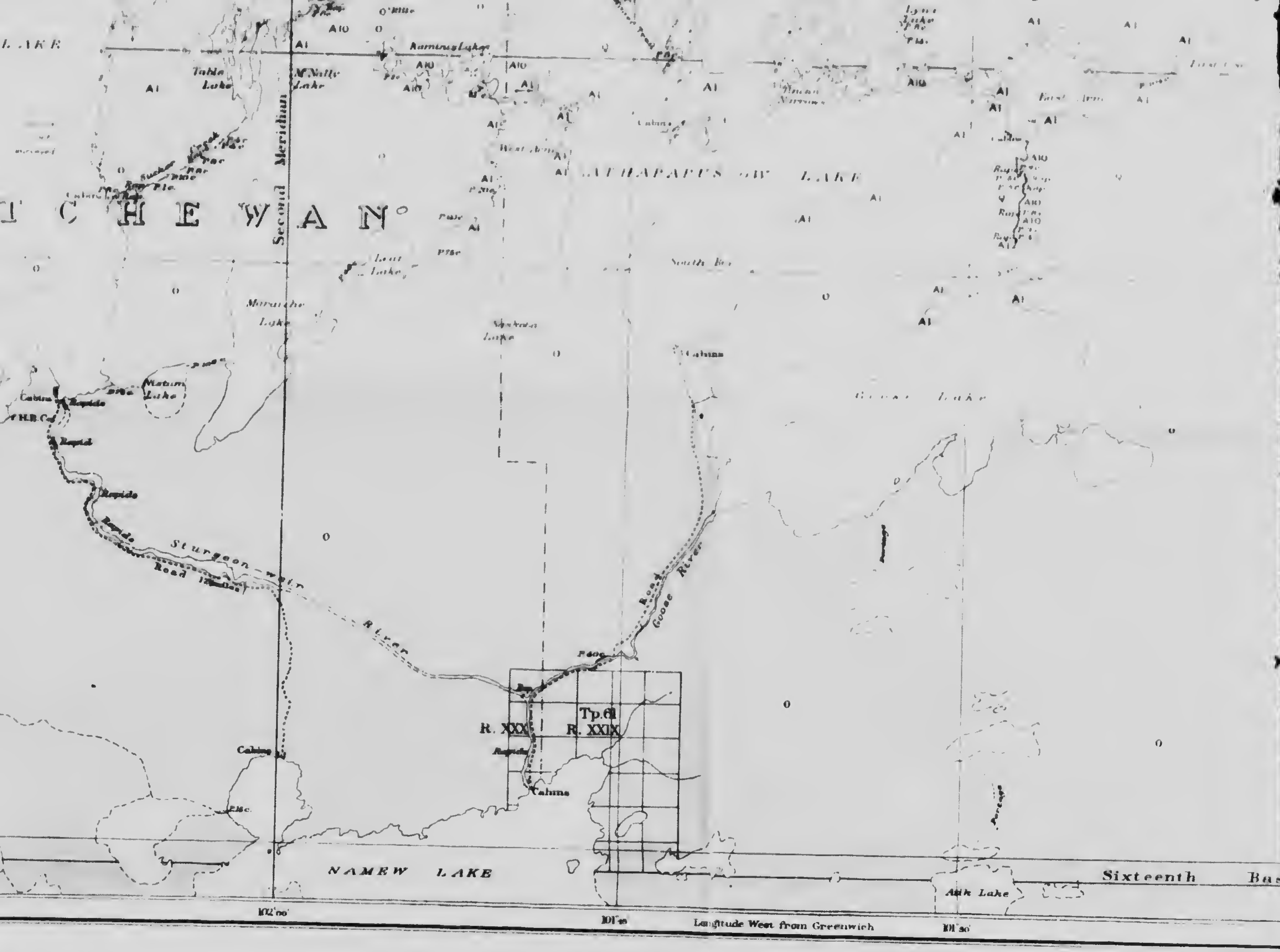
Dip and strike (schistosity)

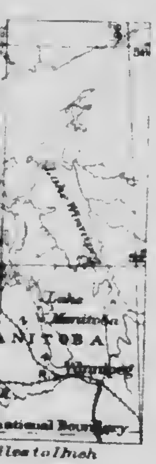
Schistosity, vertical

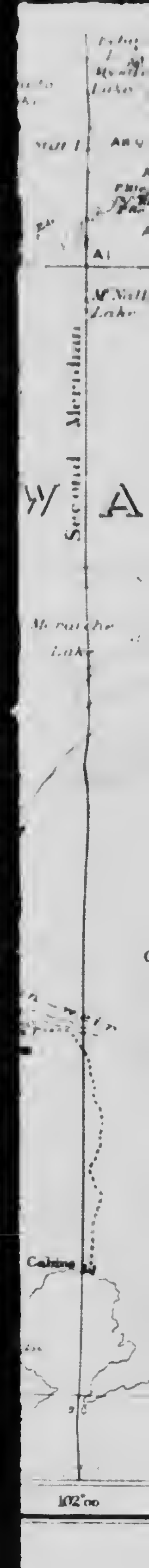
Glacial striæ

G.O. Senécal, Geographer and Chief Draughtsman.
J.J. Carr, Draughtsman.

To accompany Memoir by E.L. Bruce







ATHAPAPUSKOW LAKE REGION

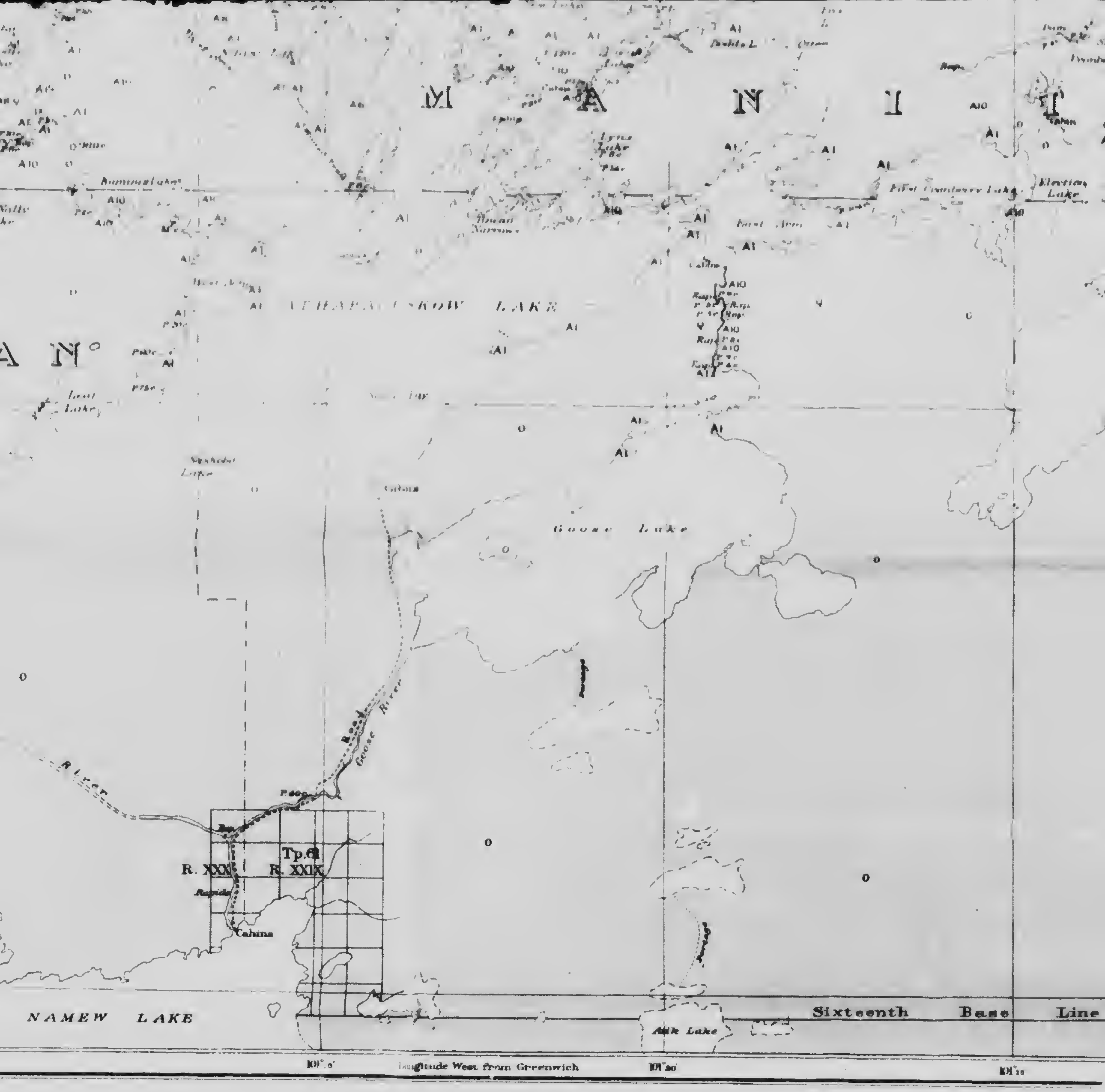
MANITOBA AND SASKATCHEWAN

Scale, $\frac{1}{190,080}$

Miles

Kilometres

3 MILES TO 1 INCH



ATHAPAPUSKOW LAKE REGION

MANITOBA AND SASKATCHEWAN

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Miles

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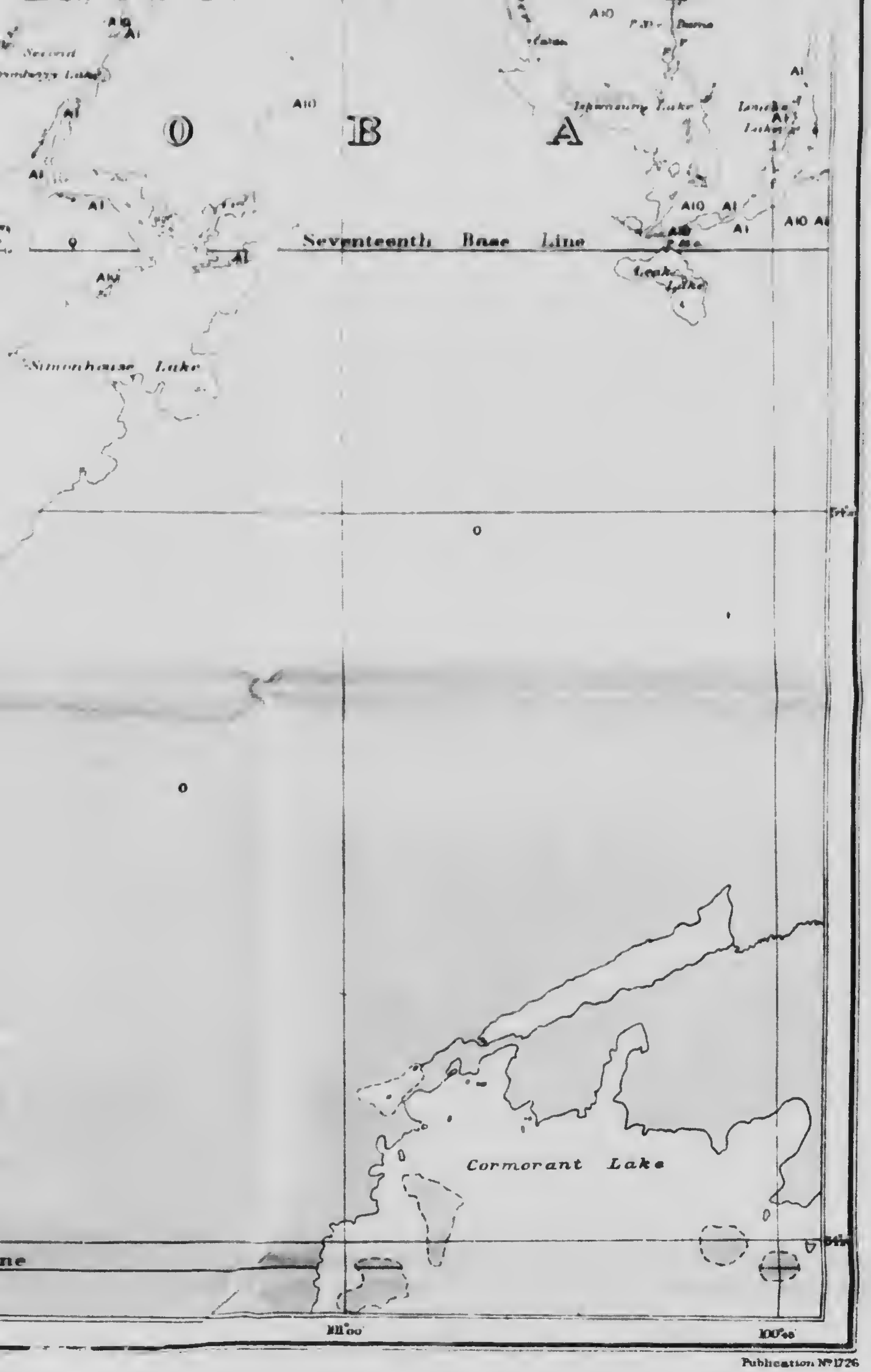

Sources of Information

Geography from surveys by E.L. Bruce, 1914–1917, and from official plans of the Department of the Interior

Geology by E.L. Bruce 1914–1917

Map compilation by J. J. Carr