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GEOLOGICAL SURVEY
WILLIAM MCINNES, DIRECTING GEOLOGIST.

Summary Report, 1917, Part D

CONTENTS

OTTAWA
GOVERNMENT PRINTING BUREAU
1918

No. 1718

SUMMARY REPORT, 1917, PART D.

SCHIST LAKE DISTRICT, NORTHERN MANITOBA.

By E. L. Bruce.

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INTRODUCTION.

During the field season of 1917 work was continued in the belt of Pre-Cambrian rocks lying north of The Pas. The rapid development of mining industries required special attention in two parts of this area, and as it was impossible to cover both fields the writer's work was restricted to an area of approximately 600 square miles along the western boundary of the province of Manitoba. This area includes that part of the belt from which copper ore is now being shipped. Mapping was continued northward into the great area of banded gneisses which bounds the promising formations on the north, partly on account of the various reported occurrences of bands of schist in that unknown region, and partly for the purpose of making a survey of some portion of the big lakes which were known only to the few people who have trapped or prospected in that country. No large, new areas of rocks similar to those associated with the valuable minerals of the district were found, and the time available was not sufficient to make complete maps of the lakes even had the character of the rocks seemed to warrant it.

As in previous years those interested in the district assisted the work in many ways. Very useful sketches of the canoe routes north of Tartan lake were kindly furnished by Mr. A. L. Moodie, and of the country north of Athapapuskow lake by Mr. L. G. Thompson. W. J. Embury again had charge of the micrometer surveys for the geographic base and also assisted very efficiently in some of the geological work.

TRANSPORTATION.

The beginning of active mining operations at the Mandy claim and the resumption of diamond drilling on the Great Sulphide properties at Flinflon, required a somewhat more frequent boat service to and from The Pas, but otherwise transportation conditions remained practically the same as in previous years. The government road from Sturgeon lake to Athapapuskow lake proceeded very slowly, and was ready for use only in the latter part of the season. A new stern-wheel steamer, the *Nipawin,* was put in commission by the Ross Navigation Company, as well as several barges. The new boat is designed to draw only 2½ feet of water, but even this was too much for conditions at the end of the season, and in October the water over the bar at Cumberland House prevented anything but canoe travel from that point northward. It is to be hoped that the government dredge that is still at Cumberland will be operated next season to clear a passage for these shallow draft boats northward from the outlet of Cumberland lake.

MINING DEVELOPMENT.

Flinflon Lake.

Diamond drilling was recommenced on the Flinflon properties of the Great Sulphide Mining Company, and prosecuted vigorously throughout the year. Attention is being given to that part of the lens lying underneath the southern part of the lake, and it is hoped to prove the extension of the mineral zone under the cover in that direction. Comfortable camp buildings are being erected, and preparations made for a thorough testing of the possibilities of the deposit.

Mandy Mine.

The beginning of production by the Mandy claims on Schist lake is the most important development in the district during the year. Ore taken from an open-cut on that property during the winter of 1917 was hauled by sleighs to Sturgeon lake, stocked there until navigation opened, and shipped by barges down the Saskatchewan river to The Pas, and thence by rail to the Trail smelter. As no spur has yet been built at The Pas from the railway to the water front, the ore had to be transferred on wagons. Even with this expensive transportation, the rich chalcopyrite ore paid handsome returns. An efficient mining plant, consisting of 125-horsepower boiler, 7-drill compressor, and hoist was brought in on the ice, installed during the spring, and, in spite of difficulties both in the way of obtaining supplies and efficient mine labour, a shaft was sunk 100 feet, and over 2,000 tons of ore hoisted and transported to the foot of Schist lake before the close of the season of navigation. It is expected that this and an additional 5,500 tons will be taken out to Sturgeon lake during the winter. The ore production for the year 1917 was:

Mined and shipped to Trail smelter, 3,500 tons—17 per cent Cu content.
Mined and stocked at Schist lake, 2,100 tons.

Dion Claim.

Shallow test pits in a rusty zone in the schists on the point immediately south of the Mandy mine opened up a network of small chalcopyrite veins that are important on account of the indication they give of a possible lens of ore similar to the Mandy. Since these bodies are lenticular, only slight mineralization on the surface may lead to rich lenses below, but, on the other hand, stringers of sulphide may represent the lower part of a lens that is completely eroded and so may not lead to any body below. Moreover, it is not a necessary condition that disseminated sulphide or small lenses of ore should always indicate the proximity of larger ones. However, such stringers should not be neglected, and whether or not there is ore beneath them can be determined only by thorough testing.

Hook Lake Claims.

A group of claims near the west shore of Hook lake is located along a vertical shear zone near a small boss of granite. Shallow open-pits have exposed a network of chalcopyrite stringers 30 inches in width and traceable for a distance of 75 feet. This discovery may be classed with that just described.

Chica Claim.

Considerable stripping has been done and an open-cut 30 feet in length by 10 feet in depth made on a claim lying just west of the mouth of the Pineroot river. The discovery is a sheared and faulted zone mineralized by pyrite and a little chalcopyrite.

Bailey Durand Claims, East of Tartan Lake.

The Bailey Durand claims extend from the first small lake below Tartan lake eastward to the third lake. Near the westerly lake three deep trenches expose heavily iron-stained rock with little sulphide yet showing. Three trenches near the easterly lake strip a 6 to 8-foot band of pyrrhotite that carries some chalcopyrite.

Other Claims.

Other claims with some showings have been located, but on most of them little work has been done. Among those that have received some attention are claims staked north of the northeast bay of Phantom lake, a pyrrhotite lens east of Ross lake, which was mentioned in the Summary Report for 1916, and some quartz claims northwest of Tartan lake.

TOPOGRAPHY.

Topographically the Schist Lake district consists of three divisions. Along the southern side of lake Athapapuskow there is a flat country, with many large muskegs, underlain by Ordovician dolomite. This is bounded at the north by an escarpment facing northward over the lower but more rugged Pre-Cambrian area upon which an occasional flat-topped hill of dolomite still remains. The central part of the district consists along the waterways of comparatively narrow, steep-sided ridges with a general northerly trend, but inland the country though higher is in places muskeg-covered with irregular granite knobs projecting above the general level. Northward, in the vicinity of Kisseynew lake, the dominant features are southwest-northeast trending cuestas with the gentler slopes (35 to 40 degrees) to the northward. West of Kisseynew lake the trend of the cuestas changes to northerly with the gentler slope to the east, but their general character remains the same. These ridges, in places continuous for some distance, are separated by wet muskegs, by swampy valleys with broad sluggish creeks, or by narrow lakes with long branching arms. Hence, land travel transverse to the structure of the country is very difficult. Moreover, since the area lies on the height of land between the Churchill and Nelson basins, the streams are small, and this section is the least easily accessible of any part of the Schist Lake district.

GENERAL GEOLOGY.

The extending of the field work to the northward and the more detailed mapping of the central part of the area resulted in some slight alterations in the table of formations as published in the 1916 report. A new formation lying conformably above the Amisk volcanics has been found in the new area to the north, and a granite, believed to be older than the upper Missi sediments at least, has been separated from the intrusives. The following table represents the succession as now determined.

Table of Formations.

Recent and Glacial.		Till, gravel, sand, clay, peat.
Ordovician.		Dolomite.
	Unconformity	
Pre-Cambrian.	Kaminis granite Granite gneiss Hybrid granitic rocks.	
	Intrusive contact	
	Upper Missi group.	Conglomerate, arkose, greywacke.
	Unconformity (?)	
	Lower Missi group.	Slate.
	Unconformity (?)	
	Cliff Lake granite porphyry.	
	Intrusive contact	
	Kisseynew group.	Sedimentary gneisses, schists, and granite gneiss.
	Amisk group.	Volcanic flows: andesites Volcanic fragmental rocks. Amygdaloidal and ellipsoidal greenstones and derived schists.

Amisk Group.

The oldest group of rocks in the district consists of volcanic rocks of various types. Of these, probably andesitic lava flows form the greatest bulk, but with the flows there are large quantities of fragmental material consisting of volcanic ash and bombs. Some of this latter type now have much the appearance of conglomerate, but the fragments are all of the same kind and are similar to the groundmass in which they are set. Movements of the rock, both during the cooling of the lavas and subsequently, fractured the rocks which now recemented are not unlike mashed conglomerate. Later, folding under great pressure and probably with a somewhat elevated temperature locally, changed the volcanic rocks into fissile chloritic schists. Some of the rocks now rendered schistose may have been originally of different composition from those that are still massive greenstone, for during a period of such great and long-continued volcanic activity, there would possibly be a certain amount of normal sedimentation with the formation of clayey bands. Under metamorphism these would more easily change to schistose rocks than would the igneous types with which they were interlayered.

Kisseynew Group.

North of the areas of Amisk volcanics, and in many places separated from them by belts of gneissoid granite, there is a great series of garnetiferous gneisses and schists. These rocks have been grouped together, although there are a large number of varieties, probably ranging widely in ages. The type which may be considered most characteristic is a strongly foliated, greyish gneiss, which has the appearance of a sedimentary rock. It is practically always garnetiferous, and in places becomes a garnetiferous quartz mica schist. The beds in the gneisses are 6 inches to 1 foot thick, and in the vicinity of Kisseynew lake dip northward at angles of 35 to 45 degrees and strike south of west. Westward at Mari lake the beds strike northward and dip to the east. A result of this structure is the formation of cuestas which in the Kisseynew Lake section have their steep faces southward. Granite gneisses and pegmatites intruded as sills between the beds form resistant facings, sometimes very thin, on the dip slopes of the beds, so that although apparently there are great areas of granite gneiss yet on crossing the upper edge of the cuesta it is found that almost the whole lower part of the steep face is made up of the more easily weathered, supposedly sedimentary formation. Besides the granite gneiss with sill structure there are many bosses intruding the sedimentary formation. Some of these are probably older than the sediments of the Missi series, but some, judging by their character, are undoubtedly younger, and if the area were promising economically, should be separated from the Kisseynew group. Structurally, the Kisseynew gneiss overlies the Amisk rocks, but where the two are in contact there is no sign of a break between them, the rock changing from a quartz hornblende schist, which is referred to the Amisk group, into a quartz feldspar biotite schist, with garnets, which is placed in the Kisseynew group. There are also in the gneissic group some bands that might possibly be derived from the volcanic rocks through contact metamorphism. The great deformation that the northern end of the Ross Lake syncline of Missian sediments has undergone further complicates the mapping of the various formations between Flinflon and Kisseynew lakes, since the arkose and greywacke might easily, under the extreme conditions that existed, be changed into gneissic rocks not unlike those of the Kisseynew group.

Cliff Lake Granite Porphyry.

A large oval boss of granite porphyry occupies the inland region between Cliff and Ross lakes on the west, and Trout and Big Island lakes on the east. It is somewhat different from any of the other granitic rocks in being distinctly porphyritic, with phenocrysts of bluish to lavender-coloured quartz showing prominently on the pinkish weathering surface. The feldspars have undergone somewhat more alteration than those of other granite masses. Under the microscope the most striking feature of the rock is a coarse graphic intergrowth of quartz and feldspar, somewhat similar to intergrowths which have been observed in granite pebbles from the upper Missi conglomerate. This, together with the presence of bluish quartz particles in the greywacke, is the evidence upon which the porphyry has been given a place in the time scale below the upper Missi formation. There is no evidence as to its relation to the lower Missi slate.

Lower Missi Formation.

A narrow band of black slate on the west side of the northeast arm of Schist lake is referred to the lower Missi formation. The cleavage of the slate is vertical and in places may be seen crossed by a faint colour banding, marking the original bedding. No unconformity was observed between the slate and greenstone, but since the slate is similar to the slate found on Amisk lake it is inferred that there is a break between the two rocks comparable to that found at Amisk lake.

Upper Missi Formation.

The bulk of this formation consists of conglomerate and arkose, but greywacke is also found. The largest area of these rocks lies north of the northwest arm of Schist lake, extending northward in a closely folded syncline. North of Hammell lake the sediments have been much deformed, the bedding curving from a northerly to a westerly strike. As a result, conglomerate has been stretched and squeezed into a streaked rock whose original character can only be recognized by actually tracing the rock from place to place.

Other small remnants of this formation occur as infaulted blocks on lake Athapapuskow, along Pineroot river, and on lake Mikanagan. One tiny remnant exists infolded in granite gneiss on the 2nd meridian north of Willow creek.

Granite Gneiss.

The granite gneiss, several bosses of which occur in the northern part of the Schist Lake area, is a faintly gneissoid, very fresh, greyish to pinkish rock. It intrudes the Missi formation.

Kaminis Granite.

The Kaminis granite is similar to the granite gneiss, but is quite massive and in places becomes porphyritic. It also intrudes all formations up to and including the Missi.

Hybrid Granitic Rocks.

A dark grey to speckled grey rock in many places forms broad margins between the massive granite and the rocks of the Amisk group. A similar rock occupies large areas southeast of Tartan lake, where there is no granite at all, or only small dykes. Microscopically, these rocks consist almost entirely of secondary hornblende, but there are all gradations to typical granite. From their relations they are believed to be merely the hybrid rocks formed by a slow and very quiet assimilation of intruded rocks by the granite batholiths.

Ordovician.

Flat-lying Ordovician dolomite overlies the Pre-Cambrian south of lake Athapapuskow, and also still remains as outliers between Athapapuskow and Mystic lakes.

Glacial and Recent.

Glacial deposits are not important, since this district was largely one of erosion during the glacial period, but small sand-plains have formed in protected places and tails of drift are found behind knobs of rock. The Schist Lake country was almost entirely north of the area covered by the waters of glacial lake Agassiz, and so did not receive the thick clay deposits that mantle the rock in the districts farther south and east. In recent times the underlying formations in undrained areas have been obscured by muskegs, but where the bedrock is one of the Pre-Cambrian formations the extent of any one muskeg is not great.

STRUCTURAL FEATURES.

North of Willow creek and Tartan lake the Kisseynew gneisses form a great northeasterly pitching syncline. The southern limb of the syncline has a strike almost transverse to the apparent strike of the axis of the Cliff Lake syncline of Missian sediments, but the latter at the northern end are folded sharply to the westward to conform to the strike of the gneissic rocks. It is assumed that the conglomerate series is cut off by a fault at the north, since it has been traced only a short distance north of Willow creek. A fault has been observed bounding the eastern side of the Cliff Lake syncline. Along the east shore of Cliff lake, greenstone is shoved over conglomerate along a fault plane that dips 45 to 50 degrees to the eastward. The fault parallels the shore along the whole eastern side of the lake, in places a few hundred yards inland, in other places at the water's edge. Evidences of it are found farther south, and the northwest arm of Schist lake is probably eroded along this zone. A less conspicuous fault crosses the upper end of the first portage on the creek above Flinflon lake. It is apparently normal, dropping the conglomerate on the west side of it down into contact with the greenstone. Most of the small areas of conglomerate on Athapapuskow lake and along Pineroot river are infaulted remnants, and the Pineroot may owe the straightness of its valley to a fault zone. No doubt there are many other faults, possibly of great magnitude, but the lack of recognizable horizons makes their determination impossible.

ECONOMIC GEOLOGY.

The general features of the sulphide bodies and their supposed relation to the later intrusions of granite were set forth in the Summary Report for 1916 and need not be repeated. Some additional facts have been ascertained concerning the history of ore deposition, and though the examination is not yet finished, a brief account of the origin of the ores in the larger bodies may be given here. An examination of polished specimens of ore from the Mandy and Flinflon lenses has been undertaken to find, if possible, the cause of the segregation of minerals and the interbanding of the various sulphides. Samples of apparently homogeneous chalcopyrite from the Mandy ore-body carry less copper than would be expected. The polished specimens show that this is because apparently pure mineral contains many inclusions of other material. There are many fragments of wall rock granulated and impregnated with pyrite, and every sample of chalcopyrite contains crushed and partly replaced pyrite. The relation of chalcopyrite and zinc blende is that of a simultaneous crystallization. In bands that consist mostly of chalcopyrite, angular pieces of sphalerite are enclosed by the copper mineral, and the relations are reversed where sphalerite is in excess of chalcopyrite. Along the boundaries of the bands the interfingering of these two minerals is exceedingly intimate. The relations of ore minerals at Flinflon is similar, but the zinc blende commonly occurs as definite vein-like filaments in the pyrite. From this brief statement it can be seen that the probable order of events in the formation of the sulphide bodies was:

(1) Formation of openings or easily replaceable zones by folding and shearing.
(2) Introduction of pyrite (in some deposits pyrrhotite) following the early part of the granite intrusions.
(3) Fracturing of the early pyrite impregnation and introduction of the chalcopyrite and zinc blende, which in part replaced the pyrite. This probably was the final effect of the granite intrusions.

Nature of the Ore Solutions.

The secondary minerals of highly altered rocks are less noticeably altered by ore-bearing solutions than are minerals of fresher rocks. At the time of the introduction of the ores of this district the lavas of the Amisk group were already largely chloritized and the feldspars almost completely altered to sericite and kaolin with some calcite. In the wall rocks of the deposits this process has been carried still farther and secondary quartz has been formed in some quantity. From the nature of this alteration the ore solutions are inferred to be hydrothermal, probably connected with the latest emanations of the cooling granite magmas.

GENERAL CONCLUSIONS.

The ore production from this new camp is the first considerable contribution of the province of Manitoba to the metal mining industry. Conditions have been most adverse, and that so much has been accomplished in so short a time is an indication of what the country may produce under more favourable conditions. The areas of promising formations are not as large as shown by the early mapping, but there are still large districts in which thorough prospecting may be expected to uncover valuable minerals. The nature of sulphide deposits makes them less easy to discover than the more resistant quartz veins, since the latter stand out on the ridges, whereas the more easily eroded sulphide bodies are covered up in the hollows. It must be expected, however, that many of the sulphide bodies, which will with improvement of conditions be staked, will be found to be valueless. The history of ore deposition shows that the valuable copper minerals were introduced only after a second fracturing of the original sulphide lens. In pyrite or pyrrhotite lenses which were not fractured, or which, though fractured, did not receive a large supply of the last highly mineralized emanations from the cooling magma, sufficient quantities of chalcopyrite or zinc blende were not deposited to make them workable.

The known quantity of chalcopyrite that can be worked under present conditions is not large, but it is hoped that improvement of transportation facilities will increase very appreciably the amount of ore available from the deposits already discovered, and there seems to be reasonable grounds to look for the discovery of other similar deposits when the country is thoroughly prospected. Since the first discovery of sulphide ores prospecting for gold quartz veins has received little attention in the Schist Lake district. Some promising veins have been staked, but have not been examined. There is every likelihood, however, that should the gold quartz deposits of Herb lake be found to be workable there will be a revival in prospecting for gold in this western part of the belt, and possibly when the early locations on Beaver lake are cancelled for lack of work that section may receive more thorough examination of some of the more promising free gold properties.

WEKUSKO LAKE AREA, NORTHERN MANITOBA.

By F. J. Alcock.

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INTRODUCTION.

General Statement.

The season of 1917 was spent by the writer in mapping an area surrounding Wekusko lake, or, as it is more commonly known, Herb lake, northern Manitoba. Since the discovery of gold-bearing quartz veins on the east shore of the lake in 1914, a great deal of interest has been taken in the region, many prospects have been located, a considerable amount of development work done, and a mill is being erected on one property. The season's work consisted in mapping an area of 840 square miles with Wekusko lake as the central feature. Surveys of lakes and rivers were made with Rochon micrometer and surveyor's compass with telemetric surveys substituted on portages and meandering streams. The smaller lakes and streams were located from pace and compass traverse with ties to more than one fixed point wherever possible.

Acknowledgments.

Thanks are due to many of the people at Wekusko lake for information about the district, among whom especial mention should be made of Mr. R. McLeod, Mr. H. Vickers, and Mr. R. Woosey. Some fine samples of gold ore from the Northern

Manitoba property were kindly supplied by Mr. Robert Kerr. A plan of the mineral claims on the east shore of Wekusko lake was furnished by Mr. C. M. Teasdale, D.L.S.

Assistance in the field was efficiently rendered by F. M. Wolverton and M. E. Roberts.

Means of Communication.

The region can readily be reached from the town of The Pas, Manitoba, by means of the Hudson Bay railway. In September, 1917, a new government road was completed from mile 82 on the railway to the southeastern corner of the lake. This road, which is 10¾ miles in length, now forms the route to the lake, both summer and winter.

Previous Work and Surveys.

In 1896 J. B. Tyrrell made a reconnaissance survey of Grass river, and gives a description of the geology of the region in his "Report on the northeastern portion of the district of Saskatchewan and adjacent parts of the districts of Athabaska and Keewatin." In 1906 Wm. McInnes visited a portion of the area; his report on the basins of the Nelson and Churchill rivers contains a general description of the geology of the region. In 1914 a reconnaissance survey was made by E. L. Bruce from Amisk lake to the Hudson Bay railway, an account of which is given in the summary report for that year. Mr. Bruce also visited the region in 1915 and 1916, and in the summary report of 1916 a map of the shore-line of Wekusko lake, prepared from micrometer surveys made by his assistants, accompanied his report. In 1913 the eighteenth base-line was surveyed across a portion of the area by G. H. Herriott.

GENERAL CHARACTER OF DISTRICT.

Topography.

The Wekusko Lake area lies along the southern margin of the Pre-Cambrian shield where it is encroached upon by flat-lying Palæozoic sediments. The region presents the usual features characteristic of the Pre-Cambrian plateau, that is, low relief, hummocky topography, and disorganized drainage giving rise to numerous lakes, with connecting streams in which rapids and falls are numerous. Locally, however, the depressions have been modified by the deposition of post-glacial lake clay forming small plains in which outcrops are few.

The average elevation of the Pre-Cambrian shield in the area varies from about 1,000 feet, in the western part, to approximately 900 feet in the eastern part of the sheet. The highest elevation on the base-line is 1,016 feet, and few hills anywhere in the area rise above 1,100 feet. The lowest point in the area is 818 feet on Grass river. The eastward slope of the portion of the plateau contained within the sheet, determined from elevations on the base-line, is approximately 4 feet per mile.

The topography is in close harmony with the geological structure. The dominant structural trend is northeast, and is expressed topographically by parallel strike ridges. It is probable that the action of the glaciers, which moved in a southwesterly direction practically along the strike of the rocks, accentuated the pre-glacial subsequent drainage, but that structure is the controlling factor in determining the valleys is shown by the relation of the topography to the geology where the structural trend is other than northeast. Puella bay and Snow lake are two examples of marked depressions following the strike of the formations and cutting across the direction of glacial movement.

There is also a close relation between the topography and the type of bedrock. As a rule the streams and lakes lie in the softer gneisses and schists, whereas the inter-stream areas are composed of the more resistant granite. In many cases the shores of the lakes are bordered with a narrow fringe of older rocks, large areas of granite and granite-gneiss forming the interlake portions. The outlines of the lakes are frequently distinctive of the rocks outcropping along their shores. Schists and sedimentary gneisses give an extremely irregular shore-line with many small bays parallel to the strike of the rocks. Granite gives smoother outlines with bays running in all directions. Both types of shore-line are well displayed on Wekusko and Little Herb lakes. On the latter, three of the four main bays, with their numerous smaller indentations, follow the strike of the gneisses; the fourth runs in a northwest direction parallel to a granite contact. The smooth outline of the western shore of the narrow northward-extending bay is also typical of the granite areas, in contrast to the minutely irregular shore-lines of the other bays.

The portion of the area along the southern edge of the sheet, underlain by the Palæozoic sediments, is flat, the surface rising for the most part in a series of steps. The actual border of the dolomite is a low escarpment varying in height up to 70 feet. It has a very irregular outline with many deep re-entrant bays. The country to the north consists to a great extent of muskeg in which small outliers are numerous.

Drainage.

The entire area lies within the drainage basin of Grass river; Wekusko lake being a mere southward extending expansion of the river. The other rivers of the district are all small and, with the exception of several small streams entering from the north, all rise within the area. Both Snow and Little Herb rivers afford good canoe routes to Little Herb, Squaw, and Snow lakes, the former being the shorter and more commonly used. Of the streams entering Grass river from the south, the largest is Wauskatasko or Carrot river. A canoe route leaving the river by a portage north of Wekusko Lake map-area leads to several lakes which drain into this river. Whitefish river, though large enough for canoe travel, is so full of log jams that it affords an almost impossible canoe route. Whitefish lake is most easily reached by making a portage of 2 miles and 8 chains from Grass river to Whitefish river, which may be ascended from this point to the lake.

Lakes and swamps Fourteen per cent of the map area is covered by lakes. They vary in size from Wekusko lake to ponds covering only a few acres. A striking feature about many of them is their length of shore-line as compared with their comparatively small areal extent. Wekusko lake has a length of shore-line of 126 miles and an area of 70 square miles; Little Herb lake a shore-line of 62 miles and an area of only 12½ square miles; Snow lake a shore-line of 14 miles and an area of only 2¼ square miles. The shores are for the most part rocky; those of Wekusko lake are especially rugged with numerous stretches of steep and even vertical cliffs. Few of the lakes are deep, Wekusko lake having a maximum depth of about 40 feet.

Much of the region is covered by muskeg; in fact, it is impossible to travel inland for any distance without traversing wet areas. The depressions between the narrow ridges are uniformly of such a character. Much of the country underlain by granite consists of knobs and small ridges surrounded by swampy country.

Glaciation.

The whole area shows abundant evidence of having been overridden by ice-sheets; the hills are rounded and everywhere striated and smoothed rock surfaces are numerous. Deposition by the glaciers was confined to the dropping of scattered erratics and to local deposits of boulder clay in the depressions and on the lee side of steep cliffs.

Glacial striæ, showing varying directions of ice movement, were observed at numerous localities throughout the area. They fall into three groups, an older set varying in direction from south 20 degrees west to south 28 degrees west, the prevailing direction being south 22 degrees west; a younger set whose direction is south 8 degrees west; and a still younger set varying from south 5 degrees east to south 7 degrees east. The facts collected confirm a previous interpretation of ice movement in the Nelson and Churchill basins.[1] The older striæ form records of the main advance of the ice-

[1] McInnes, Wm., Geol. Surv., Can., Mem. 30, 1913, p. 118.

sheet from the northeast. In its retreat the ice divided into two lobes, one of which lay north of the Wekusko Lake area and one to the east. Evidence in the area shows that an advance of the northern lobe took place producing striæ in a direction south 8 degrees west. The distinctive character of the striæ and the fact that they cross those already mentioned, show that a still later advance took place in a direction east of south recorded by the striæ trending south 7 degrees east.

Population and Industries.

The main interest in the region at present centres in the mineral properties. Next in importance comes the fishing industry. Since the building of the Hudson Bay railway winter fishing has proved profitable; the varieties caught are whitefish, pike, and pickerel. No lake trout are found in Wekusko lake, although they occur in Tramping lake. Agriculture is limited, but on five small islands in Wekusko lake there were grown in 1917 over four hundred bushels of excellent potatoes besides a large quantity and variety of garden vegetables.

GENERAL GEOLOGY.

The geological formations of the Wekusko Lake regions are arranged tentatively as follows:

Table of Formations.

Quaternary.	Recent. Pleistocene.	Peat. Lacustrine clays. Glacial drift.
Palæozoic.	Ordovician.	Dolomite.
	Great unconformity	
Pre-Cambrian.	Quartz veins. Pegmatites and lamprophyres. Granite, granite-gneiss, and more basic intrusives.	
	Igneous contact	
	Conglomerate, quartzite, paragneiss. Staurolite-garnet-schist and garnet-mica-gneiss. Quartz-porphyry. Acid volcanics and derived sericite schists. Basic volcanics (greenstone), diorite, and derived hornblende and chlorite schists.	

Basic Volcanics.

The altered basic rocks of the area consist largely of lavas which locally show well-banded flow structures. Beds of pyroclastics formed from volcanic bombs are at many places found interbedded with the flows. The texture varies considerably, often in the same flow giving gabbro, diabase, and basalt types. Under the microscope these are seen to consist largely of secondary minerals; the feldspars are largely and in some cases entirely replaced by sericite, epidote, and carbonate, and the original augite has been changed to chlorite and uralite. Ellipsoidal structure is fairly common, but few ellipses observed in the area exceed 3 feet in length. The fine-grained phases locally show an amygdaloidal structure; the amygdules vary in size up to over an inch in length and are composed of quartz, carbonate, and other secondary minerals. Included with the true surface rocks are areas of altered basic rocks, probably metamorphosed diorities and gabbros, whose relations are not definitely known.

Portions of the basic complex have been highly schisted; the common product is chlorite schist, but hornblende schist also occupies considerable areas, as, for example, along the Grass river in the eastern portion of the map-area. Though some of the hornblende schists may be of sedimentary origin, the igneous nature of the greater part of them is shown by the preservation of original ellipsoidal structure and, in thin sections, by the presence of remnants of feldspar crystals.

Along Tramping lake some sediments are mapped with the greenstone complex. The sediments include a carbonaceous slate and a narrow zone of banded iron formation. About the middle of the lake an agglomerate outcrops along the east shore and to the south a true conglomerate containing boulders of greenstone, granite, quartz porphyry, and quartz forms a narrow fringe along a portion of the same shore.

Acid Volcanics.

East of Wekusko lake is a series of acid and intermediate volcanic rocks which are important because the main gold veins of the district are located in them. These acid volcanics include quartz-porphyry, rhyolite, syenite-porphyry, and intermediate rocks of the composition of dacites. They vary in colour from light grey to dark grey and in texture from hard, massive types to highly schistose sericitic varieties. They had their origin largely as volcanic flows, interbedded with numerous bands of pyroclastics and some true sediments. They seem to be practically contemporaneous with the volcanic rocks, but they may be slightly younger. Locally, more acid rocks cut the basic flows, but all are closely folded and apparently equally schistose.

Quartz-porphyry.

Along the east shore of Goose bay is an area composed of quartz-porphyry of a rather distinct type. It is associated with basic volcanics, is light grey in colour, hard, and massive, and contains large phenocrysts of blue opalescent quartz in a dense groundmass.

Garnet-mica-gneiss and Staurolite Schist.

A considerable portion of the map-area is underlain by a garnet-mica-gneiss and staurolite schist series. The commonest rock type is a grey to rusty-weathering gneiss consisting chiefly of quartz, feldspar, and biotite; garnets of almandite variety are nearly everywhere present and locally are very abundant. The gneiss in places grades into dark garnetiferous mica schist. An analysis of the gneiss shows sedimentary characteristics; the zircon and tourmaline crystals observed in thin section are rounded, and it is, therefore, probable that most of the garnet gneiss at least represents altered sediments. Locally, however, for example north of Whitefish lake, a remarkably well-banded hybrid rock has been produced by the injection of pegmatitic material along foliation planes of the gneiss.

Staurolite schist is developed in three main areas in the Wekusko Lake sheet; the first is along Crowduck bay, the second forms an oval area crossing the seventeenth base-line and Grass river north of Little Whitefish lake, and the third lies north of Snow and Anderson lakes. West of Crowduck bay the rock forms a fringe along a granite intrusion. Garnets are abundant and staurolite crystals up to 5 inches in length are even more numerous; on the east side of the bay there is a garnet gneiss containing much fewer staurolites.

In the area north of Little Whitefish lake the staurolite crystals are smaller, averaging about one-half inch in length. They are, however, very numerous and are arranged in bands, marking original bedding planes. Local thin beds of conglomerate containing rounded quartz pebbles are interbanded with the staurolite-bearing layers. The series here is extensively drag folded. Structurally, it overlies the adjacent greenstone.

North of Snow lake the staurolite schist has an extensive development. Here, also, all gradations exist between it and the typical garnet gneiss. North of Anderson lake a distinct variety occurs which was seen nowhere else in the area. Starting with the typical schist containing large staurolites, white, radiating, columnar cyanite crystals appear and gradually become more numerous southwards until the rock grades into a greenish chlorite schist with fans of cyanite aggregates standing out on the weathered surface. The garnet-staurolite series in this area forms a syncline pitching to the north. It overlies the greenstone mass south of Snow lake, but has interbanded with it narrow belts of hornblende schist of apparently igneous origin.

The structural features and conglomeratic bands are sufficient proof of the sedimentary origin of the schists, and the high alumina content represented by the staurolites suggests that it was originally a clay sediment. It is probable that the gneiss represents the arenaceous phase and the staurolite schist the more argillaceous portions of a series which has suffered both contact and regional metamorphism.

Conglomerate, Quartzite, and Gneiss.

East of Puella bay is an area covered by clastic rocks, consisting dominantly of a sedimentary gneiss, with conglomeratic beds. A number of narrow bands of similar conglomerate occur elsewhere. The boulders in the conglomerate are rounded and of various rock types, consisting of quartz, granite, quartzite, greenstone, porphyry, and quartz-porphyry. They vary in size up to 2 feet in length. The series is locally schisted and in places red garnets are numerous in the matrix and even in some of the boulders. Some slate is associated with the coarser-grained rocks. The finer-grained portion is fairly well-bedded and nearly everywhere crossbedded, the crossbedding being of an extremely irregular type suggestive of an æolian origin; ripple-marks are found locally. The series has high, in places vertical, dips, but it is nearly always comparatively easy to recognize the top and bottom of the series and in places to determine the direction from which the materials have been derived. Much of the finer-grained portion resembles the typical garnet gneiss. It is placed higher in the series, however, on account of the conglomerate beds containing boulders of rock similar to those exposed in the region, and also because it is slightly less metamorphosed.

Structural Relations.

All the above-mentioned rocks, both igneous and sedimentary, have been folded and sheared and intruded by granite. In most places the relations of the various types are difficult to determine on account of the mantle of clay and muskeg in the depressions where the contacts are usually to be found, but at a number of places suggestive features were observed. West of Snow bay, hornblende schist is found interbedded with garnet gneiss; the preservation of original ellipsoidal structure is evidence of the volcanic origin of the schist. Along the west shore of Crowduck bay ellipsoidal andesite is found interbanded with staurolite schist. The bedding of the schist, as marked by the lines of staurolites, follows the contact with the lava flows. The latter contain no staurolites, and being only 1 to 2 feet in width are too narrow to be infolded bands. East of Wekusko lake the acid volcanic rocks are interbanded with true conglomerates, with no evidence of an unconformity beyond the presence of boulders in the sediment. No evidence was found that any of the boulders had been schisted before their inclusion in the conglomerate. The relations suggest, therefore, that there is a thick series of sediments and volcanic flows of composition varying from basic to acid, folded and intruded by granite batholiths. That there was an older series of rocks is shown by the presence of granite and quartzite pebbles; it is, therefore, possible that most of the basic volcanics of the area form the oldest rocks of the region and were intruded by granite before the deposition of the sedimentary series, but if such were the case and if this older granite is represented in the area it has not been found possible as yet to differentiate it from the younger intrusive, or to distinguish the older basic flows from those contemporaneous with the sediments. The absence of limestone, the dominance of arenaceous and feldspathic sediments, the great thicknesses, the repeated conglomeratic horizons, the presence of crossbedding and ripple-marks, and the interbedded volcanic flows point to a continental rather than to a marine origin for the series.

Granite and Granite-gneiss.

Granite and granite-gneiss cover a considerable portion of the map-area. Many varieties, differing in mineralogical and chemical composition and in texture and structure, occur. In places the granite is gneissoid, but the massive variety is more common. Mineralogically, hornblende granite, biotite granite, and binary types are found. In the Bear Creek region the granite is a coarse-grained, red variety, very massive and fresh-looking. Locally, porphyritic phases are met with along the border of intrusions, for example, on the west shore of the lake north of Loucks island, where a variety contains phenocrysts of feldspar over an inch in length. The contacts of the granitic intrusive with the older rocks are of two kinds. The first may be seen in the peninsula north of Goose bay; here the contact is a mixed zone of granite and greenstone, with large angular blocks of the latter surrounded by the granite. The whole region around Highway lake is composed of such a border zone of stoped materials. The other type of contact is excellently displayed in the rounded peninsula east of Little Herb bay. This peninsula is bordered by a narrow fringe of greenstone and staurolite schist, but the central mass is massive granite. The border of the intrusive consists of a dark, massive rock, which, under the microscope, proves to be a quartz-diorite. It has about 30 per cent green hornblende, an acid labradorite plagioclase, some orthoclase, and quartz. In places it is difficult to locate the exact contact between the dense greenstone and the border of the intrusive, although a few feet on either side the two types are entirely distinct. The central mass of the peninsula consists of typical red granite, which grades into the quartz-diorite of the border zone. A similar example of a more basic border to a granite stock may be seen in the peninsula south of Goose bay. Though it is probable that all the granite and granite-gneiss of the region is not to be referred to the same intrusion, wherever contacts with the volcanic and sedimentary rocks were observed the granite was invariably found to be intrusive.

Pegmatites and Lamprophyres.

Pegmatite dykes are numerous throughout the area. They are found in greatest abundance cutting the granite-gneiss and adjacent formations, vary in colour from red to grey, and consist of orthoclase and quartz, with minor quantities of muscovite. They vary greatly in grain, some of the larger dykes having feldspar crystals a foot in length. A few dykes contain considerable quantities of black tourmaline. North of Grass river a large dyke of coarse graphic pegmatite was seen.

Dark dykes of the composition of minettes are also found cutting the granites and all the older rocks. They are to be regarded as basic differentiates of the granite magma, complementary to the feldspathic portion represented by the pegmatites. They are usually long and narrow and extend much farther from the granitic intrusions than do the pegmatites. Though numerous, they are all too small to be mapped separately.

Quartz Veins.

The quartz veins of the region are the latest after effects of the granite intrusion. Many contain feldspar and all gradations exist between true quartz veins and true pegmatites. In some of the veins tourmaline, which is characteristically a pneumatolytic mineral of granitic origin, is abundant.

Ordovician Dolomite.

Flat-lying dolomite underlies the southern portion of the map-area; its northern boundary is an escarpment varying in height up to about 70 feet. The dolomite is thick-bedded, of a yellowish grey colour, with some of the lower beds of a reddish shade. A considerable number of fossils, chiefly corals and brachiopods, were collected. The series is separated from the Pre-Cambrian rocks by a great unconformity, and is, consequently, much younger than the ores of the district.

Pleistocene and Recent.

The Pleistocene and Recent deposits have already been referred to. Boulder clay is not abundant, being confined to depressions and the southwest sides of cliffs. Stratified clays deposited in lakes during the retreat of the Pleistocene glaciers cover much of the area. Muskegs with peat deposits are abundant in the poorer drained portions of the district.

ECONOMIC GEOLOGY.

Gold.

The ore deposits of the region which have attracted most attention are gold-bearing quartz veins. The original discovery was made in the summer of 1914 by Mr. M. J. Hackett and Mr. R. Woosey. Since that time many claims have been staked, and it is probable that a considerable amount of prospecting will be done. The following is a brief description of the more important properties of the district.

Rex.

The Rex vein lies on the east shore of Wekusko lake. It is situated close to the lake and strikes nearly parallel to the shore in a direction 20 degrees east of north. It is exposed for about 1,700 feet, varying in width to over 8 feet and rarely pinching to less than 2 feet. The country rock is a hard felsite, with interbanded conglomerate. The vein consists of white granular quartz, with younger veinlets of white vitreous quartz. Gold can be observed in hand specimens. Sulphides are not abundant, but are present in small quantities; locally, they show a banded structure. A shaft has been sunk to a depth of 117 feet and width and values have both been maintained. A mill is in process of being installed and is expected to begin operation in the spring of 1918.

Moosehorn and Ballast.

The Moosehorn and Ballast are owned by the Northern Manitoba Mining and Development Company of The Pas, Manitoba. The property consists of 90 acres, situated on the east shore of Wekusko lake, 1½ miles south of the Rex. The main lead is a quartz vein, averaging about 18 inches in width, which has been traced for a distance of over 300 feet. At the shaft, which has been sunk to a depth of 80 feet, the vein has a width of 2½ feet. The overburden yields gold readily on panning and very rich samples have been taken from the vein. Tourmaline needles are abundant in the quartz and in places they form aggregates commonly containing gold in visible quantities; arsenopyrite, pyrite, chalcopyrite, galena, and sphalerite are also present. In one specimen taken from the property a telluride, pronounced by R. A. A. Johnston to be possibly petzite, was found surrounding some of the gold particles. The property is the only one of the area which as yet has shown actual returns. A carload of ore, amounting to 57,000 pounds, was shipped to Trail, British Columbia; the returns amounted to $2,323, an average of $81.53 per ton in gold. Besides the main vein, there are other exposures of quartz on the property, which require further development.

Kiski-Wekusko.

The Kiski-Wekusko, the original discovery of the area, is situated one mile south of the Northern Manitoba Company's property. Three veins are exposed. No. 1 has a length of 700 feet, an average width of 3½ feet, and strikes north 30 degrees east, following the foliation of the biotite schist, which forms the country rock. The quartz is white to brownish and contains quantities of tourmaline, pyrite, and chalcopyrite.

No. 2 vein has a width varying up to 7 feet, and a shaft has been sunk on it to a depth of 53 feet. The schist walls are highly impregnated with arsenopyrite. No. 3 vein is narrow and sufficient stripping and trenching to determine its extent have not been done as yet.

McCafferty Claim.

The McCafferty vein lies 1½ miles east of the narrows south of Crowduck bay. The vein varies in width up to 8 feet and has been traced for over 1,600 feet. Free gold is visible in places on the surface. At the point where the shaft is being sunk the vein is divided by a horse of country rock, which is impregnated with arsenopyrite. The vein strikes 25 degrees east of north; the quartz is white and subvitreous, with small amounts of sulphides present.

Elizabeth-Dauphin Claims.

The Elizabeth vein lies 1½ miles northeast of the Rex and on the line of strike between it and the McCafferty. It has an exposed length of 800 feet and a width varying up to 5 feet, averaging about 2½ feet. It strikes 40 degrees east of north, has vertical walls, and is well defined. The country rock consists of a light-coloured rhyolite interbanded with conglomerate and cut by younger lamprophyre dykes. The quartz is white, largely of the sugary variety; the visible mineralization consists of small amounts of arsenopyrite, pyrite, and chalcopyrite. A shaft is being sunk on the vein by "The Pas Consolidated Mines."

Syndicate Claims.

The Syndicate property is situated on the south point of the peninsula northwest of Campbell island. The vein lies in greenstone schist near the contact with the intrusive granite. Both the vein and the schistosity of the greenstone are parallel to the contact. The lead has been traced for about 700 feet and averages less than 2 feet in width, but gold is found in visible quantities along its surface.

Little Herb Lake Claims.

Some development work has been done on claims on the west shore of the north arm of Little Herb lake. At the bottom of a shaft, sunk to a depth of 10 feet, four stringers unite to form a vein 2 feet 8 inches in width. The foot-wall is highly impregnated with sulphide, which carries values in gold. The hanging-wall is a ferruginous dolomite 14 inches thick, which also carries gold.

Other Claims.

Many other claims have been staked in the region and promising assays have been reported from the Nemo, Trapper, Ballard, LeRoi, Bingo, and others. Further work in stripping, trenching, and sampling is necessary to establish their values.

Summary Regarding Gold-bearing Veins.

As already shown, the quartz veins are the youngest Pre-Cambrian deposits of the region, and hence are found in all the rocks of the district, with the exception of the Palæozoic dolomite of the southern part of the area. Since the materials were derived from the granite, they are more likely to be found along the border of the intruded rock than in the granite itself. Search for gold-bearing veins, however, should not be limited to the zones immediately surrounding the exposed areas of granite, since solutions may travel considerable distances from the parent magma and since granite may underlie any of the rocks of the region at no great depth. The main veins located so far have been found either in the acid volcanic rocks or along their contacts with sediments, probably because their massive character has been favourable for preserving fissures. The smaller veins seem to have higher gold values than the larger ones. In September, 1917, a quartz lead over 100 feet wide was located on Grass river, but proved to carry insufficient gold to warrant development, although it was heavily mineralized with sulphides. There is a need yet, therefore, for detailed prospecting in the area.

Molybdenum.

Along Crowduck bay a number of veins carry small quantities of molybdenite. The largest is situated on the west bank of Grass river, about one mile above the narrows north of Crowduck bay. The vein is 3 feet wide and carries coarse masses of molybdenite, but sufficient stripping has not been done to show the extent. The vein contains feldspar and forms one of the intermediate phases between a true quartz vein and a pegmatite vein. Small quantities of molybdenite have also been found in quartz on the north arm of Little Herb lake, but there is no evidence that there are any workable deposits present.

Galena.

On the south shore of Snow lake a shear zone in a dense greenstone is impregnated with quartz, carrying considerable quantities of galena and sphalerite. At the contact with the country rock the vein matter consists almost wholly of white, translucent quartz. Towards the middle the vein is considerably mixed with a very light greyish-white, coarse to fine crystalline, slightly ferruginous dolomite. The galena is reported to carry values in silver, but the extent to which the deposit is exposed at present is very limited.

GOLD-BEARING DISTRICT OF SOUTHEASTERN MANITOBA.

By J. R. Marshall.

CONTENTS.

INTRODUCTION.

The season of 1917 was spent in the gold-bearing district of southeastern Manitoba. As the Long Lake and Halfway Lake areas received little attention in 1916 the greater part of the time was devoted to those districts, but a visit was also made to the district east of the junction of the north and south branches of the Manigotagan river and during the latter part of the season some time was spent in the vicinity of Gold lake where mining operations have been resumed.

GENERAL GEOLOGY.

Geological conditions in the vicinity of Long lake are very similar to those observed in the Gold Lake area. The oldest rocks consist of a basement complex, probably Keewatin in age, composed almost entirely of a series of lava flows with well-defined pillow structures. These are in many places intruded by quartz porphyry, quartz-feldspar porphyry, and feldspar porphyry, which constitute the gold-bearing formation of the district. All of these are abundantly intruded by hornblende granite which appears to be the youngest formation in the area. In the vicinity of Manigotagan lake and westward extensive outcrops of micaceous gneiss occur. This ranges in colour from light to dark grey and in many cases is decidedly red. It is traversed by numerous, narrow bands of red granite. No relationship has been established between the gneiss and the beds of probably Keewatin age. These gneisses have not been observed east of Manigotagan lake.

Keewatin.

Rocks of probable Keewatin age are well represented in the Long Lake area, particularly at Halfway, Cliff, Partridge, and Bulldog lakes, and in the district east of Bulldog lake. These rocks have not been recognized immediately east of Long lake, but good exposures are found along the Manigotagan river west of the next lake expansion above Long lake. These exposures form a belt which is bounded on the east by granite and on the west by granite and porphyry.

The degree of metamorphism of the original rocks of this belt depends on their proximity to the granite. Along the Manigotagan river, east of Long lake, the rocks retain some of their primary character. With the exception of local shearing, they are massive and of medium to coarse grain. The least affected types lie in the middle of the mass. Proceeding outward the massive types gradually change to schists. Near the granite the effects of the intrusion are much more noticeable and the rocks grade into a characteristic, glistening, black hornblende-schist, the foliation of which is very nearly parallel to the line of contact between the Keewatin and the granite.

Descriptions of Some Rock Types.—A considerable portion of the area north of Long lake lying between it and the north branch of Manigotagan river is underlain by volcanic rocks, some of which show distinct pillow structures and in places are faintly amygdaloidal.

The type most frequently seen is a massive or schistose, grey-green rock, with prisms of hornblende and feldspar scattered through it. About one mile west of the north end of Bulldog lake pillow structure is plainly visible on weathered surfaces of this type. Thin sections are composed essentially of common hornblende and andesine, the latter being more abundant. Orthoclase and quartz are subordinate and magnetite and long rods of apatite are accessory minerals. Associated with this type in the vicinity of Bulldog lake is an ash-grey rock, in part porphyritic, in part fine-grained and schistose. There is also a coarse volcanic breccia, consisting of angular fragments of variable size, considerably flattened, which form a rock somewhat resembling a squeezed conglomerate.

Thin sections of the porphyritic variety show phenocrysts of feldspar and hornblende in a fine-grained groundmass of feldspar, quartz, and chlorite. The feldspar phenocrysts are invariably altered to fine scales of colourless mica. None are sufficiently well preserved to be determined. Irregular grains of quartz are present and stout prisms of common hornblende altered, for the most part, to chlorite and epidote, the latter being present in large quantities. The groundmass is composed of the same minerals, feldspar predominating.

Black, glistening hornblende schist is the extreme type produced by the metamorphic action of the granite on the rocks just described and appears to be restricted to the immediate vicinity of the granite contact. The schist is well exposed on the shores of Bulldog lake, the east side of which consists wholly of hornblende schist. The rocks of much of the west shore are also of this kind, grading westward into the types described above. About one-half mile east of the north end of Bulldog lake the characteristic hornblende schist is traversed by numerous ribbon-like masses of granite, which increase in number and size until finally the rock consists of ribbons of schist enclosed in granite.

Wanipigow Series. [1]

The schists and gneisses of supposedly sedimentary origin have not been observed at Long lake or immediately north of it. Extensive outcrops of quartz-biotite and quartz-feldspar schists and gneisses occur in the immediate vicinity of Manigotagan lake. These schists and gneisses are invariably of fine texture and predominantly of a red colour. Locally, some are grey and have a pronounced sheen on the cleavage surfaces. They possess a well-defined foliation in a general east and west direction, and have dips ranging from 50 to 85 degrees north. Lithologically, they are similar to

[1] Wallace, R.C., Geol. Surv., Can., Sum. Rept., 1916, p. 175.

the schists and gneisses observed at Clearwater lake and points on the Manigotagan river. As at Clearwater lake and other points, they are intruded by many narrow ribbon-like bands of red granite, the trend of which corresponds to the direction of foliation of the schists and gneisses.

Thin sections of the gneiss show the rock to be composed principally of fresh-looking quartz and feldspar, the former predominating. The two make up four-fifths of the rock. The feldspar, which is remarkably fresh, consists of orthoclase and acid plagioclase, the latter greatly in excess. The other minerals are brown biotite, minor quantities of muscovite, and some garnet. All the minerals have pronounced elongation in the direction of foliation.

A narrow band of conglomerate, not more than one-quarter of a mile in extent, was observed at the northeast corner of Slate lake, which lies east of Long lake. The conglomerate has a thickness of about 30 feet. It consists of a grey-green matrix, distinguishable with difficulty from the matrix of the porphyry. The pebbles consist of greenstone, quartz, jasper, and porphyry fragments which greatly outnumber the others. It is intensely metamorphosed, and is unconformable on what appears to be a feldspar porphyry.

Porphyries.

Feldspar-porphyry, quartz-porphyry, and quartz-feldspar porphyry are very conspicuous formations in the area examined. They have their most extensive exposures at Long lake, where they intrude the Keewatin and are themselves intruded by granite. The porphyries are of considerable economic importance, since many of the gold-bearing quartz veins are found in them.

Lithologically, the porphyries are of fine to medium texture, grey-green in colour, and have numerous phenocrysts of quartz, or feldspar, or of both. Generally, they have a marked foliation, the direction of which is clearly shown by the courses of the streams. Locally, they have been sheared, the shear zones seen being well defined, but not exceeding 30 feet in width. Where shearing has taken place there has been partial replacement of the rock by quartz.

Locally, the porphyry grades abruptly into granite. The mineralogical composition of the two rocks is identical, and in the field it is difficult to decide whether certain phases should be assigned to the granite or to the porphyry. Intrusive relationships between the granite and porphyry are clearly shown on the trail between Long and Halfway lakes, but on lithological and structural grounds it seems best to consider the porphyry as the finer-grained aspect of the granite magma.

Thin sections of the porphyry show the rock to be composed of irregular phenocrysts of quartz and plagioclase feldspar in a felt of the same minerals. The proportion of feldspar phenocrysts to quartz phenocrysts varies considerably, some sections containing one without the other. The feldspar appears to be wholly of the oligoclase variety, and is almost entirely altered to sericite, epidote, and zoisite. Alteration has affected the groundmass similarly. There are also small amounts of chlorite, apatite, biotite, magnetite, and titanite.

Granite.

Granite occurs north of Long lake, east of Bulldog lake, and east of Garner lake, as large masses, innumerable dykes, and small bosses which penetrate the older rocks.

About three-quarters of a mile north of the east end of Long lake the granite intrudes the porphyry and Keewatin. The outcrop is approximately three-quarters of a mile in width, narrowing rapidly to the east, where it ends abruptly against the Keewatin. To the west the outcrop increases in width and is almost continuously exposed to Gold lake.

About one-half mile east of Bulldog lake the granite intrudes the Keewatin, the contact metamorphism producing a band of the glistening, black hornblende schist previously mentioned. The contact is sinuous, with a general northwest-southeast trend, and extends south of Garner lake.

In the vicinity of Long lake and westward to Gold lake the granite was studied in more detail than in the other parts of the area. Intrusion appears to have taken place along planes of foliation. This is particularly noticeable in the case of the gneisses and schists, in which there are many narrow dykes of granite parallel to the foliation.

The granite is much less sheared and foliated than the other rocks. Three principal types are distinguishable: hornblende granite, biotite granite, and a biotite granite of a decidedly red colour, which may or may not be of a different age than the other types.

The hornblende granite is a medium-grained, fresh-looking rock, with black hornblende crystals scattered through the main mass of feldspar and quartz. The amount of quartz varies considerably, in some specimens forming 20 per cent of the rock. Thin sections show oligoclase, orthoclase, hornblende, and quartz; a few crystals of apatite, zircon, and magnetite also occur.

The biotite granite is of much the same texture as the hornblende type. The effects of weathering are more pronounced. Biotite, more or less altered to chlorite, is an abundant constituent.

South of the area under consideration, Wallace[1] describes granites lithologically similar to those just mentioned, also a red granite which he considers younger than the others. The red granite, which is found at Manigotagan and Caribou lakes, intruding the gneisses and schists, is a medium-grained, reddish biotite granite, with varying amounts of ferromagnesian constituents. It has not been found in direct contact with the other types.

There is little doubt that the granite has been the mineralizing agent in the district. Gold-bearing quartz veins are found at Long lake in the granite and in both the Gold Lake and Long Lake areas the veins which have given the highest values are situated near the contact of the porphyry and the granite.

ECONOMIC GEOLOGY.

Gold-bearing quartz veins occur principally in the porphyry, but are also found in the granite and in the Keewatin rocks. Most veins are in narrow shear zones of variable width. The average width, however, is small, and the whole width of the shear zone is not replaced by vein material.

In the Long Lake area the largest veins are in the granite and the outcrops of these show larger amounts of metallic minerals than those of veins in the other rocks. Northeast of the north end of Halfway lake there are large masses of quartz in the Keewatin rocks, but they are, at the surface at least, practically barren of metallic minerals.

Numerous small veins and stringers of quartz occur in all the rocks of the area. These, however, are very irregular in length and variable in direction. In length they vary from a few inches to 1½ feet.

Two of the quartz masses of the area deserve special mention on account of their size.

About one-quarter of a mile northwest of Walton's cabin, on the trail to Halfway lake, is a vein of quartz in the granite. The trend of the vein is southeast, its maximum width 8 feet. The mass can be traced on the surface for 400 feet, and throughout this distance it has an average width of 3 feet. Pyrite is the most abundant metallic mineral and small quantities of chalcopyrite, bornite, and marcasite are present.

About half a mile northwest of the west end of Long lake there is a mass of white quartz extending in a direction south 55 degrees east. The mass can be traced on the surface for 400 feet, and has throughout that distance an average width of 35 feet. To the east the mass disappears under the muskeg. To the west masses of quartz can be seen at intervals for another 400 feet. The vein contains chalcopyrite, with lesser quantities of pyrite and small amounts of bornite and arsenopyrite.

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[1] Wallace, R.C., Geol. Surv., Can., Sum. Rept., 1916, p. 175.

MINING DEVELOPMENT.

No underground work had been attempted in the vicinity of Long lake to the close of the field season of 1917, but a small amount of surface work had been done on many prospects. Very few prospectors visited the area during the summer of 1917, and these remained for very short periods. Hence the amount of actual development work done during my stay in the area was negligible.

Active operations were resumed in the Gold Lake area in July, 1917. The Gold Pan Mining Company, Limited, of which L. H. Wolvin, of Winnipeg, is president, re-opened the Gold Seal shaft. In September, when a visit was paid to this area, a small gang of men were engaged in putting things in order for operating as soon as winter should set in. Little progress could be expected until that time on account of the lack of fuel, which must be transported from a distance, and on account of the necessity of moving machinery from the Moose and Gold Pan properties. It was the intention of the company to develop the properties sufficiently during the winter to determine their real value. High grade ore, valued at about $1,400, was taken from the shaft of the Gold Pan mine, and this represents the total output of the district for the summer of 1917.

At Rice and Gold lakes no regular work was in progress.

Scarcity of labour, on account of war conditions, and the lack of proper transportation facilities are undoubtedly the two factors most responsible for the lack of progress in the different camps. There seems little likelihood of rapid development in the immediate future unless some new and important finds are made to stimulate interest and to attract the real prospector.

STAR LAKE AREA, MANITOBA.

By J. R. Marshall.

INTRODUCTION.

According to instructions, the writer visited the Star Lake gold area in June to collect samples so that assays might be made to ascertain the mineral content of the veins of that district. At that time there was no actual work in progress and there were only two prospectors in the area. To these gentlemen, Mr. David Guthrie and Mr. Neil Martin, the writer is indebted for courtesies extended.

LOCATION.

Star lake is in the province of Manitoba, approximately 5 miles southwest of Ingolf, which is on the main line of the Canadian Pacific railway. The actual mineral belt extends south and west of Star lake, also north and east to the Canadian Pacific railway and beyond.

Star lake may be easily reached from Ingolf by way of a chain of small lakes with only two short portages, so that transportation facilities are extremely favourable for prospecting and early development work.

CLAIMS.

A number of claims were visited, but as several of these are close to one another only four samples were collected. Samples were taken from the following properties.

Penniac Gold Reef Mine.

The Penniac Gold Reef mine is located approximately three-quarters of a mile southwest of Star lake. The country rock is hornblende granite and conglomerate, the former, so far as could be determined from the small area examined, intrusive into the conglomerate. The ore-bearing body is a quartz vein in granite close to the contact with conglomerate. A shaft has been sunk on the vein to a depth said to be 65 feet. The ore removed from the shaft has so obscured the surface extension of the vein that it is impossible to determine its dimensions. A supposed continuation of the vein outcrops about one-quarter of a mile south of the shaft, hence the general trend of the vein is north and south. A sample was selected from the dump, but, as this has doubtless been picked over many times, such a sample could not be considered as representing the true value of the vein. The assay of this sample gave 0·24 ounce per ton of gold, a trace of platinum, and a trace of silver.

Sunbeam Group.

This group of claims is located south of Star lake and east of the Penniac. Here a dyke of hornblende granite intrudes an older granite, only the southern wall of the dyke being exposed. It trends in a general northeast-southwest direction, and an area 200 feet east and west by 100 feet north and south has been uncovered. Both dyke and country rock have been mineralized by pyrite, bornite, and chalcopyrite. A pit about 8 feet in depth has been opened up in the dyke and from this pit a sample was taken. The following assay was obtained: gold, 2·75 ounces; silver, 0·15 ounce; platinum, a trace.

Waverley Claim.

The Waverley claim is situated one mile south of Star lake. In this vicinity there are several veins and stringers of milky quartz in the granite, all trending in a general north and south direction. The vein exposed on the Waverley appears to be the largest, having a maximum width of 4 feet. For a distance of 30 feet it averages 1 foot in width. A sample gave the following assay: gold, 0·8 ounce; traces of platinum and silver.

Gold Coin Claim.

The Gold Coin claim is situated immediately north of the Waverley. The ore-body is a quartz vein in the granite, the quartz partly replacing a small shear zone. The maximum width of the vein does not exceed 3 feet, and its extension can be traced for a distance of 60 feet in a north and south direction. The metallic minerals of the vein and wall rock are pyrite and arsenopyrite. The sample selected gave the following assay: gold, 2·30 ounces; platinum, 0·10 ounce; silver, a trace.

MOLYBDENITE, NEAR FALCON LAKE, MANITOBA.

By E. L. Bruce.

CONTENTS.

INTRODUCTION.

The region in the vicinity of lake of the Woods has been prospected for many years; but, although money and effort have not been spared, the results on the whole have been disappointing. Attention has been paid almost exclusively to gold quartz veins, and although those so far worked have proved to be very irregular in size and inconsistent in their values, there still seems to be hope of finding payable deposits of this type. Recently claims have been staked for molybdenite in Manitoba near the Ontario boundary. The claims lie in tp. 9, range 16, W. 1st mer. Falcon lake, a body of water of considerable size, draining into Shoal lake and thence into lake of the Woods, lies just south of the locations. In summer Falcon lake can be reached from Ingolf, a station on the Canadian Pacific railway just east of the Manitoba-Ontario boundary, by a canoe route that leads through Long Pine and West Hawk lakes, and there is another good water route, by way of the Falcon river, from Shoal lake, where the Greater Winnipeg Water District railway terminates. In winter there is good connexion with the railway by road. Summer roads could be built without great expense.

The country has the typical, broken, lake-dotted character of the Pre-Cambrian, and has somewhat greater relief than most areas of similar rocks in Canada.

Three days were spent by the writer in the district, and although accompanied by Mr. W. J. Gordon, who is thoroughly acquainted with it, the time was altogether too short to make a satisfactory study of the geology. Moreover, work was very seriously hindered by snow, which left only cliff faces and hummocks exposed. The writer has, however, had access to a private report by Geo. Hanson, to the published reports of Parsons on the lake of the Woods district, for the Ontario Bureau of Mines, and of R. Wallace, for the Public Utilities Commission of Manitoba. The latter report does not include Falcon lake, but deals with the Star Lake district just north of it.

GENERAL GEOLOGY.

The following is a very brief summary of the geological relations. The oldest rocks consist of a volcanic complex of schists and ellipsoidal-weathering greenstones. Involved in these are certain areas of sedimentary rocks, which have not yet been separately mapped. The volcanics, and probably the sediments as well, are intruded by a fresh, reddish to grey granite-gneiss, which forms the country rock both to the northwest and southeast of the narrow belt of basic rocks between West Hawk and Falcon lakes. Parsons [1] says of the part of this belt crossed by the Manitoba-Ontario boundary: "The Keewatin formation is here about 4 miles wide and consists of fine-grained, highly altered rocks, which show little trace in the field of their origin. The most abundant rock is biotite schist, but hornblende schist is common. Near the contact of this formation with the Laurentian on the north, the rock becomes coarser-grained and is almost granitoid in texture, though much darker, than the Laurentian gneiss with which it is in contact."

West of Finnel lake, which lies just north of Falcon lake, there are many areas of ellipsoidal-weathering greenstone. In fact, this greenstone seems to have a greater areal extent than any other Keewatin type; but, since this massive rock stands up in ridges and hence was bare at the time the district was visited, whereas the lower country, which is probably underlain by schists, was snow-covered, the predominance of the ellipsoidal lavas may have been only apparent.

Wallace states that there are areas of conglomerate, but these are not delimited on his sketch map.[2] Parsons quotes Lawson's[3] table of formations for the lake of the Woods district, but does not describe conglomerates except to say: "The agglomerates may be in many cases acidic tuffs and breccias, but as a matter of fact it is often difficult to decide whether they are conglomerates, or tuffs, or simply crushed rocks, commonly called 'autoclastic rocks'." Lawson[4] states that conglomerates are rare in the lake of the Woods district and limited in area. He considered them to be related to the volcanic agglomerates.

On the sketch map in the report by Wallace, previously quoted, a boss of granite is outlined north of Falcon lake. It intrudes the Keewatin rocks, but is considered to be different from the Laurentian granite gneiss bounding the belt of basic rocks. This is the youngest formation with the exception of areas of muskeg in undrained hollows and the small amount of glacial debris mantling the solid rock in protected places.

1 Rept. Ont. Bureau of Mines, 1912, p. 201.
2 Report to the Public Utilities Commission of Manitoba.
3 Parsons, A. L., Rept. Ont. Bureau of Mines, 1912, p. 173.
4 Geol. Surv., Can., Ann. Rept., vol. I, 1885, pt. CC, p. 50.

On the northwest side of the basic belt, near the Keewatin-Laurentian contact, a large number of pegmatite dykes of all sizes cut the older formation. Most of these are entirely within the schist and greenstone, but the largest one seen may be the pegmatitic edge of the main body of gneiss. A wide muskeg-filled valley, however, separates it from the nearest outcrop of normal granite gneiss. The pegmatites occur in a belt lying parallel to the approximate line of contact between the two formations, and, though not continuous, they form a zone about 2 miles in length north of Falcon lake. It is along this zone that claims have been staked for molybdenite.

The pegmatites consist mostly of a pink-weathering feldspar and quartz. Some of them are almost wholly feldspar, others seem to grade into typical quartz veins. In one place a pegmatite consisting of nearly equal amounts of quartz and feldspar gradually changes along its strike to a quartz vein with a feldspar border on each side, and farther along to an ordinary quartz vein. Muscovite is a fairly abundant constituent of the pegmatites and beryl is found, but is somewhat rare. Some molybdenite occurs in almost all the pegmatitic dykes of this zone. In one sample from the district native bismuth occurs associated with the molybdenite.

Although in all cases related to pegmatites, the molybdenite is found with the following physical characters.

(1) As a constituent of typical pegmatite dykes.
(2) In equigranular granitic dykes.
(3) In quartz veins.

In the typical pegmatite dykes the molybdenite occurs as crystals varying from a fraction of an inch up to 2 inches in diameter. The size of the larger individuals seems to vary according to the distance of the dyke from the parent granite mass, the larger crystals being found in the dykes close to the edge of the main granite area. In these dykes, however, the total amount of molybdenite present is not greater, and possibly is even less than in those farther from the intrusive.

In the equigranular dykes the molybdenite crystals are much smaller, occurring as small hexagonal plates rather than as the large almost equally dimensioned crystals found in the typical pegmatites.

In quartz veins molybdenite flakes are found in veinlets traversing the quartz. These veins lie near the typical pegmatites, and in some of them the veinlets are made up largely of molybdenite, with only very narrow borders of feldspar. The molybdenite does not seem to be secondary in any sense except that the veinlets are a little later in age than the quartz veins, which they cut. In type they are similar to the occurrences in the larger dykes.

The molybdenite-bearing quartz veins are not large and they contain too little of the mineral to make them workable, even if they were of sufficient size. The equigranular dykes carry more molybdenite than the other types, but all those seen were too small to be important. In the pegmatites it is very difficult to obtain an idea of the proportion of molybdenite. The crystals are scattered irregularly through the quartz and feldspar, so that a face showing no crystals may show several when a thin layer has been broken off. Ordinary sampling under such conditions is worse than useless. The only method of arriving at an accurate estimate of the content of a vein is to take out and mill a fairly large quantity. Judging from dyke material broken from the face of a small open-cut the molybdenite content is less than one-quarter of 1 per cent of molybdenite. This is in the only opening of any size made in the dykes. At this place the dyke is from 2½ to 3 feet wide and has been open-cut for 20 feet to a depth of 3 feet. The pegmatitic material breaks easily and a small quantity of almost pure molybdenite could no doubt be produced by cobbing such material, but it is doubtful if this could be done economically with so low grade a product as this seems to be. However, the accessibility of the district, the large number of well exposed dykes varying from 2 feet to 12 feet in width, and the ease with which a considerable quantity of the material could be taken out, without expensive mining machinery, make it possible that this prospect might be commercially worked at the present time.

The molybdenite content may be expected to continue fairly constant, but the depth to which the dykes extend cannot be foretold. Since they undoubtedly join the parent mass of granite below, the depth from the surface to which they reach depends upon the attitude of the granite. This can be ascertained only by drilling or by underground work.

RECONNAISSANCE SOIL SURVEY OF THE AREA ALONG THE HUDSON BAY RAILWAY.

By W. A. Johnston.

CONTENTS.

INTRODUCTION.

General Statement.

The Hudson Bay railway, a Canadian Government railway, extends from The Pas, on Saskatchewan river, to Port Nelson, on Hudson bay, a distance of 424 miles. The railway runs in a general northeastern direction from The Pas and at two points crosses the Nelson river which empties from lake Winnipeg into Hudson bay and is the principal river of the region. The first crossing is at Manitou rapids, 242 miles from The Pas, and the second at Kettle rapids, 332 miles from The Pas. North of Kettle rapids the railway runs on the north side of the river and is within a few miles of the river for the greater part of the distance to Port Nelson. The railway is constructed as far as the second crossing of the Nelson river and is graded from there to Port Nelson. The town of The Pas is the terminus of a branch line of the Canadian Northern railway, and is distant from the city of Winnipeg 483 miles by rail. It is a town of about 1,500 inhabitants, and is the distributing centre for a large part of the country lying north of the Saskatchewan river.

During the past season a reconnaissance soil survey was made of the belt of land lying immediately along the Hudson Bay railway for 350 miles from The Pas to Limestone river. It was known that the central portion of this railway traversed a "clay belt," which probably has agricultural possibilities of considerable importance, but little information was available regarding the actual extent along the railway of the possible agricultural lands.

Acknowledgments are due to the resident engineers, government officials, and members of the construction corps of the Hudson Bay railway for information freely given and assistance rendered during the prosecution of the field work along the Hudson Bay railway. As a source of information regarding altitudes along this railway the profile of the railway has been utilized. The altitudes thus obtained have been checked by the results of precise levelling furnished by the Topographical Surveys Branch of the Department of the Interior. Precise levels have been carried by this branch along the Hudson Bay railway from The Pas for 242 miles, as far as Manitou rapids on the Nelson river. Sectional maps, sketch maps, and profiles of base-lines and meridians of the area along the railway, published by the Department of the Interior, Ottawa, have also been utilized.

Previous Work.

The results of work published prior to 1911 and dealing with the general region of which the area along the Hudson Bay railway forms a part, have been summarized, and a general bibliography is given by Wm. McInnes, of this department, in Memoir No. 30, entitled "The basins of Nelson and Churchill rivers," published in 1913.

Reports and papers published since that time, dealing with the region along the line of the Hudson Bay railway, include the following:

Kindle, E. M. "Notes on the geology and palæontology of the lower Saskatchewan River valley"; Geol. Surv., Can., Mus. Bull. 21, Geol. Ser. 31, 1913.

Chambers, Ernest J. "The unexploited west"; Dept. of the Interior, Ottawa, 1914.

Trémandon, A.H. de. "The Hudson Bay road" (1498-1915); Dent, London and Toronto, 1915.

Tyrrell, J.B. Presidential address, "Notes on the geology of Nelson and Hayes rivers"; Trans. Roy. Soc., Can., 3rd. ser., sec. IV, vol. X, June, 1916. Discussion of papers; Bull. Geol. Soc. Am., vol. XXVIII, No. 1, March, 1917, pp. 146-147.

Cormie, John A. "The Hudson Bay route"; The Geog. Review, published by the Am. Geog. Soc. of New York, July, 1917, pp. 26-40.

Campbell, J. A. "Northern Manitoba"; The Pas, Man., Nov., 1917.

GENERAL CHARACTER OF THE REGION.

Climate.

General Statement. Records of meteorological observations at The Pas, published by the Meteorological Service of Canada, are available for seven years from 1910 to 1917, and at Port Nelson for nearly two years, during 1916 and 1917. Records of maximum and minimum temperatures during the summer months of 1917 at Kettle rapids have been furnished by Mr. T. B. Campbell, divisional engineer on the Hudson Bay railway. Records of maximum and minimum temperatures of the central part of the region during parts of 1906 and 1908 are given by Wm. McInnes, of this department.[1]

Precipitation. The total annual precipitation (rainfall and melted snow) at The Pas for the years 1911 to 1916, inclusive, varied from 8·60 inches to 18·89 inches, the average being 15·14 inches. This average is nearly 5 inches less than that of Winnipeg. The summer rainfall, however, is nearly as great as that of Winnipeg. The average rainfall for June, July, and August for seven years is 7·23 inches, that of Winnipeg for the same period of time being 7·87 inches. The average annual snowfall is about 35 inches. No records of precipitation at other points in the district, except at Port Nelson, are available. The records at Port Nelson for two years show that apparently the average precipitation is slightly less than at The Pas.

The small amount of the average precipitation is in reality favourable to agriculture in this region, for although the rainfall is small a large part comes during the growing season when it is most required, and a small amount is sufficient because a large amount of moisture is supplied by capillary action from ground-water and ground-ice. The small amount of precipitation also favours the possibilities of artificial drainage in the large areas, which are deficient in natural drainage and are swampy in character.

Temperature. The most important climatic factors in relation to agriculture in this region are the mean temperature of the growing season and length free from killing frosts. The following table shows the average monthly mean temperature at The Pas for the months of May to September, inclusive, for seven years from 1910 to 1917. For the sake of comparison, the average monthly mean temperatures for the same period of time at Edmonton, Alberta, and Prince Albert, Sask., are added.

[1] Geol. Surv., Can., Mem. 30, 1913, p. 14.

Monthly Mean Temperatures, Degrees F., May-September, 1910-1917.

—	May.	June.	July.	Aug.	Sept.
The Pas	47·6	58·6	63·9	59·9	48·7
Edmonton	51·0	57·7	60·5	60·0	50·0
Prince Albert	50·1	59·0	62·2	59·2	49·2

The average monthly mean temperature for June, July, and August (the principal growing months in this region) is somewhat higher at The Pas than at Edmonton or Prince Albert, the average temperature at The Pas being 60·6, at Edmonton 59·4, and at Prince Albert 60·1. The average monthly mean temperature for the five months, May to September, is only slightly less at The Pas than at Edmonton or Prince Albert, the average at The Pas being 55·74, at Edmonton 55·84, and at Prince Albert 55·94. During the years 1910 to 1917, inclusive, no killing frosts occurred at The Pas in June, July, and August. In 1916 no killing frosts occurred from May 14 to September 15, giving a growing season free from killing frosts of 123 days, which was 5 days longer than that of Winnipeg for the same year. In 1917 the last killing frost in the spring was on May 30, and the first in the autumn on October 3.

Regarding summer temperatures of the central part of the region, including the greater part of the "clay belt," the observations of Wm. McInnes show that in 1906 the mean temperatures for July and August, in Burntwood and Grass River valleys, somewhat exceeded the average for July and August for the past seven years at The Pas and were nearly as high as those at more southerly points in Manitoba in the same year.

In the northern part of the region the mean summer temperatures are considerably lower than those at The Pas, as is shown by a comparison of the records of temperature at Kettle rapids and at Port Nelson with those at The Pas. The average monthly mean temperature for June, July, and August in 1917 at The Pas was 60·8 degrees, at Kettle rapids 53·4 degrees, and at Port Nelson 50·2 degrees. In 1916 the mean summer temperature at Port Nelson was 52·3 degrees and at The Pas 62·3 degrees. During both those years the mean summer temperature at The Pas was somewhat above the average for seven years. Hence it seems reasonable to conclude that the average mean summer temperature of that portion of the region along the railway, extending from Kettle rapids to Port Nelson, is 7 to 10 degrees lower than that of The Pas.

The meteorological records show that temperatures during the growing season are as favourable at The Pas as at Prince Albert, or at Edmonton, at both of which localities, as is well known, the cereals common to temperate latitudes have been successfully grown for many years. The temperature records of the central part of the region cover only short periods of time, but the fact that garden vegetables have been successfully grown at several points for many years, together with the evidence of comparatively high summer temperature and the large amount of sunshine, owing to the length of summer days, have led those best acquainted with the region to conclude that the central part, extending at least as far as the valley of the Nelson river at Manitou rapids, is climatically suited for the growth of the hardier cereals.[1]

Topography.

Relief. The region traversed by the Hudson Bay railway may be divided into three portions of different physical character, a southern part underlain by Palæozoic

[1] Tyrrell, J. B., Geol. Surv., Can., Ann. Rept., vol. XIII, pt. F, p. 7. McInnes, Wm., Geol. Surv., Can., Mem. 30, 1913, p. 13.

limestone thinly drift-covered, a central part underlain by Pre-Cambrian crystalline rocks partly concealed by drift deposits, and a northern part in which the bedrock is almost entirely concealed by drift. The surface of the region as a whole is of varying relief, but for the most part of very low relief, and, excepting in the southern part, near the Saskatchewan river, it has a general slope towards Hudson bay. For 110 miles northeast from The Pas the country is underlain by nearly flat-lying limestone, which is exposed at the surface over large parts of the area. The surface of the limestone is nearly level, but in places low limestone cliffs and ridges of boulder clay interrupt the general evenness of the surface. A low ridge of boulder clay crosses the Saskatchewan river at The Pas and rises 30 to 40 feet above the level of the river. Drift ridges of low relief also occur near Clearwater lake from mile 13 to mile 21 and near mile 31. At The Pas the general altitude of the surface is 880 to 900 feet above the sea. At mile 59½ from The Pas the highest point on the railway is reached at an altitude of 962 feet. Beyond this point the limestone surface descends by a series of low escarpments 10 to 15 feet high, until the contact of the limestone with the Pre-Cambrian rocks is reached near mile 110 at an altitude of about 800 feet. From mile 110 to near the second crossing of the Nelson river at Kettle rapids the country is underlain by Pre-Cambrian rocks, which are, however, in large part concealed by drift deposits. In places numerous outcrops of Pre-Cambrian rocks occur and have the low relief and irregular mammillated surface characteristic of much of the Pre-Cambrian region of northern Canada. The general surface is somewhat undulating and has greater local relief than it has in the area underlain by limestone, or in the northern part, where the drift deposits are thick, but nowhere do the hills rise more than 200 feet above the valleys, and the average local relief is less than 100 feet. The area extending for about 100 miles from the south end of Setting lake to the valley of the Nelson river at Manitou rapids has the greatest local relief of any part of the area, and hence a large part of its surface is naturally drained. Much of the surface is occupied by lake clays, which form a mantle over the undulating surface of the Pre-Cambrian rocks and conform somewhat to the general surface of the underlying rocks, which they largely conceal. The general altitude of the upland surface is 700 to 800 feet and the valleys are 50 to 100 feet lower. The area extending for 90 miles from Manitou rapids to the second crossing of the Nelson at Kettle rapids is, for the most part, of low relief, bedrock outcrops are not numerous except in the southwestern part, and much of the surface is nearly level and swampy in character. At Manitou rapids the valley of the Nelson river is narrowed and is 120 feet deep, the general altitude of the upland being about 700 feet. Ten miles northeast of the river crossing the general altitude is 50 to 75 feet higher. Beyond this point the surface gradually declines until the second crossing of the Nelson is reached. In places drift hills, or ridges, occur, rising 20 to 50 feet above the general level. The most prominent series of drift ridges extend for about 8 miles southwest of Kettle rapids. These ridges have a general altitude of 450 to 500 feet above the sea and form the southwestern edge of the deeply drift-covered northern part of the region. At Kettle rapids the valley of the river is cut chiefly in drift deposits, bedrock being exposed only in the bottom of the valley. The main valley is nearly a mile wide and is about 100 feet deep. From Kettle rapids for 20 miles to Limestone river the surface is remarkably even. The surface declines from an altitude of 430 feet, 2 miles northeast of Kettle rapids, to 300 feet at Limestone river. No hills occur, and the even sloping surface is interrupted only by an occasional low gravel ridge, or by narrow trench-like stream valleys, and, except for narrow strips along the streams, is very largely swampy in character. The drift deposits in this part of the region probably average nearly 100 feet in thickness, and completely conceal the bedrock except in the valley of Nelson river. Limestone similar to that of the southern part of the region probably underlies a considerable part of the nearly level area between Kettle rapids and Limestone river, for it outcrops in the valley of the Nelson river at Limestone rapids and at Spruce rapids, but the even surface is largely owing to the deposition of a thick sheet of boulder clay, the somewhat irregular surface of which has been planed off by marine erosion and the depressions filled by deposition of marine sediments.

The southern part of the region, extending for 110 miles northeast from The Pas, forms part of the Manitoba lowland developed upon Palæozoic limestones. The central part, extending for about 200 miles, forms part of the Laurentian plateau, the surface of which is partly masked by glacial and glacial lake deposits. The northern part is an uplifted and slightly dissected till plain, the surface of which is, in places, somewhat modified and rendered more even by marine erosion and deposition.

Drainage. The whole area is drained by rivers flowing to Hudson bay. The southwestern part for about 60 miles northeast from The Pas drains into the Saskatchewan river, flowing southeast to lake Winnipeg. The remaining part is drained by Nelson river and its tributaries. The Nelson river is the largest river of the region and empties from lake Winnipeg to Hudson bay. Its main tributary is Grass river, the large lake expansions of the lower part of which, and its tributary, the Mitishto, or Limestone, river, are within a short distance of the railway on the north side for over 100 miles. Numerous smaller streams tributary to Grass and Nelson rivers are crossed by the railway, and the region, as a whole, but especially in its central part, is pre-eminently one of lakes and rivers. In the southern part of the region two large lakes, Clearwater and Cormorant, are touched by the railway. In the central part the most important lakes near which the railway passes are Setting, Halfway, Wintering, Landing, and Armstrong. In large areas throughout the region the surface drainage is poorly developed, and wherever the surface is nearly level swamps occur. In the northern, deeply drift-covered part of the region lakes are of less common occurrence than in the central and southern parts, the swampy undrained areas are of large extent, and the stream valleys are few in number and are steep-sided, trench-like depressions cut in the drift deposits.

Timber.

Nearly the whole of the region along the railway is wooded, but the areas in which the forest growth is large enough to be of much value commercially, except for pulpwood, are small. The principal forest trees of the region are the black and white spruce, aspen and balsam poplar, birch, and tamarack. The white spruce occurs chiefly on the fairly well drained tracts along streams and lakes, and also on the upland areas in places which have been protected from forest fires. The black spruce occurs chiefly in the swampy areas, and, on account of the wide extent of these areas, it is the predominant species of the region. It also occurs in the fairly well drained tracts where the forest growth is for the most part of a mixed character. Tamarack occurs chiefly in the swampy areas along with the black spruce. In the central and deeper portion of the swamps it is the predominant species, and in places for miles, especially in the northern part of the region, the only timber is dwarf tamarack. The aspen and balsam poplar occur most abundantly in the naturally drained clay areas. In the upland clay areas the aspen, or common, poplar is the predominant species, and has replaced the old forest growth of spruce or of mixed timber, which has been largely destroyed by forest fires. The poplar also occurs in the fairly well drained tracts along with spruce, birch, and jack-pine. Jack-pine occurs chiefly on the sandy ridges and where the bedrock outcrops at the surface or has only a thin covering of soil, but also, in places, along with spruce, birch, and poplar, in the naturally drained clay areas.

Inhabitants.

There are as yet practically no settlers engaged in agriculture in the region along the railway, except in the southern part, in the vicinity of The Pas. Small settlements have sprung up and road houses and stores have been established at a number of points along the railway in connexion with railway construction work and to meet the needs of the railway employes and those engaged in mining operations and in hunting and fishing. The largest settlement is at Pikwitonei, at mile 214, which is construction headquarters. Small settlements also occur at Thicket portage, Armstrong lake, Moose Nose yard, and Kettle rapids.

GENERAL GEOLOGY.

Pleistocene and Recent.

General Statement. The superficial deposits of Pleistocene age, which overlie the bedrock and occupy the surface over a considerable part of the area, consist of glacial till or boulder clay in the form of ground moraines and terminal moraines, and fluvio-glacial deposits in the form of esker ridges of sand and gravel, glacial lake, and marine deposits. The Recent deposits consist chiefly of organic material formed in swamps and shallow ponds and only partly altered to peat.

Glacial Striæ. Glacial striæ showing directions of ice movements in the region are of widespread occurrence and vary considerably in direction. There are at least three sets which appear to be distinct. One set, which is the most persistent, has a general southwesterly trend. Another set, trending nearly due west and distinctly later than the southwesterly bearing striæ, occurs at numerous places along the railway from Kettle rapids, on the Nelson river, nearly as far west as The Pas. In places, also, striæ bearing nearly south occur and seem to be distinct from and later than the southwesterly bearing striæ. The widespread occurrence of the westerly striæ, overriding striæ tending southwest, shows that at least a slight re-advance of the ice coming from the east took place, and this movement may have been of considerable extent. The southerly striæ also seem to indicate a slight re-advance of the ice from the north. The directions of ice movement in the general region of which the area along the Hudson Bay railway forms a part have been discussed by Wm. McInnes,[1] of this department. The observations along the line of the railway are in harmony with the conclusions reached by Mr. McInnes.

The Till Sheet. The till sheet, or ground moraine, of the glacier is thinnest and least continuous in the southwestern part of the region, gradually becoming thicker in the northeastern part. In the lower portion of the Nelson River valley it probably averages nearly 100 feet thick, and almost completely conceals the bedrock. Good sections of the till are exposed along Nelson river near the mouth of Limestone river. No definite evidence of the occurrence of more than one till sheet was found. At one place on the south side of Nelson river, about one-half mile below the mouth of the Limestone river, 80 feet of till was seen to be underlain by 6 feet of bluish-grey, laminated clay. The till at this locality is remarkable for its clayey character and for the few stones and boulders which it contains. It holds in places fragments of marine shells, and is apparently the result of overriding by the ice-sheet and incorporation in its body of previously formed marine sediments.

Terminal Moraines. Terminal moraines, marking positions of the ice-front during times of halt of the ice-sheet in its general retreat from the region, occur at only a few places. A well marked moraine, to which reference has been made in different reports on the region, crosses the Saskatchewan river at The Pas. On the south side of the river The Pas moraine extends south along the railway for about 10 miles and then turns towards the southeast. North of the river the moraine extends northeast along the east side of Reader lake and along the west side of Clearwater lake. No well developed moraines were seen along the railway from The Pas to beyond the first crossing of the Nelson river at Manitou rapids. Northeast of the Manitou

[1] Geol. Surv., Can., Mem. 30, 1913, pp. 118-123.

rapids low morainic ridges are crossed by the railway at miles 272 to 274, near Landing river, and at miles 312 and 313, near the crossing of Kettle river. The most important moraine, or series of moraines, is traversed by the railway for about 8 miles southwest of the second crossing of the Nelson river at Kettle rapids. This moraine has an average local relief of 30 to 40 feet and a general altitude of 450 to 500 feet above the sea. It is cut through by the Nelson river at the rapids above Kettle rapids and extends southward for at least several miles, its general trend being in a nearly north and south direction. The Pas moraine probably marks the westerly limit in the Saskatchewan valley of re-advance of the ice coming from the east. The Kettle Rapids moraine marks the position of the ice-front during a time of halt of the ice-sheet in its general retreat towards the east, and probably marks the position of the ice-front, which, in this region, formed the border of lake Agassiz at the time of its latest stage.

Eskers. Esker ridges of sand and gravel occur at several places in the region. The most prominent esker occurs about 10 miles northeast of Manitou rapids. The crest of the ridge has an altitude of 750 to 775 feet. The ridge is 10 to 25 feet high, trends in a general east and west direction, and can be seen from the railway for about 8 miles. Its surface is in places thinly covered by lake clay. A sandy esker is crossed by the railway at mile 286, near Moosenose lake. It has a general altitude of 650 feet and extends in a nearly east and west direction for several miles. A large esker occurs about 2 miles west of Kettle rapids and extends for nearly 2 miles on the south side of the railway. It is 10 to 50 feet high, the altitude of the highest part being about 475 feet above the sea. It is somewhat winding, but has a general east and west trend. It declines in altitude towards the west and spreads out to form a fan. The general east and west trend of the esker ridges shows that the ice-sheet in this part of the region retreated towards the east.

Lake Agassiz Beaches and Clays. Beaches formed during late stages of glacial lake Agassiz [1] are present in places in the southwestern part of the region. The best developed beach occurs near The Pas. South of The Pas this beach extends almost continuously for nearly 15 miles along the Canadian Northern railway from near Westray station to within 3 miles of The Pas. On the north side of the river at The Pas it appears again about one mile west of the railway and extends northeast. Two miles north of Westray the beach has an altitude of 898 feet, 5 miles south of The Pas it rises to 906 feet, and north of The Pas it is somewhat higher. A lower beach also occurs along the west side of the boulder clay ridge at The Pas, but this beach probably marks the shore of a local lake held up for a time by the morainic ridge at The Pas acting as a barrier to the flow of the river. At miles 109 and 110, near the contact of the Palæozoic limestone and Pre-Cambrian rocks, two well-formed beaches occur, with altitudes of 845 and 828 feet respectively. Northeast from this locality no definite lake beaches were seen. The absence of beaches in the northeastern part of the lake basin and the high altitudes at which the lake clays occur show that the lake must have been held up on the northeast, the ice-sheet acting as a dam.

Lake clays, which are the result of sedimentation in the basin of lake Agassiz during one or more of its late stages, are thickest and most widespread in the central part of the region. They also occur in river valleys and as small areas occupying depressions in the surface of the till in the southern part of the region to within about 15 miles of The Pas and in the northern part to within a few miles of Kettle rapids. They occur up to an altitude of 900 feet in the southern part of the region and down to 450 feet in the northern part. The clays are in places well stratified and occur in definite layers or bands, each layer consisting of a lower, light-coloured, silty portion and an upper, dark-coloured, clayey part. The layers are thicker in the lower than in

[1] Upham, Warren, Geol. Surv., Can., Ann. Rept., vol. IV, 1889-9, pt. E. McInnes, Wm., Geol. Surv., Can., Mem. 30, 1913, pp. 125-127. Tyrrell, J. B., Bull. Geol. Soc. Am., vol. XXVIII, No. 1, March, 1917, pp. 146-147.

the upper part of the deposits and number 150 in a thickness of 10 feet of the clay, which was the greatest thickness observed in the cuts along the railway. They are probably of greater thickness in the valleys. They form a mantle over the surface of the till, or bedrock, and roughly conform to the irregular underlying surface. In places they pass over the summits of low hills and are shown by excavations along the railway to have nearly as great a thickness on the summit as on the sides of the hills. On the higher hills the bedrock is usually exposed on the surface.

The Pas beach and the two lower beaches, 109 and 110 miles northeast of The Pas, probably mark in this region the shore-lines of lake Agassiz in its late and successively lower stages during the time of deposition of the lake clays of this region. The lake was held up on its northeast side by the retreating ice-sheet. This is shown by the facts that the land in the northern part of the region is not high enough to have acted as a barrier, and was still further depressed relatively to sea-level at the time of withdrawal of the ice-sheet.

Marine Deposits. Well formed beaches occur near the railway crossing of Limestone river at altitudes of 273, 292, and 305 feet. Between Limestone river and the Nelson River crossing at Kettle rapids there are several beaches at higher altitudes. Near the crossing of Clemens creek, at mile 340½, a beach occurs at an altitude of 378 feet. At miles 335 and 336, 3 and 4 miles northeast of Kettle rapids, beaches occur at altitudes of 413 and 388 feet respectively. The highest beach seen in the northern part of the region is crossed by the railway 2¼ miles southwest of Kettle rapids, and has an altitude of 430 feet. At Limestone river there are well developed gravel beaches. The higher beaches are poorly developed, the highest being the weakest. Fossil marine shells are abundant in the beaches near Limestone river up to an altitude of 305 feet, but no fossils shells were found in the higher beaches. It is probable, however, that they are all marine, for they form a series of successive beaches, which descend towards Hudson bay, and it is not to be expected that marine fossils would occur in the higher beaches, for uplift proceeded as the ice-sheet withdrew and a certain length of time must have elapsed after the withdrawal of the ice-sheet before migration of the marine species to this locality took place. No beaches higher than 430 feet above the sea were observed in the northern part of the region, and it is probable that 430 feet is approximately the amount of post-glacial uplift in this part of the region. Stratified marine sands underlain by a small thickness of silty clay occur in places in the northern part of the region and are well exposed in sections along Nelson river, near the mouth of Limestone river, where they have a thickness of 20 to 30 feet and fill depressions in the surface of the underlying boulder clay.

SOILS.

Distribution and General Character.

In the area immediately along the railway from The Pas to Limestone river swamp soils occupy approximately 185 miles, or 52·8 per cent of the total; boulder clay soils 27 miles, or 7·7 per cent; lake (stoneless) clay soils, 105 miles, or 30·0 per cent; esker and beach sand soils, 3·5 miles, or 1·0 per cent; and bedrock outcrop, 28 miles, or 8·0 per cent. This estimate refers only to the belt of land immediately along the railway, but probably forms an approximate estimate of the distribution of the soils in a wider belt along the railway, except that in a wider belt the water areas occupy a part of the surface, which, judging from the maps of the region, is approximately 15 to 20 per cent of the total area.

The areas which may be regarded as forming agricultural land include an undetermined, but fairly large, part of the swampy areas where the swamp deposits of moss and peat are only 1 to 3 feet in thickness and where drainage is possible, a part of the boulder clay areas where the soil is not too stony for agricultural purposes, and the lake or stoneless clay areas. The lake clay areas, which form the great part of the agricultural land, are most extensive and continuous in the central part of the region, extending for about 100 miles along the railway from about mile 130, near the south end of Setting lake, to about mile 230, near Armstrong lake. In this belt, along the railway, about 65 per cent of the surface is naturally drained clay land, nearly free from stones and with little or no covering of moss. This tract forms part of a larger area in which a considerable part of the surface is occupied by lake clays, and which extends along the railway for about 150 miles from the upper portion of the valley of Metishto river to the valley of Nelson river. The basin in which these clays occur extends northerly to the southern shore of southern Indian lake and for a considerable distance south of the railway, and is estimated to include an area of upwards of 10,000 square miles.[1]

The soils of the region are all drift soils, with the exception of the swamp soils; that is, they are developed upon superficial deposits of Pleistocene and Recent ages. These deposits are for the most part calcareous. The soils are only slightly leached and hence are calcareous in character, an important factor which tends to render them somewhat friable, prevents acidity, and promotes the formation and retention of humus in the soil. The soils are practically all timbered, but the trees are for the most part small and are not deeply rooted, hence the land is not difficult to clear.

Description.

Swamp Soils. It is characteristic of the area along the Hudson Bay railway that wherever the surface is nearly level, or gently sloping, swampy conditions prevail, and the surface is covered by a blanket of moss and peat varying in thickness from 1 to 10 feet, or even more. The swampy conditions are caused partly by the nearly level surface and poorly developed character of the drainage and partly by the nearly impervious character of the subsoil. The subsoil is nearly impervious because of its clayey character throughout a considerable part of the region, and because of the presence of ground-ice which persists wherever the surface is moss-covered until late in the summer, and in the northern part of the region is in places more or less permanent. The swamp deposits consist very largely of organic material, which, especially in the northern part of the region, is only in small part or not at all altered to peat. In places to a depth of 6 to 8 feet the organic material consists of compacted layers of moss or other vegetable matter, showing very little evidence of decomposition, its slightly altered character being apparently due to the presence of ground-ice and cold ground-water, which effectually prevent oxidation.

Of the area immediately adjacent to the railway for 350 miles from The Pas to Limestone river the swamp deposits occupy about 185 miles, or 52·8 per cent of the surface. The most extensive swamps in the area occur between the first and second crossings of Nelson river and in the northern part of the region, but numerous swampy areas of varying extent occur throughout the region. The south-central part from the vicinity of Setting lake to Armstrong lake has the smallest proportion of swamp land of any part of the area.

The swampy areas are almost entirely wooded with small spruce and tamarack. The more extensive swamps are usually sparsely timbered with stunted tamarack in their central portions. Treeless bogs, or natural hay marshes, are of uncommon occurrence. The largest treeless bog, or wet marsh, noted along the railway, begins at mile 33, near the southwest corner of Cormorant lake, and extends for several miles northeast to Little Cormorant lake. A wet marsh also extends southwest from Little Frog lake about 10 miles from The Pas.

It is possible that a part of the swamp lands will eventually be utilized for agricultural purposes, for much of the surface is shown by the railway profile to have a sufficient natural slope to permit of artificial drainage. In areas where the surface

[1] McInnes, Wm., Geol. Surv., Can., Mem. 30, 1913, p. 21.

moss and peat is only about 3 feet in thickness it has been found that after drainage and cultivation the peat largely disappears; for the bulk of the peat is greatly reduced by oxidation, and when mixed with the undersoil or mineral soil forms a soil of high fertility. Moss or peat in itself is almost valueless as a soil, and where these deposits are deep the lands are of little value for agricultural purposes. In the swamp lands of the southern and central parts of the region the swamp deposits are, in places, of considerable depth, but in large parts of the areas, especially in the central portion of the region underlain by lake clays, they are, as shown by ditch cuttings along the railway, only 1 to 3 feet in depth.

Boulder Clay Soils. The soil of the boulder clay areas consists, for the most part, of fine sandy loam, underlain by clay loam or clay, and contains in both the surface soil and subsoil stones and boulders which are, in places, numerous enough to seriously interfere with agriculture. In places, however, the surface soil is nearly free from stones. Gravelly sand and sandy loam soils also occur in the northern part of the region extending for about 10 miles southwest from Kettle rapids. The soil is calcareous throughout the greater part of the region, and is especially so in the southern part, which is underlain by limestone. The surface soil has the light colour characteristic of most timbered soils and lacks the black colour of the prairie soils, indicating a relatively lower content of organic material. In most places a thin covering of moss and other vegetal material occupies the surface and forms a supply of organic material, which, when mixed with the mineral soil by cultivation, would increase the organic content of the soil and produce a soil of high fertility. In areas which have been repeatedly burnt over the light colour of the soil is most pronounced.

The boulder clay soils occupy the surface for about 27 miles along the railway, or 7·7 per cent of the whole distance. The most important areas are in the southern part of the region, in the vicinity of The Pas, and in places for about 60 miles northeast along the railway. The largest area occurs along the south side of Clearwater or Atikameg lake, from mile 12½ to mile 21. In places in this area the limestone outcrops at the surface, or has only a thin covering of soil. Smaller areas occur at miles 8 to 9 and at miles 10 to 11 on the north side of Little Frog lake, and at miles 30 to 32 and 59 to 60. There are also a few small areas near the outlet of Cormorant lake, at mile 42.

The surface of the boulder clay areas is, for the most part, undulating or sloping. The areas are almost entirely wooded, the commonest trees being aspen and balsam poplar, birch, jack-pine, and spruce. The trees are small, for the most part not exceeding 8 inches in diameter, and are not deep-rooted, hence the land is not difficult to clear. Most of the areas have been burnt over at different times, and in places the forest has been fire-killed in recent years. Brûlé areas occur near miles 14 and 21.

Lake Clay Soils. The surface soil of the lake clay areas, which form by far the greater part of the agricultural land of the region, consists, for the most part, of greyish-brown to dark-brown clay loam or clay. The subsoil consists of greyish clay. Both surface soil and subsoil are almost entirely free from stones and boulders. The surface soil is darkened by weathering and by the presence of organic matter only to the depth of a few inches to 1 foot, and is not sharply distinguished from the subsoil into which it passes gradually and which is quite unaltered in places at a depth of 1 or 2 feet. The light colour and low organic content of the soil are most pronounced in areas which have been repeatedly burnt over. This occurs chiefly on the ridges which have been most exposed to forest fires, but over a large part of the area which is still forested the surface soil is well darkened by organic matter. The soil is somewhat calcareous and contains a considerable proportion of silt and fine sand, which, with the organic matter content, render it somewhat friable. Its highly productive character is evidenced by the luxuriant growth of the natural vegetation.

The lake clays occupy the central part of the region along the railway. The area in which the clays are most extensive and in which a large part of the surface is naturally drained extends along the railway for about 100 miles from mile 130, near the south end of Landing lake, to about mile 230, near Armstrong lake. In this distance about 65 per cent of the surface is naturally drained clay land, the balance being swamp or rock outcrop. This, however, refers only to the belt immediately along the railway. If a wider belt is considered, say 10 miles on each side of the railway, the proportion of clay land is probably about the same, except that in the wider belt the water areas occupy possibly 15 to 20 per cent of the surface. In this stretch of about 100 miles the most extensive areas of clay land occur south of Halfway lake from mile 144 to mile 158, and between Wintering and Landing lakes from mile 162 to Thicket portage, at mile 185. A fine stretch, broken only by small swamps and occasional rock outcrops, extends from Thicket portage for 20 miles to Tremaine lake, and an area of considerable size extends southwest from Pikwitonei. Southeast of Kiski and Setting lakes a part of the surface is naturally drained, but the greater part of the surface is occupied by shallow swamp deposits, which overlie the lake clays. The lake clays also occur in other parts of the region, but the extent of naturally drained clay land is more restricted. In the southern part, underlain by limestone, the lake clays occur in the valley of Mitishto, or Limestone river, which drains Limestone lake and is crossed by the railway at mile 70. Clay areas, in part overlain by shallow swamp deposits, also occur along the railway from miles 93 to 100, 101 to 103, and 105 to 109. Lake clay areas, in part naturally drained, also occur along the railway between Pikwitonei river and Nelson river at Manitou rapids. The largest areas are in the vicinity and southwest of Armstrong lake. Much of this area, however, is hilly, and numerous rock outcrops and small swamps occur. The clays occur along the valley of Nelson river at Manitou rapids, but northeast from the river there are only small detached areas. Of the total distance of 350 miles along the railway from The Pas to Limestone river, the naturally drained lake clay areas occupy about 105 miles, or 30·0 per cent of the total.

The surface of the lake clay areas is, for the most part, undulating, or sloping, and in places has a maximum local relief of 50 to 75 feet. The undulating character of the surface is most pronounced in the central part of the region, underlain by Pre-Cambrian rocks, and is the result of deposition of the lake clays over the uneven surface of the solid rocks. The original depressions have been partly filled and the general relief reduced, but a large part of the present surface has sufficient relief to give it natural drainage, or to render artificial drainage possible. In the region underlain by nearly flat-lying limestone, the surface of the lake clay areas is nearly level, and, except along the stream valleys, is poorly drained.

The lake clay areas are, for the most part, timbered with aspen and balsam poplar, birch, spruce, and jack-pine, the commonest tree being the aspen, or common poplar. Most of the trees are small and are not deep-rooted, hence the land is not difficult to clear. Most of the upland areas have been burnt over within twenty years and are now clothed with an open mixed forest of small trees. The open character of the forest permits of a luxuriant growth of native grasses, including the blue-joint and the wild rye, mixed with wild pea-vine, strawberry vines, etc. In places the forest has been recently killed by fires. The most extensive brûlé areas extend along the railway from miles 191 to 203, from 220 to 225, and from 231 to 236. Other smaller areas occur between miles 119 and 122½, from miles 182 to 183, 187 to 188, and from 226 to 228 in the vicinity of Armstrong lake.

Esker and Beach Sand Soils. The esker and beach sand soils are of small extent and are of little importance from the standpoint of agriculture, but the deposits are of importance as a source of sand and gravel for ballast, etc. The soil, for the most part, consists of gravelly sand, the surface of which is in the form of long, narrow ridges, varying in relief from 5 to 50 feet. The beach ridges are of less relief than the esker ridges. They rarely exceed 10 feet in height and are 100 to 300 feet wide, but extend considerable distances. Beach ridges occur near The Pas, on the north side of the river, and about one mile west of the railway, at miles 109 and 110, and in the northern part of the area at several places between Manitou rapids and Limestone river. Esker ridges occur chiefly in the north-central part of the region. The most important of these is about 10 miles northeast of Manitou rapids, and the railway runs along the side of it for several miles. Esker sand and gravel ridges also occur near mile 286, a divisional point on the railway, and at mile 229, near Kettle rapids.

BEDROCK OUTCROP.

The largest areas in which the bedrock outcrops at the surface, or has only a very thin covering of soil, are in the southern part of the region underlain by limestone, extending for 110 miles northeast from The Pas. Limestone outcrops at the surface, or has only a very thin covering of soil, from mile 21½ to mile 27½, between Clearwater and Cormorant lakes, along the north side of Little Cormorant lake, and at the narrows between Cormorant and Little Cormorant lakes. Outcrops also occur from miles 51½ to 53½, along the north side of Limestone lake from mile 63 to mile 67, and from mile 76 to mile 83. Numerous small outcrops also occur at other points. The areas are timbered chiefly with small jack-pine, a part of which is fire-killed. The largest brûlé areas extend from mile 21½ to mile 25 and for about 3 miles along the north side of Limestone lake. Numerous small outcrops of Pre-Cambrian rocks occur in the central part of the region. In the northern part, from about 10 miles southwest of Kettle rapids to the Limestone river, no bedrock outcrops occur except in the valley of Nelson river. Of the total distance along the railway from The Pas to Limestone river the bedrock outcrops occupy about 28 miles, or 8 per cent.

BRICK CLAY.

Clays suitable for the manufacture of common brick are of widespread occurrence in the central part of the region from near the southern end of Setting lake to the vicinity of Armstrong lake, a distance of about 100 miles. They also occur in the southern part of the region in the valley of Mitishto, or Limestone river, and as small areas occupying depressions in the surface of the boulder clay. They occur along Nelson river, at Manitou rapids, and also in places north of Manitou rapids. They are nearly uniform in character throughout the region, but are somewhat more calcareous in the southern part, underlain by limestone, than in the central part. They are practically free from stones or pebbles. Numerous cuts along the railway expose thicknesses of 6 to 10 feet of the clays overlying boulder clay, or bedrock. A sample of clay collected from a section showing a thickness of 8 feet of the clay, along the railway on the east side of Pikwitonei river, near mile 214, has been tested by J. Keele in the laboratories of this department. Mr. Keele reports as follows:

"Lab. No. 614. Drab calcareous clay from Pikwitonei river, Man., on Hudson Bay Railway line, mile 214.

"This clay has good plasticity when wet, is fairly smooth and free from coarse particles. Its working qualities are good and it might be used for making field drain tile. The clay should be dried slowly to avoid cracking.

"It burns to a hard but porous, salmon-coloured brick at ordinary temperatures, but if fired to a higher temperature it shrinks greatly and the colour becomes bad.

"This clay should be worked by the soft mud process for brick-making; the addition of about 15 per cent of sand would improve the drying qualities of the clay and reduce the drying shrinkage, which is rather high. The commercial limit of burning is about 1,800 degrees F. There are occasional grains of limestone in the clay, but if they do not run larger in the deposit than those in the sample they will not do much damage to the burned brick. If the sand in the vicinity contains limestone particles it is better not to use it."

SEMI-REFRACTORY CLAY AND PURE QUARTZ SAND OF SWAN RIVER VALLEY.

By W. A. Johnston.

In a report by J. B. Tyrrell on the geology of northwestern Manitoba, published in 1892 by the Geological Survey of Canada, a series of sandstone and shale deposits of unusual character, occurring in Swan River valley, Man., was described. At that time this part of Manitoba was almost entirely unsettled and the deposits were not considered to be of economic importance. It seemed probable, from Mr. Tyrrell's description of the deposits, that part of the sands might prove to be sufficiently pure for use in the manufacture of glass, and that part of the shale might prove to be refractory or semi-refractory in character, and hence be of value at the present time owing to the growing demand for such materials. Accordingly, at the suggestion of J. Keele, of this department, the Swan River locality was visited during the past season, the sections described by Mr. Tyrrell were re-examined, and samples of the sandstone and shale collected for purposes of testing. The samples have been tested in the laboratories of this department at Ottawa. The following is Mr. Keele's report, giving the results of the tests:

"Locality, north bank of Swan river, Manitoba, SW. ¼ sec. 10, tp. 37, range 26, W. 1st mer.

"Description, clay sample.

"Grey shale, very gritty, contains a quantity of fine sand and numerous scales of mica.

"This shale, when ground, requires only 17 per cent of water to bring it to the best working consistency. It has good plasticity and would work well in almost any kind of clay-working machinery.

"Its drying qualities are good, and owing to its sandy texture the shrinkage on drying is small, being less than 5 per cent.

"It burns to a buff colour and hard body at cone 03 (about 2,000 degrees F.). When burned to cone 8 (2,354 degrees F.) the colour is dark buff, with numerous dark fused specks. The body at this temperature is very dense, the absorption being only 2 per cent and the total shrinkage 8 per cent. The shale softens when raised to a temperature of cone 20 (2,786 degrees F.)

"This material is suitable for the manufacture of various shades of buff face brick and for hollow block for building purposes. It is probably suitable for sewer-pipe and electric conduits, and brick for boiler setting and stove linings. It is not quite refractory enough to be classed as a fireclay, but its semi-refractory qualities make it desirable for some of the above uses.

"This is the most useful clay so far discovered in the province of Manitoba.

Sand.

"The sand overlies the shale at the above locality.

"This is a fine-grained quartz sand, containing numerous grains and pellets of dark, pasty clay.

"When the sand is dry practically all of it passes through a 40-mesh screen, but the clay particles do not, so that a fairly clean separation of the clay and sand can be made.

"The following mechanical analysis shows the grain size:

Retained on 60-mesh screen, 13·70 per cent.
Retained on 80-mesh screen, 40·20 per cent.
Retained on 100-mesh screen, 25·54 per cent.
Through 100-mesh screen, 19·96 per cent.

"A partial chemical analysis made by H. A. Leverin, of the Mines Branch, shows the presence of 96·42 per cent of silica and 0·17 per cent of iron, the balance being probably alumina.

"The low iron content of the sand suggests its use for the manufacture of glass, if the texture of the sand is not too fine for this purpose."

Occurrence and Distribution of Clay and Sand.

The section from which the samples of sand and clay were obtained is exposed on the north bank of Swan river in SW. ¼ sec. 10, tp. 37, range 26, W. 1st mer., about 10 miles downstream from the town of Swan River. The section here, as described by Mr. Tyrrell, is as follows:[1]

	Feet.	Inches.
Plastic, stratified superficial clay	8	0
Unstratified clay with a few pebbles lying unconformably on and filling the irregularities in the underlying rocks (till)	8	0
Fine, white, soft, stratified Cretaceous sandstone	2	4
Fine, white, soft, stratified Cretaceous sandstone	2	2
Soft, white and light yellow sandstone with intermingled beds of dark grey clay shale	5	6
White sand and dark grey clay shale thinly interbedded	3	0
Soft, plastic, dark grey clay shale	4	6
Thin band of small fragments of lignite	0	½
Hard, lead grey clay shale weathering into rounded butte-like shapes	12	0

The sample of clay referred to in Mr. Keele's report was obtained from the clay shale at the base of the section, and is a representative sample of the lowest 10 feet. The upper 2 feet of the shale is somewhat darkened by carbonaceous material and was not sampled. At this locality the bank of the river rises steeply from the water's edge, and the successive beds are, for the most part, well exposed. The shale beds at the base weather into relief on account of their superior hardness. The shale, however, where exposed is not greatly indurated and can be readily excavated. As shown by the description of the section, the overburden at this point is considerable. Similar clay shale was found to occur as noted by Tyrrell[2] at intervals near the water's edge along the lowest terrace of the river for a distance of 1½ miles above this point. The shale probably underlies an area of several square miles, but is exposed only in the lowest part of the river valley 50 to 60 feet below the general level of the plain through which the river flows. A broad terrace 10 to 15 feet above the bed of the river borders the river in places and along this terrace the shale has the least overburden. The shale is not known to outcrop downstream from the point where the above described section occurs. It extends upstream for a distance of at least 1½ miles, the last exposure being near the southwest corner of section 9. A small outcrop of similar appearing clay occurs in a stream cutting along the townline between townships 36 and 37 at the edge of the river valley on the west side of Swan river, and about 4 miles from the town of Swan River. No samples of clay, however, were obtained from this locality, and it is not certain whether the clay is similar to that occurring at the localities lower down on the river.

The sample of sand referred to in Mr. Keele's report is a representative sample of a thickness of 5 feet of the soft sandstone beds overlying the shale. The sand is, for the most part, unconsolidated, at least where exposed at the surface, and crumbles readily under the hand. It is interbedded with thin layers one-eighth to one-half inch thick of slightly indurated clay, the sand beds being 2 to 8 inches thick. The beds of sand and clay are well defined and do not grade into each other, so that the sand is practically free from the finer material and can be readily separated from the clay by dry screening. Sands of similar character were also found to occur, as noted by Tyrrell, in sections exposed along the river about 1½ miles above this point. On the

[1] Geol. Surv., Can., Ann. Rept., vol. V, 1889-90-91, pt. E, p. 111.

[2] Ibid, p. 110 E.

north side of the river, near the southwest corner of section 9 of the same township, a thickness of 10 feet of the white sands is exposed overlain by 25 to 30 feet of sand and clay. On the south side of the river one-eighth mile downstream from the last-mentioned locality 17 feet of the sands are exposed overlain by 15 feet of alluvial sand and silt.

Accessibility and General Character of the District.

The deposits of semi-refractory clay and pure quartz sand occur in Swan River valley, in northwestern Manitoba, 9 to 10 miles northeast of the town of Swan River. The town is situated on Swan river, and is on the Winnipeg-Prince Albert branch of the Canadian Northern railway, 294 miles northwest of Winnipeg. A branch line of the Canadian Northern railway extends west from Swan river for 74 miles to Preeceville.

The district surrounding the town of Swan River and including the greater part of the Swan River valley is a well established farming district, and a large part of the land is under cultivation. The township in which the deposits occur is, for the most part, occupied by settlers, but is in part forested. The townships lying to the northeast of this township are only partly settled, and are, for the most part, well forested with aspen and balsam, poplar, birch, spruce, and tamarack.

Swan river flows in a valley 25 to 60 feet deep through a nearly level plain which slopes gently towards the northeast. The valley gradually becomes deeper downstream for 10 miles from the town of Swan River and then becomes shallower. The river is 100 to 200 feet wide at low water and 1 to 2 feet deep, flowing rapidly, for the most part, over a bed of gravel and boulders. The river varies greatly in volume between stages of high and low water. At extreme low water, at the town of Swan River, the bed of the river is nearly dry. Lower down the river, where the outcrops of sand and clay occur, the flow of the river is increased by tributary streams and by springs, and has a more uniform flow. At high water stages the river apparently rises in places as much as 10 feet.

No coal or natural gas is known to occur in this part of Manitoba, but an abundance of firewood is available. The nearest coal fields are those of the Souris valley, in southeastern Saskatchewan. Limestone of good quality outcrops near Winnipegosis, on lake Winnipegosis in the northern part of the lake, on Dawson bay, and on islands in the north end of Swan lake,[1] but is not known to occur in Swan River valley or along the Canadian Northern railway in northwestern Manitoba, except at Winnipegosis, where an outcrop occurs 1½ miles from the station, in sec. 9, tp. 31, range 18.

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[1] Ibid, p. 110 E.

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