PROVINCE OF MANITOBA

DEPARTMENT OF MINES AND NATURAL RESOURCES

HON. C. H. WITNEY
Minister

STUART ANDERSON
Deputy Minister

MINES BRANCH

J. S. RICHARDS
Director

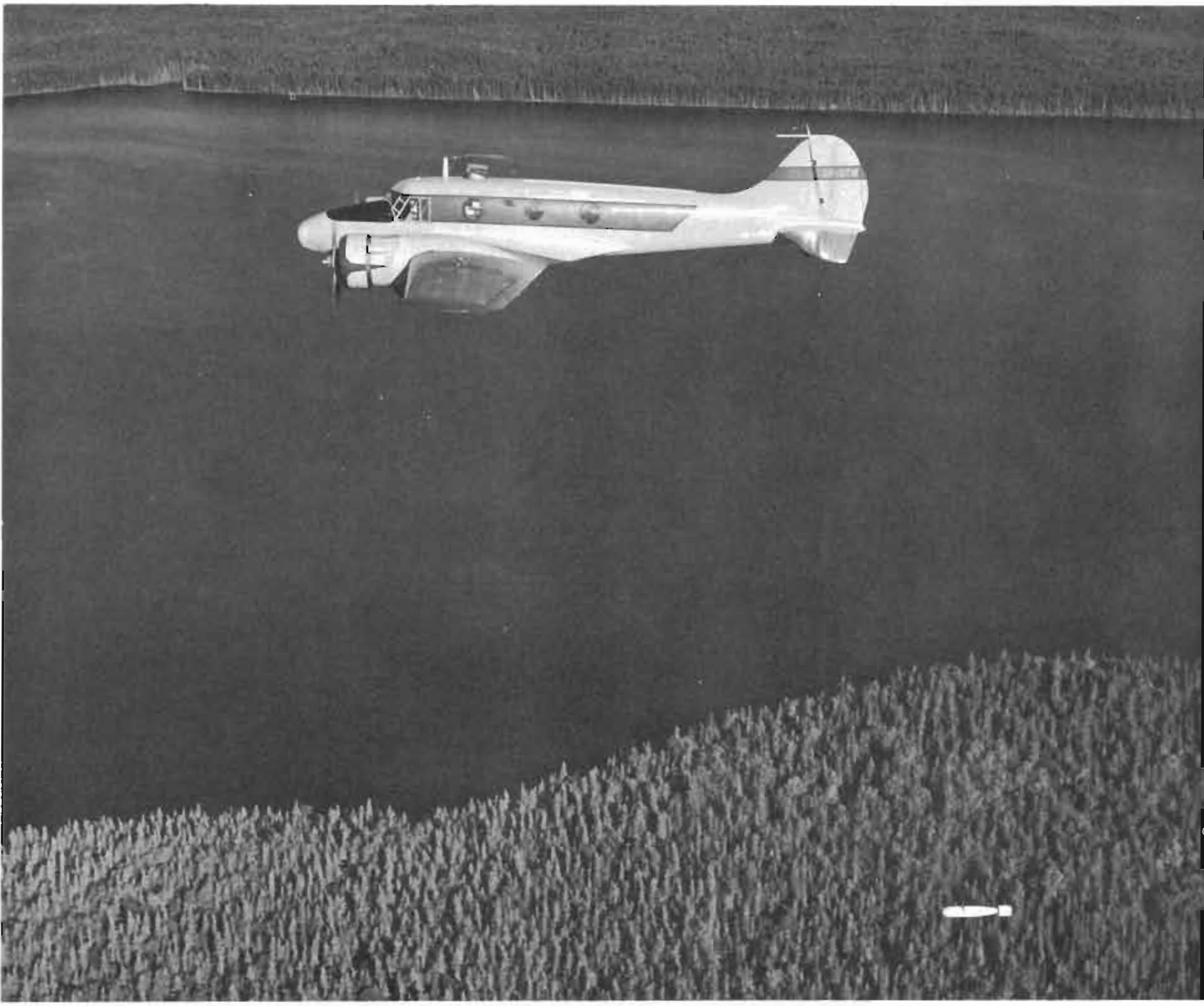
GEOLOGY AND MINERAL RESOURCES OF MANITOBA

by

J. F. Davies, B. B. Bannatyne
G. S. Barry, and H. R. McCabe

Winnipeg, 1962

Price: $1.00



FRONTISPIECE

Aeromagnetic Survey, Northern Manitoba. The detector towed at the end of the cable measures variations in the intensity of the earth's magnetic field which is locally affected by the type of underlying bedrock.

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PREFACE

In 1936 the Mines Branch prepared "A Guide for Prospectors in Manitoba." This publication dealing exclusively with Precambrian geology was widely circulated and passed through four editions, 1936, 1937, 1945, and 1952. Much new information on Manitoba geology and mineral deposits has become available since 1952 when the "Guide" was last revised. The past 10 years have witnessed the greatest surge in mineral exploration in the history of the province.

To bring the "Guide" completely up to date would require almost complete re-writing of the manuscript. This has afforded the opportunity of including, in the present book, discussion of post-Cambrian formations, non-metallic mineral deposits and petroleum occurrences. No general publication dealing with these has been available for many years.

The present publication differs greatly from the "Guide" in respect to material included, method of presentation, and general treatment. For this reason, it appears advisable to acquire an entirely new title, "The Geology and Mineral Resources of Manitoba."

Preparation of this outline has been the joint reponsibility of the four authors. Chapters I and II and brief sections of Chapters III and IV were written by J. F. Davies. G. S. Barry compiled by far the greater part of Chapters III and IV. Chapters V, VI and VII dealing with Post-Cambrian Geology, Industrial Minerals, and Petroleum, were written by B. B. Bannatyne and H. R. McCabe.

In preparing this book an attempt has been made to present information that will be of practical value to geologists, exploration companies, and prospectors, and of general interest to students and the public who seek some knowledge of the natural history and mineral resources of Manitoba.

J. F. DAVIES,
Chief Geologist.

CREDITS

Photos and illustrations have been obtained or compiled from the following sources:

Canadian Institute of Mining and Metallurgy:
"Structural Geology of Canadian Ore Deposits"
Vol. I: Figures 9, 19, 27
Vol. II: Figures 21, 23, 31

Dominion Observatories: Figure 4 (simplified)

Economic Geology: Figure 20, plan (Hanson, 1920)

Geological Association of Canada: Figures 5 and 35 (modified)

Geological Survey of Canada: Figure 20, section (Alcock, 1923); Figure 24 (Williams, 1960)

Hudson Bay Exploration & Development Co. Ltd.: Plate 2

International Nickel Company of Canada Limited: Figure 29

Manitoba Department of Industry and Commerce: Frontispiece, Plates 3, 8, 11, 12, 17, 18

Manitoba Department of Mines and Natural Resources:
Plates 1, 7, 9, 13, 14, 16, 19

Robertson, D. S.: Figure 26 (from unpublished manuscript)

Royal Canadian Air Force: Plates 4, 5, 10, 15

Sherritt Gordon Mines Limited: Plate 6

Watt, M. P.: Plate 20

NOTE: The regional geological maps, Figures 2, 8, 10, 14, 16, 17, 18, 22, 25, 28, 30, 32, 33, 34 and 37 were compiled from maps published by the Manitoba Department of Mines and Natural Resources (Mines Branch) and the Geological Survey of Canada, with some additions and deletions.

TABLE OF CONTENTS

ILLUSTRATIONS

PLATES

TABLES

CHAPTER I

INTRODUCTION

For over 200 years prior to the end of the nineteenth century the wealth coming from the northern areas of Manitoba was derived almost entirely from furs. With the decline of the fur-bearing capacity of the north, the contribution of this part of Manitoba to the provincial economy declined markedly. Serious prospecting in the province began just before World War I and the first mineral production, from the Mandy mine near Flin Flon, occurred in 1917.

Although the period around 1930 marked the beginning of significant mineral production the growth of the industry was generally slow. Central Manitoba Mines Limited started producing gold in 1927 and ceased operations in 1937. In 1930 Hudson Bay Mining and Smelting Company Limited commenced zinc and copper production at Flin Flon. God's Lake Gold Mines Limited and San Antonio Gold Mines Limited first produced in 1932; the Gods Lake deposit was mined out in 1943; San Antonio is still producing. Sherritt Gordon Mines Limited operated their copper-zinc mine for a year in 1931-32, then closed down until 1937 when operations were resumed; the orebodies were finally exhausted in 1951. Between 1931 and 1945 the annual value of Manitoba's production rose from $10,077,417 to only $14,429,423.

The first important advances in the mineral industry of Manitoba following World War II occurred in 1945 and 1946 when important nickel-copper deposits were investigated at Lynn Lake. These were brought into production in 1953 by Sherritt Gordon Mines Limited. The Howe Sound Exploration Company Limited (later The Britannia Mining and Smelting Company Limited) commenced gold production at Snow Lake in 1949. Several small copper and zinc mines were opened by Hudson Bay Mining and Smelting Company Limited near Flin Flon in 1948 and the years following. More recently the same company began developing other copper and zinc orebodies near Snow Lake.

The province enjoyed a surge in exploration activity during the period 1954-1957. Although the tempo dropped off somewhat in 1958 the level of activity has remained well above normal. In 1960 the province witnessed the official opening by Hudson Bay Mining and Smelting Company Limited of a new zinc mine near Snow Lake and the commencement of milling and refining operations at the Thompson nickel mine of The International Nickel Company of Canada Limited.

Although metallic minerals (gold, copper, zinc, nickel) account for the greater part of Manitoba's mineral production, non-metallic (industrial) minerals figure largely in the economy of the southern, more heavily populated parts of the province. Limestone, clay, gypsum, bentonite, sand, gravel, and salt, are produced in large quantities in southern Manitoba. Many of these products are used in the construction and building trades; consequently, industrial mineral production has grown gradually along with expansion of population and industrial centres.

Petroleum was first discovered in the southwestern corner of the province in 1950 and production has attained a value about equal to that of industrial minerals.

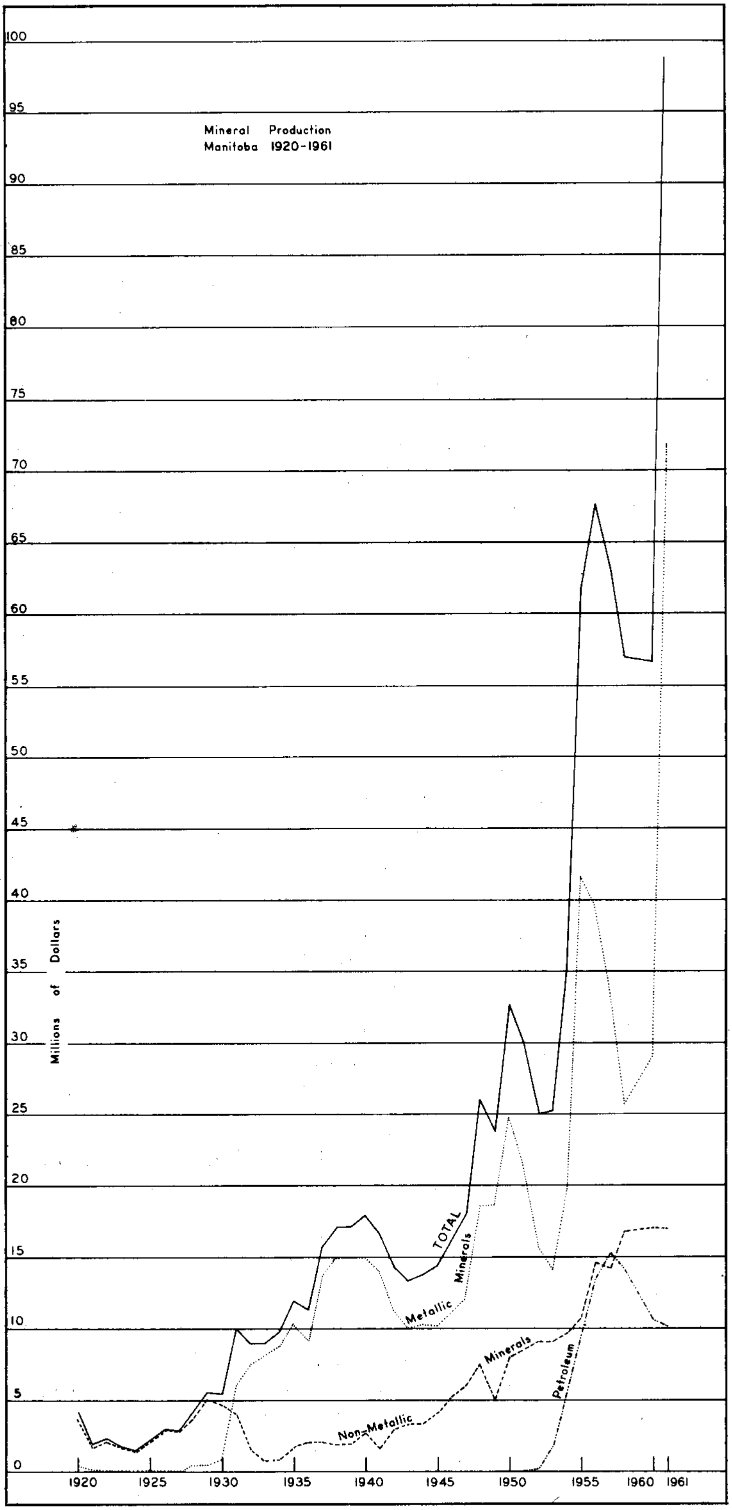


FIGURE 1 *Manitoba Mineral Production*

It can be seen, therefore, that Manitoba has a diversified mineral industry from which the entire province has profited. The value of the three classes of mineral commodities and the value of total mineral production are shown in Figure 1 for the years 1920 to 1961.

PHYSIOGRAPHIC FEATURES

The physiographic features of Manitoba reflect the types of underlying bedrock. Manitoba may be divided into four physiographic provinces. The largest of these is the Precambrian Shield which covers three-fifths of the 250,000 square miles comprising Manitoba. The Shield is a relatively flat, though hummocky, area whose elevation is less than 1,000 feet above sea-level and whose maximum relief seldom exceeds 100 feet. Rock outcrops are extensive and depressions in the surface are occupied by numerous small and large lakes and swamps.

The present peneplaned surface of the Shield represents the roots of ancient lofty Precambrian mountain systems which were eroded down and levelled off prior to deposition of the Palaeozoic rocks which overlie the Precambrian rocks west of Lake Winnipeg and around Hudson Bay.

The Hudson Bay Lowland surrounding Hudson Bay is a poorly drained area of low relief underlain by flat-lying Palaeozoic limestone resting on Precambrian rocks. Much of the country is low and swampy.

The Manitoba Lowland, also underlain by flat-lying Palaeozoic rocks, forms the surface occupied by Lake Winnipeg, Lake Manitoba, Lake Dauphin, and Lake Winnipegosis. The north and east boundary of this area is the Precambrian Shield and the west boundary is marked by the Manitoba escarpment. Most of this Lowland is low and swampy, the major exception being the area to the south of Lake Winnipeg and Lake Manitoba. Elevations vary from 700 to 900 feet above sea-level.

The southwestern part of the province is characterized by the Manitoba Escarpment, a high area of hills and valleys underlain by Mesozoic rocks. The boundary between the Lowlands and Escarpment follows closely the eastern outcrop edge of the predominantly shale formations of Cretaceous age. Several series of hills on the Escarpment have been named Porcupine Mountain, Duck Mountain, Riding Mountain and Pembina Mountains. The highest point in Manitoba is situated in Duck Mountain and attains an elevation of 2,727 feet above sea-level.

Drainage in the province is eventually into Hudson Bay. The major rivers in the south, the Winnipeg, Red, Assiniboine, and Saskatchewan, drain into Lake Winnipeg which in turn is drained by the Nelson River into Hudson Bay. The Hayes and Gods rivers drain the country northeast of Lake Winnipeg. The largest river in the province, the Churchill, drains the northern part of the province and flows into Hudson Bay at the port of Churchill. All of these rivers were once transportation routes for the early fur traders. Today, several of them are the sites of hydro-electric projects designed to serve the growing power needs of Manitoba.

GENERAL GEOLOGY OF MANITOBA

For the purposes of geological description Manitoba may be considered to consist of two main geological environments, (1) the area underlain by Precambrian rocks, and (2) the areas on which the Precambrian rocks are overlain by younger, flat-lying, unmetamorphosed sedimentary rocks of Palaeozoic, Mesozoic and Tertiary ages. These two environments differ not only in geological character but also in the types of mineral products derived from them.

The Precambrian Shield consists of large areas of granitic rocks and related gneisses in which are contained numerous smaller belts of highly folded and moder-

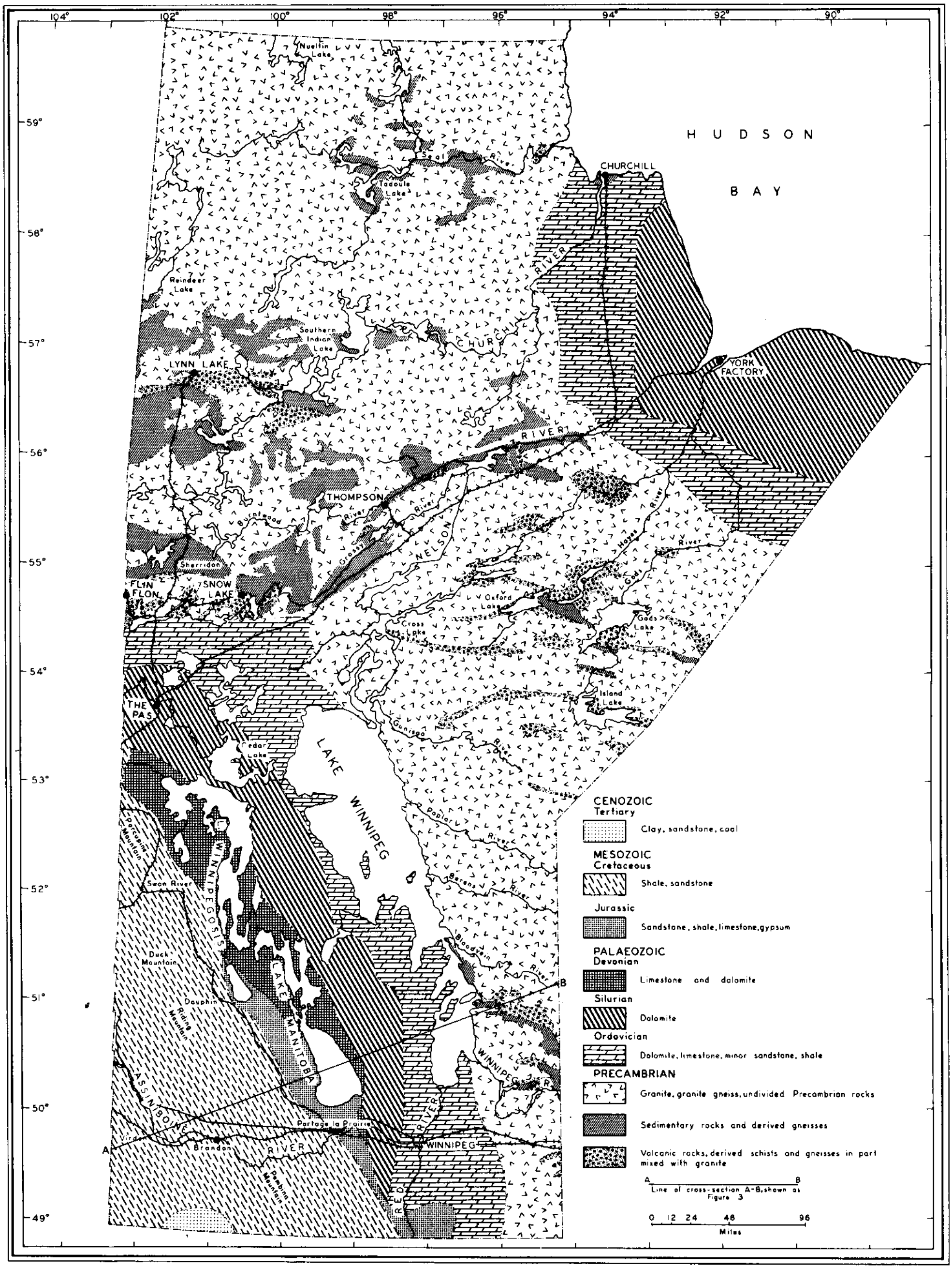


FIGURE 2 *Geology of Manitoba*

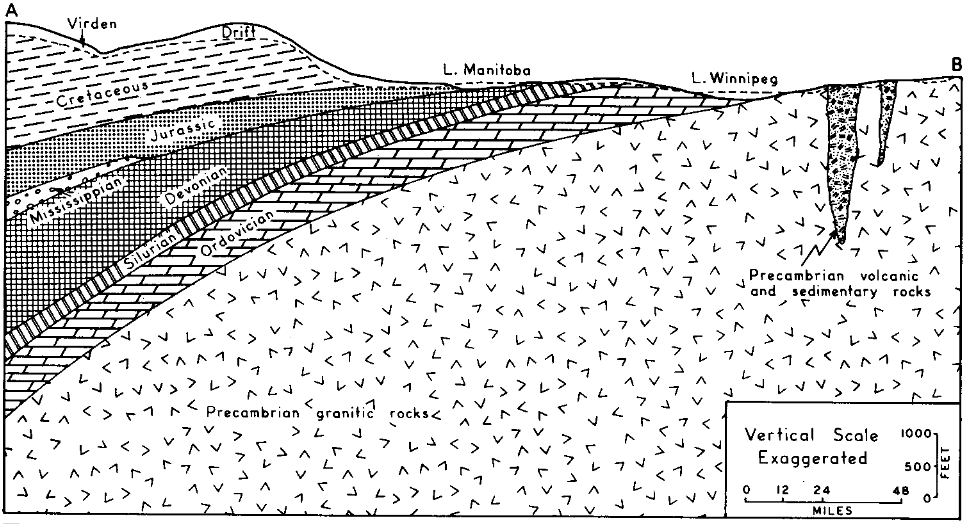


FIGURE 3 *Geological Cross-Section A-B*

TABLE 1
GEOLOGIC SYSTEMS IN MANITOBA

	ERA	SYSTEM	LITHOLOGY
	Cenozoic	Palaeocene	Shale, sandstone, minor lignite
	Mesozoic	Cretaceous	Shale, bentonite, sandstone
		Jurassic	Shale, siltstone, dolomite, anhydrite, gypsum
	Palaeozoic	Mississippian	Limestone, dolomite, shale, siltstone, anhydrite, petroleum
		Devonian	Limestone, dolomite, shale, salt, potash
		Silurian	Dolomite, argillaceous dolomite, shale
		Ordovician	Dolomite, dolomitic limestone, sandstone, shale
		Cambrian (?)	Glauconitic sandstone
Precambrian			Volcanic, sedimentary, metamorphic and granitic intrusive rocks.

ately metamorphosed volcanic and sedimentary rocks. The volcanic rocks consist of andesite, basalt and low rank chloritic schists (typical "greenstones") as well as volcanic breccias of various kinds (rhyolitic, dacitic, and andesitic in composition), and more highly metamorphosed equivalents of the volcanic types (hornblende-plagioclase schists and gneisses, some of which may be granitized). Interbedded with or overlying the volcanic rocks and derived schists and gneisses are sedimentary rocks (quartzite, arkose, conglomerate, greywacke, slate) and their metamorphic derivatives (quartz-feldspar gneisses, quartz-mica schists, etc.) In many areas the sedimentary and volcanic rocks appear to be structurally conformable or almost so; elsewhere disconformities are evident. Both series have been folded intensely and the strata lie at angles commonly ranging from 45 degrees to vertical. Numerous faults, some extending for miles, others short and narrow, cut the greenstone belts and granitic rocks. Relatively small bodies of diorite, gabbro, and peridotite invade the greenstone and sediments in most areas, and all greenstone-sedimentary belts are surrounded by large masses of younger granite and granite gneiss.

The main metals recovered from deposits in the Precambrian Shield are gold, copper, zinc, and nickel. Large deposits of lithium and chromium are known to occur in the province but production from these has not yet been achieved (1962).

The following types of mineral deposits occur in the areas listed below:

(a) GOLD: West Hawk Lake, Rice Lake, Gods Lake, Island Lake, Knee Lake, Snow Lake, Herb Lake, Lynn Lake.
(b) COPPER-ZINC: Flin Flon, Snow Lake, Sherridon, Lynn Lake.
(c) COPPER-NICKEL: Lynn Lake, Herb Lake, Bird River.
(d) NICKEL: Thompson, Island Lake.
(e) LITHIUM: Bernic Lake, Cat Lake, Gods-Knee Lakes, Herb Lake.
(f) CHROMITE: Bird River, Euclid Lake.

Post-Cambrian rocks in Manitoba consist of flat-lying Palaeozoic, Mesozoic, and Cenozoic limestones, shales, and sandstones that overlie the steeply tilted Precambrian rocks. The Palaeozoic rocks (Ordovician, Silurian, Devonian, and Mississippian) consist largely of limestones and dolomitic limestones. The Mesozoic rocks (Jurassic, Cretaceous) are mainly shales and sandstones. In the Hudson Bay Lowlands a few hundred feet of Ordovician and Silurian strata overlie the Precambrian. In southern Manitoba the thickness of the younger rocks varies from zero at the outcrop edge to over 5,000 feet in the extreme southwest corner of the province. The beds slope southwest at a few feet per mile and the various systems form long narrow northwest-trending belts.

The Palaeozoic and Mesozoic strata were not folded into mountain systems or intruded by magmas, as were the Precambrian rocks, and metallic mineral deposits are unknown in the younger rocks. Mineral products derived from these rocks consist of petroleum (Mississippian), calcium limestone (Devonian), dolomitic limestone (Ordovician, Silurian), silica sand (Ordovician), bentonite (Cretaceous), and salt (from brines in various formations). Extensive deposits of rock salt and potash (Devonian) in the western part of the province comprise a potential source for production of these materials.

Consolidated or semi-consolidated Cenozoic rocks are not widespread in Manitoba and occur only at Turtle Mountain near the southern border of the province, where they consist of sandstone and clay, with thin seams of low-rank coal. Unconsolidated Pleistocene and Recent deposits, however, are found throughout all parts of the province. In Precambrian areas the unconsolidated materials consist of clay, boulder till, sand and gravel. In many places these deposits are relatively thin and discontinuous, filling in the depressions on the rock surface.

The most extensive Pleistocene deposits in the south are glacial lake clays which were deposited in the basin of Lake Agassiz. Deposits of gravel are widespread and near Carberry sand deposits of the Assiniboine delta cover a large area. The Pleistocene and Recent deposits in the south are several tens of feet thick and cover most of the Palaeozoic and Mesozoic strata so that these are exposed mainly along the eastern edge of the Manitoba Escarpment and in the stream valleys that have been cut through the unconsolidated cover. Towards the eastern edge of the Manitoba Lowland, however, where the underlying Precambrian surface is relatively high, the overlying limestones are exposed in several places, rising a few feet above the level of the plains.

The Cenozoic (Pleistocene) deposits are of economic importance for the numerous deposits of gravel used in road building and the construction industry and for clays used in the manufacture of brick, lightweight aggregate, Portland cement, and other clay products.

The general geologic features of Manitoba are shown on Figure 2 and the succession of rock strata is outlined in Table 1. A diagrammatic cross-section (Figure 3) illustrates the relationship between the various formations.

MINERAL POTENTIAL

The most extensive program of exploration and mine development in Manitoba has taken place since 1945. Tens of millions of dollars have been spent on geological surveys, geophysical surveys, both from the air and on the ground, and on diamond drilling. These programs have resulted in some outstanding successes. New mines that have come into production since 1945 include those at Lynn Lake (nickel-copper), Snow Lake (gold, zinc, copper), near Flin Flon (zinc, copper), and Thompson (nickel).

Until 1945 little exploration was carried out north of latitude 55 degrees. Since that time the mineral frontier has been pushed north to latitude 57 degrees; it is in the area between these two latitudes that the Lynn Lake and Thompson mines are located. The northern limit of mineral exploration continues to move still farther north. Until very recently little or no prospecting had been carried out north of latitude 57 degrees. This was a result of two main factors: (1) difficult access, (2) lack of geological knowledge of the area. Only parts of the far northern regions of Manitoba have been mapped geologically and even these have been studied in only a reconnaissance manner. Indeed much of the central and southern parts of the Precambrian has been mapped only on a reconnaissance scale and there are large areas requiring more detailed investigations. This work is being carried out by the Manitoba Mines Branch and the Geological Survey of Canada but, because of the very nature of the work, progress is slow.

Numerous deposits of value will undoubtedly be discovered in the areas where little prospecting or geological mapping has yet been done. Former active areas,

A. Geologist and assistant at work.

PLATE I *B. Mid-day on a northern lake.*

such as the extensive greenstone belts northeast of the north end of Lake Winnipeg also warrant further investigation for base metal deposits; during the thirties when prospecting activity was directed to the search for gold, little attention was paid to other deposits and these areas have not been tested thoroughly with the newer tools of prospecting. Even in the well-established mining districts the newer geophysical techniques have recently disclosed numerous base metal deposits some of which have developed into producing mines.

Investigation into the economic recovery and utilization of certain mineral products may result in development of several known deposits in Manitoba. Large low-grade chromite deposits are present north of the Winnipeg River; the grade is too low and the iron:chrome ratio too high to permit, at present, competition with imported ores. Manitoba has large deposits of lithium minerals in pegmatites but markets for lithium are limited at present. Some pegmatites also contain beryllium and caesium and these may eventually be profitable to mine, the main problems being lack of market for caesium and low grade and tonnages of the beryl deposits.

Further increases in industrial mineral production may be expected. As population and industry expand the demand for clay products, sand, gravel, gypsum, and building stone will increase, although the increases may not be as spectacular as in the field of metallic minerals. Potash deposits comparable in grade to those being mined in Saskatchewan are present in western Manitoba. These may form the basis of a profitable operation. There is room for expansion in the manufacture of clay products. Few bricks are now manufactured in Manitoba; most local demand is supplied by brick imported from other western provinces of Canada. However, Manitoba has some good quality clays and shales which may be suitable for the manufacture of bricks. Deposits of kaolin, silica sand, marl, peat moss and other substances require further investigation as to uses and markets.

There appears to be limited opportunity for an increase in Mississippian oil production in the southwest part of the province. However, Devonian and Ordovician formations, which appear to offer the best possibilities for future oil discoveries in Manitoba, have been explored only to a limited extent.

SOURCES OF INFORMATION

The following chapters describe the general geologic features and mineral deposits of Manitoba. Only the essential aspects of the geological environment and brief descriptions of the various deposits in different areas can be presented in a summary of this nature. Selected references are listed in appropriate places. These should be consulted for further details. Complete lists of references may be found in the following publications of the Mines Branch:

Publication 51-1: Bibliography of Geology of the Precambrian Area of Manitoba to 1950. G. C. Milligan.

Publication 51-2: Bibliography of Geology, Palaeontology, Industrial Minerals, and Fuels in the Post-Cambrian Regions of Manitoba to 1950. Lillian B. Kerr.

Publication 57-3: Bibliography of Geology of the Precambrian Area of Manitoba 1950-1957. G. S. Barry.

Publication 57-4: Bibliography of Geology, Palaeontology, Industrial Minerals, and Fuels in the Post-Cambrian Regions of Manitoba 1950-1957. B. A. Mills.

Map 59-5: Geological Index Map of Manitoba.

Current lists of Geological Publications by the Manitoba Mines Branch.

Many published reports have been used freely in the preparation of this summary. In addition, unpublished data in the files of the Mines Branch have provided much useful information. Of particular value in the preparation of this review have been "A Guide for Prospectors in Manitoba," and "The Mineral Resources of Manitoba" by the late George E. Cole, Director of Mines from 1930 to 1945; these publications are now out of print.

Reports on Manitoba geology published by both the Mines Branch and the Geological Survey of Canada are available from the Mines Branch offices in Winnipeg and The Pas. Persons contemplating mineral exploration in the province should also obtain copies of the following regulations from the same offices:

1. Regulations under the Mines Act for the Disposal of Mining Claims and Placer Claims in Manitoba.
2. Regulations under the Mines Act for the Disposal of Quarrying Claims, Boring Claims, and Amber Claims in Manitoba.
3. Regulations under the Mines Act for the Disposal of Oil and Natural Gas Rights on Crown Lands and the Exploration, Development and Production of Oil and Natural Gas in Manitoba.

Vertical aerial photographs at various scales are available from:

NATIONAL AIR PHOTO LIBRARY
Department of Mines and Technical Surveys
OTTAWA, ONTARIO

Those readers unfamiliar with geologic terminology and methods of prospecting will find it profitable to obtain the book "Prospecting in Canada" by A. H. Lang. This is published as Economic Geology Series, No. 7, third edition, by the Geological Survey of Canada, Ottawa.

CHAPTER II

THE PRECAMBRIAN SHIELD

Investigations in the Precambrian Shield, whether geological mapping, airborne geophysical surveying, ground geophysical surveying, diamond drilling, or routine prospecting, are greatly affected by the extent of rock outcrop and amount of overburden present in various areas.

The Precambrian surface was profoundly modified by the continental ice-sheets that covered the area during Pleistocene time. The Patricia ice-sheet, centered west of James Bay, and the Keewatin sheet, centered west of Hudson Bay, advanced over Manitoba, removing surficial material and gouging out numerous basins now occupied by lakes. Melting of the ice-sheets resulted in deposition of large amounts of glacial drift. Most of this is in the form of ground moraine composed of clay-rich till. Over parts of the Shield in Manitoba stratified lake clays overlie the till. Eskers, kames, outwash plains, drumlinoid forms, and glacial flutings are common in some parts of the Precambrian.

East of Lake Winnipeg the glacial drift is thin and consists mainly of clayey boulder till occupying the hollows between rock ridges. Thin beds of stratified lake clays overlie the till in places. Northeast of the north end of Lake Winnipeg the drift is considerably thicker and rock exposures are not so abundant. There, also, the drift is largely boulder till that occurs as ground moraine, in places modified to drumlinoid and fluted forms. Drift ridges in the form of eskers, kames, and terminal moraines, and composed of poorly stratified sand and gravel, are present northeast of Lake Winnipeg. Outwash material composed largely of sand occurs to the west of some of the terminal moraines. Thick deposits of stratified glacial lake clays and silts are exposed in several places and overlie the till deposits.

Varved clays overlie the drift, again largely boulder till, in the area along and northwest of the Hudson Bay railway. North of and parallel to the Burntwood River prominent ridges of stratified sand and gravel probably represent an interlobate morainal deposit formed by melt waters at the juncture of the Patricia and Keewatin ice-sheets. North of the Burntwood River, thick deposits of glacial lake clays, overlying clayey boulder till and drift composed of sand, gravel, and boulders, extend as far north as the Churchill River. Large areas between the Burntwood and Churchill rivers contain few outcrops. However, farther west, between the edge of the Palaeozoic formations (in the vicinity of Wekusko Lake) and Granville Lake, outcrops are abundant and glacial deposits relatively thin.

Stratified clay deposits have not been reported from north of the Churchill River and it appears that this marks the northern limit of Lake Agassiz which probably covered most of Manitoba to the south. The area north of the Churchill River is characterized by thick till deposits overlain by extensive outwash plains composed of sand and gravel, eskers, kames, and other fluvio-glacial deposits. Throughout large parts of this region outcrops are scarce and confined mainly to the shores of lakes and rivers. In the south part of the region north of the Churchill

River, around Lynn Lake and as far east as Northern Indian Lake, rock exposures generally are more extensive than to the north.

The principal areas of Precambrian volcanic and sedimentary rocks in Manitoba are shown in Figure 2. The typical sequence in these areas is a dominantly volcanic series overlain by a dominantly sedimentary series. Both series have been invaded by small mafic and ultramafic intrusions and by batholithic bodies of granite and granite gneiss. Problems of correlation between different volcanic-sedimentary belts of Manitoba have been discussed by Harrison (1951). Because of difficulties in correlation, the usual practice has been to apply local names to the different series. The volcanic and sedimentary series respectively have been named Wasekwan and Sickle in the Lynn Lake area; Amisk and Missi in the Flin Flon and Herb Lake area (such names as Laguna, pre-Laguna, Wekusko, and Snow, have also been applied to these rocks in the Herb Lake area); Hayes River and Oxford in the Oxford-Knee-Gods lakes area; and Rice Lake group and San Antonio formation in the Rice Lake-Beresford Lake area. In some districts it is possible to recognize both pre-sedimentary and post-sedimentary granitic intrusions. Elsewhere only post-sedimentary intrusions are recognized.

A third series of sedimentary rocks has been suggested for certain areas; for example, at Island Lake, the Hayes River volcanic rocks were said to be overlain by a sedimentary series younger than the Oxford series and named the Island Lake series (Wright, 1928). McMurchy (1944) on the other hand, considers the Island Lake series to be equivalent to the Oxford series. A similar departure from the simple sequence of a volcanic series overlain by a sedimentary series is found in the Rice Lake district. The Rice Lake group consists of a lower volcanic series and an upper sedimentary series; both are intruded by granitic rocks and the whole assemblage is overlain by the San Antonio formation (conglomerate and feldspathic quartzite). Plutonic intrusions, although supposedly younger than the San Antonio formation, invade the "upper sedimentary series" of the Rice Lake group but are not seen to invade the San Antonio rocks.

Although the term Hayes River was extended to Cross Lake for the volcanic rocks there, the sedimentary rocks have been called the Cross Lake series. These may be equivalent to the Oxford sediments or Island Lake series if the latter is a separate stratigraphic unit.

Dawson (1952) applied the name Assean Lake series to unaltered interbedded volcanic and sedimentary rocks that he believed overlay schists and gneisses along the Hudson Bay railway. Gill (1951) considers the schist and gneisses as metamorphic equivalents of the Assean Lake sediments. Similarly, the term Great Island series has been applied by Taylor (1958) to fresh-looking quartzose sediments overlying interbedded volcanic and sedimentary rocks in the Seal River area. In neither area are sufficient data available to indicate the validity of the various proposals.

A particular problem arises in connection with the Kisseynew gneisses of the Sherridon area. These dominantly quartzo-feldspathic and hornblende-plagioclase gneisses of sedimentary origin resemble the Grenville gneisses of Ontario and Quebec except that they contain much less crystalline limestone than the Grenville. As in the case of the Grenville there is considerable uncertainty regarding the relative age of the Kisseynew rocks. They may be equivalent to both the Amisk and Missi, they may be younger than the Amisk but older than the Missi, or they may be equivalent to the Missi. A fourth possibility is that they may be separated from the Amisk and Missi rocks by a major fault (Kisseynew Lineament), in which case they could be either younger or older than both the Amisk and Missi.

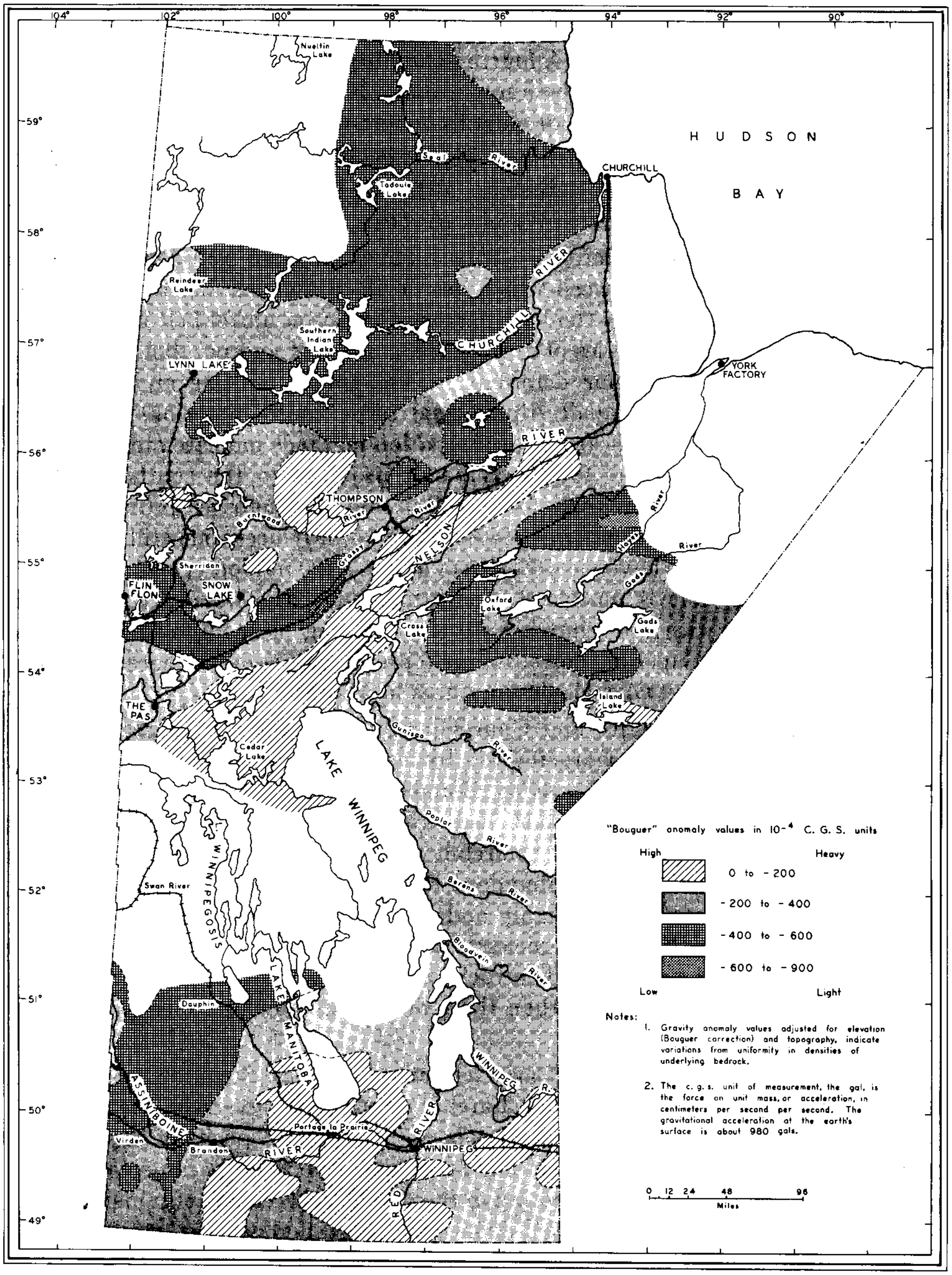
Milligan (1960) has suggested that Kisseynew-type gneisses in the Lynn Lake area were derived from Sickle sediments, although he admits the possibility that they may be equivalent in part to Wasekwan rocks.

The Precambrian of Manitoba can be divided into two well-defined geologic provinces, the boundary between which lies north of and parallel to the Hudson Bay railway and along which the long narrow Thompson nickel belt occurs. This belt is characterized by: a series of gravity lows, north of and parallel to a strip of high gravity (Fig. 4); extreme deformation, i.e., thrust faulting and high-grade metamorphism; numerous small Alpine-type serpentinite intrusions; and large nickel deposits. Dating of rocks by disintegration methods indicate minimum ages of about 2,600 million years for the Superior province to the southeast of the boundary, and 1,700 million years for the Churchill or Athabasca province to the northwest. Close to the boundary between the two provinces, but still within the Superior province, rocks have yielded ages of about 2,100 million years. The reason for this "disturbed" zone is imperfectly understood but it may be related to orogenic activity associated with the Churchill province having been impressed upon the border areas of older Superior rocks. Figure 5 presents data on the ages and major tectonic features of the two geologic provinces in Manitoba.

Geologically the Superior and Churchill provinces differ in several respects. The Superior province is characterized by east-trending volcanic-sedimentary belts in which volcanic rocks are as abundant or more abundant than sedimentary rocks. Grade of metamorphism generally is low to moderate. The sedimentary-volcanic belts of the Churchill province trend in various directions and sedimentary rocks are more abundant than volcanic rocks. In general, also, the sedimentary rocks are more highly and extensively metamorphosed and more complexly folded (e.g., Kisseynew gneisses) than either the volcanic or sedimentary rocks of the Superior province. The rocks underlying the Churchill province in Manitoba are, in general, lighter than those of the Superior province (see gravity map, Figure 4).

Gold deposits in "greenstone" are characteristic of the Superior province but are not particularly abundant in the Churchill province. Conversely, the Churchill province contains numerous base metal deposits; although deposits of this type are widespread in the Superior province they are not as economically important as the gold deposits. In reality the distinction in the characteristic type of mineralization of the two provinces is not as well-defined as the differences in other geologic features,but apparently it has affected the attitude of exploration companies toward prospecting. Certainly the assumption that the Superior province is a "gold district" and therefore not favourable for the occurrence of base metals and, conversely, that the Churchill province is a base metal area and for this reason not favourable to the occurrence of gold, is not valid.

As a consequence of increasing knowledge of absolute ages of Precambrian rocks (see Figure 5), the use and meaning of the terms "Archaean" and "Proterozoic" have become even more confused than previously. It has been customary to



Notes:

1. Gravity anomaly values adjusted for elevation (Bouguer correction) and topography, indicate variations from uniformity in densities of underlying bedrock.
2. The c. g. s. unit of measurement, the gal, is the force on unit mass, or acceleration, in centimeters per second per second. The gravitational acceleration at the earth's surface is about 980 gals.

FIGURE 4 *Gravity Anomaly Map*

designate as "Archaean" all the rocks of the Superior block in Manitoba, with the possible exception of the San Antonio formation at Rice Lake. This designation was compatible with the few known absolute ages of 2,600 ± million years. The one possible exception, the San Antonio formation, was believed to unconformably

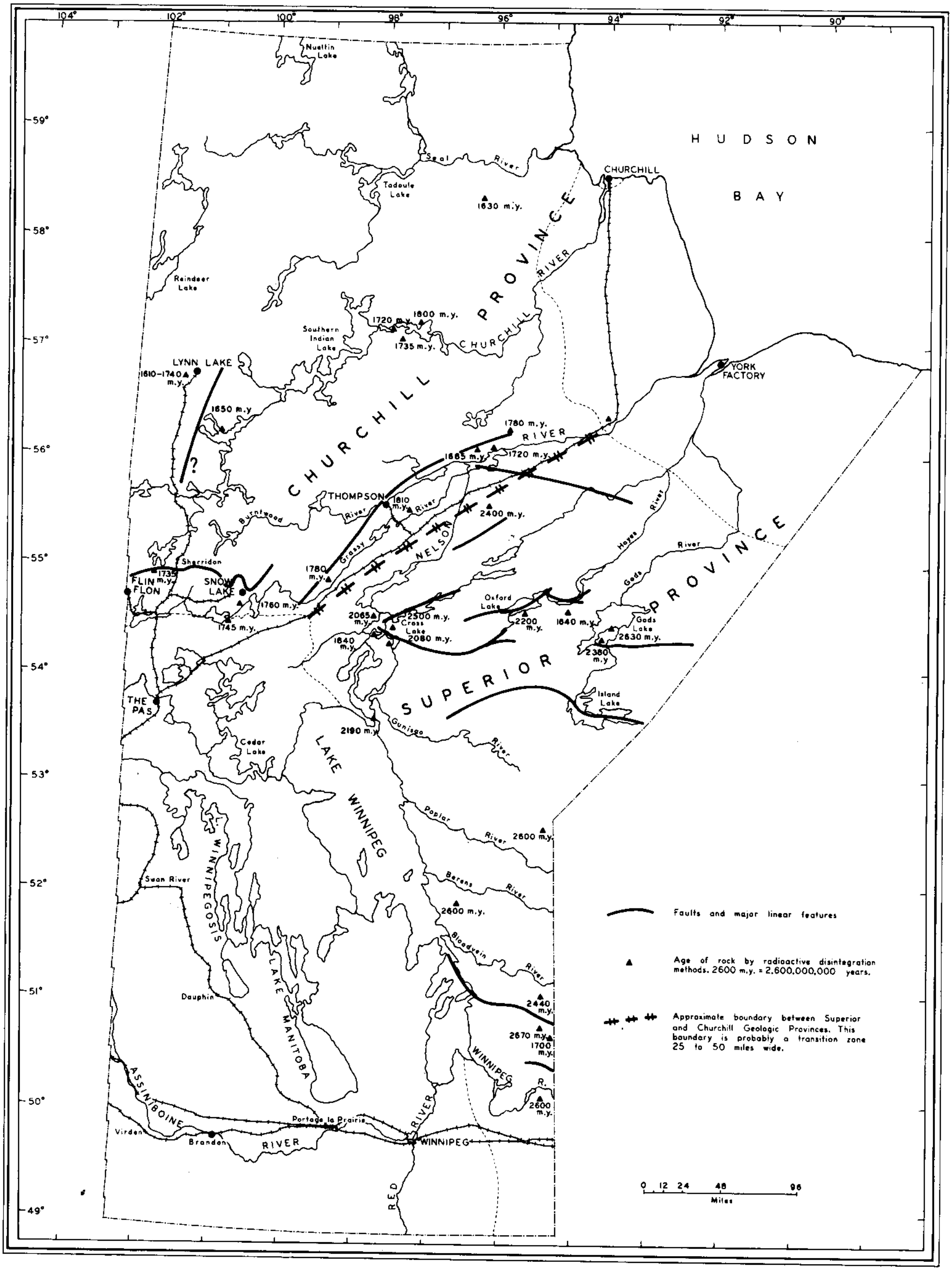


FIGURE 5 *Major Tectonic Features and Age Determinations*

overlie all intrusive rocks of the Rice Lake area. However, recent age determinations (Lowdon, 1961) has shown that one granitic pluton is much younger than the quartz diorite upon which the San Antonio rocks lie and it is probable that this pluton is also younger than the San Antonio formation, although the two are not in contact.

It may be noted that a number of determinations within the Superior province yield ages of 1,800 million years. One such determination is that of the young granitic pluton at Rice Lake. Rocks of this age, therefore, can hardly be considered Archaean in the classical sense. For the same reason, rocks of the Churchill province (all 1,800 million years or less) are not Archaean. Whether or not they are all, or in part, Proterozoic depends on the definition accepted for this term.

A re-appraisal of Precambrian classification and nomenclature is needed and until such is forthcoming it is perhaps advisable to avoid use of the terms Archaean and Proterozoic, at least insofar as they apply to the Churchill and Superior blocks in Manitoba.

The lithology of the Precambrian volcanic and sedimentary rocks is simple in general but complex in detail. Briefly the volcanic rocks consist of light- to dark-coloured andesites and basalts (commonly ellipsoidal), volcanic breccia (andesitic, dacitic, and rhyolitic), and tuffs. Interbanded with these in places may be coarse-grained massive hornblende-plagioclase rocks that have often been regarded as coarse centers of flows but more probably are sill-like intrusions related in origin to the volcanic rocks. The sedimentary rocks are mainly impure quartzites and greywackes, although conglomerate, slate, and arkosic rocks are also common. Stock-like masses and small batholithic bodies of massive granitic rocks (actually most are tonalites) invade the volcanic-sedimentary series and in most areas are elongated parallel to the trend of these rocks. Outside the volcanic-sedimentary belts, and forming the bedrock over most of the Precambrian Shield, are complexes of "granite" and granite gneisses (here, also, many or most of the rocks are not true granites but closer to granodiorites and tonalites). Sedimentary and volcanic rocks associated with these granitic rocks may be extensively granitized.

In some of the volcanic-sedimentary belts diabase dykes and various sills and dykes of quartz-feldspar porphyry are common. The porphyry intrusions are apparently related to the massive granite (and quartz diorite or tonalite) intrusions. In some areas pegmatite dykes and irregular intrusions of this rock invade the volcanic and sedimentary rocks. These may contain concentrations of valuable minerals such as beryl and spodumene. In contrast to these are the simple quartz-feldspar-mica pegmatites commonly developed in sedimentary gneisses and areas of granite gneiss and granitized gneiss. These generally are barren of valuable silicate minerals.

"Late" diabase dykes comparable to the Keweenawan dykes of the Precambrian of eastern Canada are not abundant in Manitoba. However, a few have been recognized and, like the Keweenawan dykes, they trend in a northerly direction for miles, cutting across large areas of granitic rocks.

Structurally the Precambrian is exceedingly complex. In many areas the sedimentary and volcanic rocks have been isoclinally folded, and extensively faulted. Dips normally are steep, though in such areas as near Sherridon recumbent folding in the Kisseynew gneisses has resulted in flat dips. Major unconformities are recognizable in places, but in many areas, even though the sedimentary rocks may be separated from the underlying volcanic rocks by an unconformity, no angular discordance between the two series is evident.

Mineral deposits containing gold, copper, zinc, nickel, iron, chromium, lithium, beryllium and other rare elements (tin, caesium, tantalum, tungsten, molybdenum, and uranium) are present in the volcanic-sedimentary belts of Manitoba.

The extent and intensity of prospecting and geological mapping has varied greatly for different parts of the Shield. The main areas of prospecting up to 1945 were around Flin Flon, Herb Lake, and the Rice Lake-Beresford Lake area. Some prospecting for gold had been done prior to 1945 in the Gods, Oxford, Knee and Island lakes district but little has been done since then. However, since 1955 the area has attracted some attention as a potential district for base metal deposits. Prospecting has continued in the Flin Flon and Herb Lake-Snow Lake districts up to the present. Areas of prospecting activity that have become prominent since 1945 are Lynn Lake and Thompson. New mines have come into production in both areas. Little prospecting has been done north of latitude 57° 00′.

Geologic literature abounds in references to "favourable" rocks and structures in the formation of mineral deposits. It is not intended to discuss these in detail here; reference will be found to such factors in the discussion of individual areas. However, it is of considerable importance to point out the potential of areas of sediments and sedimentary gneisses of the Precambrian. There appears to have developed a philosophy that areas of gneiss and sediments are unfavourable prospecting ground, a philosophy fortunately which is gradually being dispelled. From the structural standpoint the sedimentary gneisses of the Churchill province are eminently favourable, for these rocks are much more complexly folded and faulted than are the rocks of the Superior province.

The mineral potential of sedimentary rocks and gneisses in Manitoba is perhaps best illustrated by reference to the copper-zinc deposits in Kisseynew gneisses at Sherridon, the Stall Lake and Chisel Lake copper and zinc deposits near Snow Lake, and the high-grade nickel deposits in sedimentary gneisses and granitic gneisses along the Thompson belt. Details of these occurrences will be found in the following chapters.

The detail with which geological mapping has been done in various parts of Manitoba is shown in Figure 6. It is evident that large parts of the province have received only reconnaissance studies and that little geological investigation has been done in the far northern part of the province.

Besides geologic maps, there are available aeromagnetic maps of most of the area north of 58° 00′ latitude, flown by the Geological Survey of Canada — 1956 to 1957. Aeromagnetic maps compiled by exploration companies and submitted to the Mines Branch, are available for the following areas:

(1) The area encompassing Cross Lake, Oxford Lake, Knee Lake, Gods Lake, and Island Lake.
(2) A small area northeast of Lynn Lake.
(3) A narrow strip along the Hudson Bay Railway.
(4) The limestone-covered area south of Flin Flon.
(5) A small area near the south end of Lake Winnipeg.
(6) The area southwest of Port Nelson, on Hudson Bay.

The Manitoba Mines Branch has published aeromagnetic maps covering some 1,500 square miles around Sherridon and a further 1,500 square miles in the extreme southeast corner of the province.

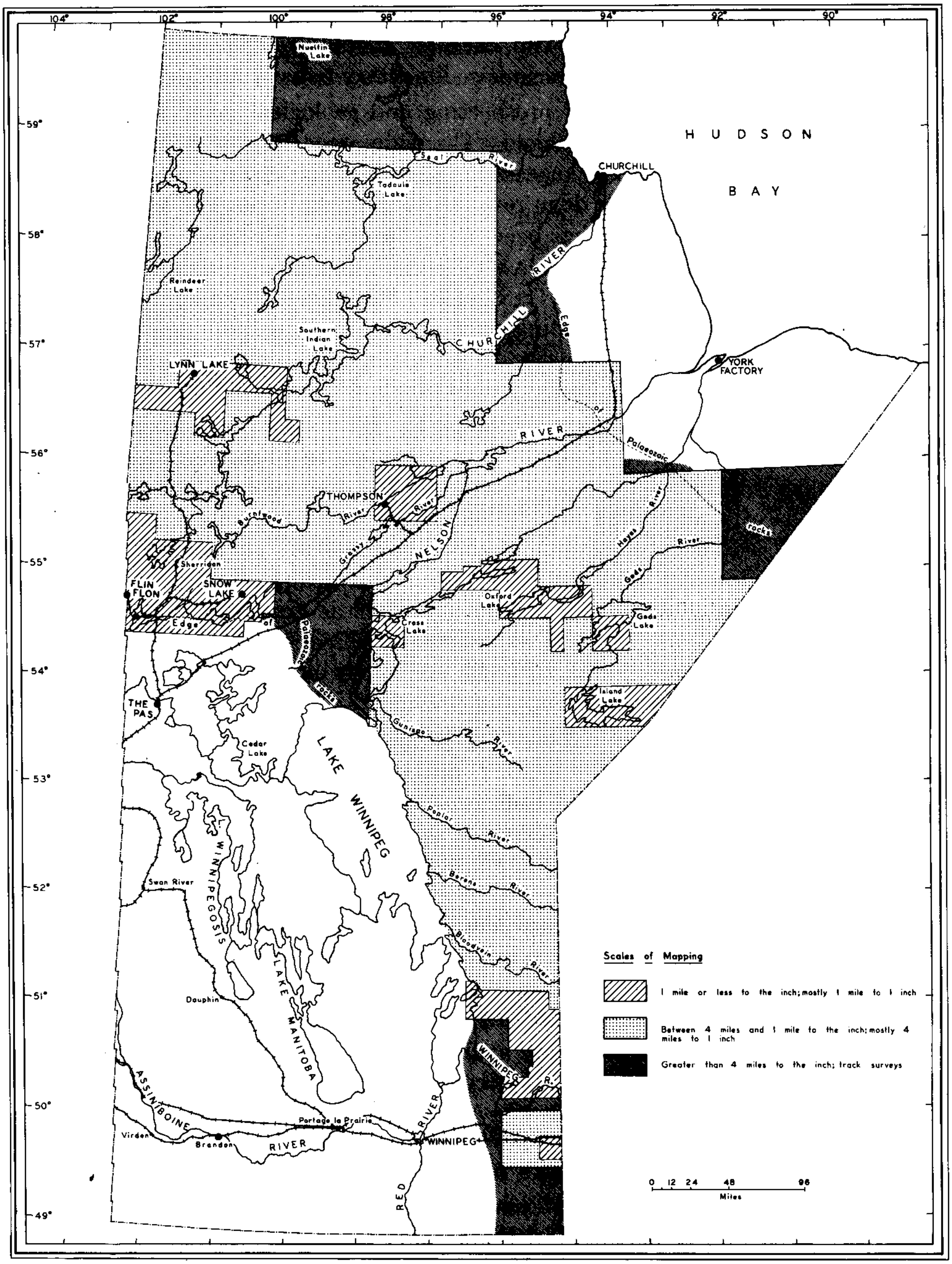


FIGURE 6 *Precambrian Areas of Manitoba — Covered by Geological Mapping*

Arrangements have recently been made between the Federal and Provincial governments to complete, over a period of several years, aeromagnetic coverage of the remainder of the Precambrian of Manitoba.

Electromagnetic survey. One of the loops is energized by an electric current, whose field causes a secondary current to be induced in underlying conductors such as sulphide bodies. The second loop is the detector.

PLATE II

MINERAL OCCURRENCES IN MANITOBA'S PRECAMBRIAN

Metallic minerals are currently (1962) recovered in five areas of Manitoba: (1) Flin Flon — copper, zinc, gold, silver, cadmium, tellurium and selenium, (2) Thompson — nickel, minor copper, and platinoid metals, (3) Snow Lake — zinc, copper, gold, silver, lead, (4) Lynn Lake — nickel, copper, cobalt, and (5) southeastern Manitoba — gold. Areas which formerly produced include Sherridon (copper-zinc), Herb Lake-Snow Lake (gold), north of Cranberry Portage (gold), and Gods Lake (gold).

Within these producing and former producing areas other deposits, some of which are potential producers, are present. These include copper-zinc and gold deposits near Lynn Lake, numerous copper-zinc deposits (besides those now being mined) between Snow Lake and Flin Flon, and copper-zinc deposits near Sherridon. Still other metallic deposits of possible promise are nickel deposits at Herb Lake, nickel deposits at Island Lake, and copper-nickel deposits and chromite deposits in southeastern Manitoba.

Large lithium pegmatites occur as dykes in southeastern Manitoba and near Herb Lake in the northern part of the province. Some of the pegmatites in southeastern Manitoba also contain masses of caesium ore; others carry disseminated beryl. Recent discoveries of lithium-bearing pegmatite have been made near Knee

Lake and Gods Lake but these have not been fully investigated. Small quantities of beryl are known to be present in pegmatite dykes at Cross Lake.

Manitoba did not enjoy the surge of prospecting for uranium during the post-war years. However, several apparently small low-grade occurrences are known near Falcon Lake, Rice Lake, and Herb Lake. Other minerals which are present in various parts of the province but which have not been exploited successfully include tin (Winnipeg River area), tungsten (Falcon Lake area and Herb Lake-Snow Lake district), and molybdenite (Falcon Lake, Winnipeg River, Herb Lake-Snow Lake, and Thompson areas). Short-fiber, apparently poor-quality asbestos has been noted in serpentinitized peridotite near Flin Flon, Thompson, Knee Lake, Island Lake, east and west of Rice Lake, and north of the Winnipeg River (Bird River, Maskwa Lake). Some of these areas may warrant further exploration for asbestos.

Although numerous magnetite iron formations are known throughout many parts of the province, few have attracted attention as sources of iron ore. They are numerous along the Manitoba-Ontario boundary east of the south end of Lake Winnipeg and in the Lynn Lake district. Other iron-formations have been reported from near the Seal River, Thompson, Knee Lake, Gods Lake, and Cross Lake. Besides these, a large magnetic anomaly in the Neepawa area is caused by iron-bearing material. The anomaly covers several square miles and its source lies in Precambrian rocks overlain by about 2,500 feet of Palaeozoic and younger strata. Core recovered from a well drilled in this area contained 30 per cent iron.

Currently producing mines (1962) in Manitoba are listed in Table 2:

TABLE 2

PRODUCING MINES

MINE	LOCATION	COMPANY	RECOVERED METALS
San Antonio	Rice Lake	San Antonio Gold Mines Limited	gold
Flin Flon	Flin Flon	Hudson Bay Mining and Smelting Company Limited	copper, zinc, gold, silver
Schist Lake	South of Flin Flon	Hudson Bay Mining and Smelting Company Limited	copper, zinc
Chisel Lake	SW of Snow Lake	Hudson Bay Mining and Smelting Company Limited	zinc, copper, gold, silver, lead
Lynn Lake	Lynn Lake	Sherritt Gordon Mines Limited	copper, nickel, cobalt
Thompson	Thompson	International Nickel Company of Canada Limited	nickel, copper

Deposits undergoing or that have undergone development and from which future production is either assured or probable are shown in Table 3:

TABLE 3

PROBABLE FUTURE PRODUCERS

MINE	LOCATION	COMPANY	RECOVERABLE METALS
Stall Lake	SE of Snow	Hudson Bay Mining and Smelting Company Limited	copper, zinc
Pipe Lake	SW of Thompson	International Nickel Company of Canada Limited	nickel
Moak Lake	NE of Thompson	International Nickel Company of Canada Limited	nickel
Bernic Lake	Bernic Lake	Chemalloy Minerals Limited	lithium, caesium
Irgon	Cat Lake	Lithium Corporation of Canada, Limited	lithium

Other deposits which are to be developed for production shortly include the Osborne Lake and Ghost Lake copper-zinc deposits (near Snow Lake) held by Hudson Bay Mining and Smelting Company Limited.

Besides the foregoing deposits, there are a number of others which are considered marginal under existing conditions of supply and demand, metal prices, costs of productions, grade, and problems of ore treatment.

These are included in Table 4.

TABLE 4

POTENTIAL PRODUCERS

DEPOSIT	LOCATION	COMPANY	METALS
Spot Claims	West of Cat Lake	Lithium Mines and Chemicals Limited	lithium
Eagle deposit	West end of Cat Lake	Lithium Corporation of America Limited	lithium
Buck deposit	East end of Bernic Lake	Lithium Corporation of Canada Limited	lithium
New Manitoba	SW of Cat Lake	New Manitoba Mining and Smelting Company Limited	nickel, copper

Deposit	Location	Company	Metals
Euclid	Euclid Lake	Gunnar Mines Limited	chromium
Bird Lake	Bird Lake	Petra Chromite Limited	chromium
Chance	N. of Bird River	Maskwa Nickel Chrome Mines Limited	nickel, copper
Page	N. of Bird River	Manitoba Chromium Limited	chromium
Chrome	N. of Bird River	Gunnar Mines Limited	chromium
Moonbeam	West Hawk Lake	Homestake Explorations Limited	gold
Lit	E. of Herb Lake	Green Bay Mining and Exploration Limited	lithium
Violet	Crowduck Bay, Herb Lake	General Lithium Mining and Chemical Corporation Limited	lithium
Last Hope Lake	E. of Lynn Lake	Last Hope Lake Gold Mines Limited	gold
Fox Lake	S.W. of Lynn Lake	Sherritt Gordon Mines Limited	copper, zinc

In order to complete the list of the more important deposits in the province former producers are cited in Table 5:

TABLE 5

FORMER PRODUCERS

Deposit	Location	Metal
Central Manitoba Mine	Southeastern Manitoba	gold
Gunnar Mine	Southeastern Manitoba	gold
Jeep Mine	Southeastern Manitoba	gold
Ogama-Rockland Mine	Southeastern Manitoba	gold
God's Lake Mine	Gods Lake	gold
Nor-Acme Mine	Snow Lake	gold
Laguna (Rex) Mine	Herb Lake	gold
Gurney Mine	Near Cranberry Lakes	gold
Mandy Mine	South of Flin Flon	copper
Cuprus Mine	Southeast of Flin Flon	copper
North Star, Don Jon Mines	East of Flin Flon	copper
Sherritt Gordon Mine	Sherridon	copper, zinc

In the following chapters the geology and mineral deposits in the Precambrian Shield are discussed in some detail; still further details may be found in references listed at the end of each section. Below are summarized some generalizations regarding the mineral occurrences in the areas discussed in the following chapters:

WEST HAWK LAKE -- FALCON LAKE

Deposits of gold, lithium, tungsten, beryl, molybdenum, and uranium have been discovered in this area. The most important deposits are those containing gold. Numerous gold-bearing quartz veins occur in shear and fracture zones in volcanic rocks. Many of these occur around the margins of the Falcon Lake Stock, a differentiated gabbro-"granite" body that intrudes the volcanic rocks. A pipe-like body of silicified "granite" carrying sulphides and gold occurs in the central part of the stock. Pyrite, pyrrhotite, chalcopyrite, and sphalerite are the common sulphides.

Numerous large sulphide zones occur within the volcanic rocks around West Hawk Lake. They consist largely of pyrrhotite and pyrite and carry only small amounts of chalcopyrite, sphalerite, and galena. Gold is generally absent from these zones.

Spodumene, lepidolite, and beryl are present in a few pegmatite dykes near Star Lake, West Hawk Lake, and Falcon Lake. Radioactive pegmatites occur in a schist band along the highway west of West Hawk Lake. Uraninite has been identified but the amount of uranium-bearing material is small.

Scheelite and molybdenite occur west and southwest of Barren Lake. The scheelite occurs in sheared volcanic rock and is associated with epidote, brown garnet, and calcite. The grade and volume of tungsten-bearing material is low. The molybdenite occurs as large flakes and clusters in a pegmatite dyke composed dominantly of pink feldspar and quartz. Some disseminated molybdenite has been found in quartz veins.

CAT LAKE — BIRD LAKE — WINNIPEG RIVER

The most important deposits in the Winnipeg River - Cat Lake area of south-eastern Manitoba are chromite, copper-nickel, and lithium and associated minerals.

Chromite is restricted to the top part of the lower (peridotite) section of the differentiated Bird River Sill. By reason of its mode of origin it is improbable that any chromite deposits will be found in other rocks of the area, except possibly in gabbro which lies in contact with the peridotite. However, it is possible that other chromite deposits will be found in peridotite not already investigated. At the present time there is little incentive for further exploration for chromite as the grade and chrome:iron ratio of the known deposits are too low to compete with foreign ores.

The known pegmatite dykes that contain lithium, beryllium, and caesium nearly all occur in volcanic rocks a few hundred or a few thousand feet from the contact between the "greenstone" and granitic intrusions. Steeply dipping dykes are not well zoned and are likely to contain only a single valuable mineral, either beryl or spodumene. Flat-lying dykes generally are zoned and consist of several layers of different compositions and textures, each layer containing various lithium minerals (spodumene, lepidolite, amblygonite, petalite), and in places pollucite and beryl. The valuable minerals are concentrated towards the centers of the flat-lying, zoned dykes. Dykes which contain only beryl as the valuable mineral generally occur closer to the granite than do the lithium pegmatites; some beryl dykes occur within marginal phases of granitic intrusions.

Large tonnages of lithium ores, and masses of the caesium-bearing mineral, pollucite, have been outlined but production will depend on available markets. Efforts to outline economic beryl deposits have been unsuccessful to date.

Deposits of copper and nickel-copper occur in gabbro and peridotite or in greenstone intruded by these rocks, where they are in contact with younger granitic intrusions. Several deposits have been drilled but tonnages and grade of material so far outlined are inadequate to support a profitable operation.

RICE LAKE — BERESFORD LAKE AREA

The only known occurrences of economic importance in this area are gold deposits. These occur as quartz veins in shear and fracture zones, for the most part in the widest parts of the greenstone belt extending from Lake Winnipeg to the Manitoba-Ontario boundary. Although the quartz veins occur in nearly all rock types in the area, those which contain notable quantities of gold occur mainly in mafic rocks — gabbro, diabase, basalt. The veins in mafic rock are accompanied by extensive carbonatization of the country rock and both carbonatization and pyritization of the wall-rock. Both gold and alteration are most prevalent in and along veins in mafic rock. Veins in the more felsic rocks usually lack wall-rock alteration and the gold content is erratic, with small high-grade shoots separated by large volumes of barren quartz. The common sulphide in the gold-bearing quartz veins is pyrite.

A few small low-grade disseminated nickel occurrences are present in serpentinized peridotite and gabbro near Lake Winnipeg, Leaf Lake, and Garner Lake. Little work has been done on these but the area may merit further attention for nickel and other base metal sulphide deposits.

Several low-grade uranium occurrences are present in quartzo-feldspathic schists and gneisses along the south part of the Rice Lake belt. Typical "showings" consist of low-grade radioactive schist intruded by pegmatite or pegmatitic granite. The radioactivity appears to be closely associated with concentrations of biotite.

Towards the Manitoba-Ontario boundary numerous iron-formations consisting of magnetite and "chert" extend for distances of several miles. Although they may represent a source for commercial iron production little investigation has been carried out on them.

AREA NORTHEAST OF LAKE WINNIPEG

Gold deposits occur in "greenstone" belts at Island Lake, Bigstone Lake, Gods Lake, Knee Lake, Oxford Lake, and along the Echimamish River. An occurrence of nickel lies at the west end of Island Lake and a small deposit of high-grade copper ore has been outlined near the west end of Oxford Lake. Lithium-bearing pegmatites have recently been discovered near Knee Lake and Gods Lake. Several bands of iron-formation have attracted some attention at Knee Lake and near Pipestone Lake.

The gold deposits in this area occur in shears in volcanic rocks commonly along the contact between different rock types. The most important deposit (Gods Lake mine) occurred in tuff beds lying between a diorite-gabbro sill and andesite. Many workers have commented on the close association, in this area, between the gold-bearing quartz veins and sills or dykes of quartz-feldspar porphyry and/or granitic stocks.

The nickel deposit at Island Lake occurs in a serpentinized peridotite intruding volcanic rocks. The deposit is exposed on only a few islands and few data are available. However, the serpentinite lenses appear to lie along a major fault forming a broad arc extending from Ponask Lake to the east end of Island Lake.

Large bodies of serpentinite along the Fox River have been investigated for nickel. Exposures are poor and the drift cover thick. There is some structural evidence that the serpentinite follows a major "break" extending northwest toward Split Lake where it may unite with the Thompson "break." This belt probably warrants further attention but the heavy drift cover will require the use of costly, refined geophysical surveys and extensive diamond drilling.

THOMPSON BELT

Exploration along this nickel belt is hampered by lack of outcrop. However, it has been possible to delineate the most favourable areas as lying along a narrow strip of intensely deformed, metamorphosed, and granitized rocks enclosing remnants of less altered sediments, and all intruded by lenticular serpentinite bodies.

Disseminated nickel deposits occur within the serpentinite and at least one massive sulphide deposit, at Thompson, lies in a sedimentary schist band intruded by serpentinite. Most of the so-called massive ore is a sulphide breccia containing numerous fragments of wall-rock schist, pegmatite, "pegmatized" schist, and quartz. The pegmatite, which occurs locally within the ore zone is intrusive into both the schist and serpentinite.

The nickel ores consist primarily of pyrrhotite and pentlandite. Only minor chalcopyrite is present. However, the sulphides contain metals of the platinum group.

Exploration along the extensions of the belt, where it is overlain by Palaeozoic limestone, has been undertaken.

FLIN FLON AREA

The copper-zinc deposits of the Flin Flon area characteristically occur within andesitic volcanic rocks and display well-defined structural control; they occur in shear zones or drag-folds. The wall-rocks are usually schistose and consist of chlorite schist, sericite schist, or graphite schist; usually the wall-rocks are also extensively silicified and carbonatized. The deposits are closely associated with quartz-feldspar porphyry or diorite which may occur within or alongside the ore zone. Individual orebodies are tabular or lenticular and vary from 100 feet to several hundred feet long and a few feet to 70 feet or more wide.

The sulphides, mainly pyrite, pyrrhotite, chalcopyrite, and sphalerite, are commonly banded. Besides copper and zinc the ores contain recoverable quantities of gold, silver, cadmium, selenium and tellurium. Some of the deposits contain only chalcopyrite, others contain both chalcopyrite and sphalerite as the valuable sulphide minerals.

In addition to the gold contained in the sulphide deposits, numerous quartz veins carrying pyrite or arsenopyrite, and smaller quantities of chalcopyrite and sphalerite, are gold-bearing. Commonly these quartz veins are associated with sulphide deposits. Elsewhere they are entirely separate from the sulphide occurrences. Many of the gold-bearing quartz veins are closely related to dykes of quartz-albite porphyry. The veins occur in shear or fracture zones in volcanic rocks commonly near the contact with large granitic bodies, or in the marginal parts of the granitic bodies themselves. The only gold production from quartz veins in this area has been from the Gurney mine near Cranberry Lakes where the veins occurred as a replacement of a band of tuff.

FILE LAKE — SNOW LAKE — WEKUSKO LAKE AREA

The economic sulphide deposits in this area are similar mineralogically to those of the Flin Flon area. They consist largely of pyrite or pyrrhotite with chalcopyrite, sphalerite, and galena. Some deposits contain mainly chalcopyrite, others dominantly sphalerite as the valuable sulphide. The sphalerite-rich deposits (e.g., Chisel Lake) also contain more lead, gold, and silver than the copper-rich ores (e.g., Stall Lake).

Unlike the Flin Flon deposits, many of those in this area occur in schists and gneisses such as quartz-hornblende gneiss, garnetiferous quartz-biotite gneiss, chlorite-biotite-garnet gneiss, and hornblende-plagioclase gneiss; these rocks were

PLATE III *Diamond drilling. Drills probe deep beneath the surface to locate possible mineral deposits suspected as a result of geological studies, airborne geophysical surveys, and ground geophysical surveys.*

probably derived from both sedimentary and volcanic types. The Flin Flon deposits, on the other hand, occur in only relatively unmetamorphosed volcanic rocks.

The area from Elbow Lake to Herb Lake contains numerous gold deposits, the most important of which was the Nor-Acme deposit at Snow Lake. Many of the gold deposits are associated with folds (Nor-Acme, Squall Lake deposits), or occur in shear zones.

Although quartz veins are present in the ore-bearing structures, in some deposits the gold occurs mainly in silicified and carbonatized wall-rocks containing either fine or coarse arsenopyrite (Nor-Acme, Squall Lake). In other deposits, however, gold occurs in lenses and stringers of quartz in shear zones (Rex deposit at Herb Lake, and deposits near Elbow and Morton lakes). Some veins near Snow Lake and Herb Lake contain scheelite but attempts to outline an economic tungsten deposit have been unsuccessful.

Many of the gold-bearing quartz veins and silicified rocks are closely associated with a distinctive quartz-eye granite that occurs in many parts of the district.

Other deposits of significance in the area are small bodies of copper-nickel in gabbro at Wekusko Lake and pegmatite dykes containing spodumene at Crowduck Bay and east of there.

KISSISSING AREA

Pyrrhotite bodies carrying chalcopyrite and sphalerite occur in a series of complexly folded quartzite and quartzo-feldspathic gneisses interbedded with which are bands of hornblende-plagioclase gneiss. The Sherritt Gordon copper-zinc deposit occurred in a shear zone at the folded contact between thinly bedded quartzite and hornblende-plagioclase gneiss. The sulphides were within a pegmatite that had intruded along the contact and was later fractured. Pyrrhotite, pyrite, chalcopyrite sphalerite, and chalmersite (cubanite) were the common sulphides. Some gold and silver were recovered from the ore.

Other sulphide deposits, some recently discovered, occur under similar conditions, i.e., along contacts between rocks of different competencies.

A few gold deposits are known to be present in the gneisses several miles east of Sherridon. Until recently little work has been done on these and few details are available.

LYNN LAKE DISTRICT

Deposits in this area consist of the copper-nickel ores in gabbro and related mafic intrusions, copper-zinc deposits in volcanic rock, and gold-bearing quartz veins.

The Lynn Lake copper-nickel ores occur in gabbro "plugs" intruding volcanic and sedimentary rocks. The Lynn Lake plug consists mainly of gabbro, norite, and amphibolite. The orebodies within the mafic intrusion are closely related to faults which cut it and which may have localized the sulphide deposits. However, the orebodies themselves are displaced by the faults.

In the vicinity of the orebodies alteration to talc, serpentine, and amphibole is extensive. The sulphides are mainly pyrrhotite, pentlandite, and chalcopyrite.

Some of the orebodies consist of disseminated sulphides; one, at least, is a massive sulphide deposit containing altered inclusions of country rock, forming a breccia ore.

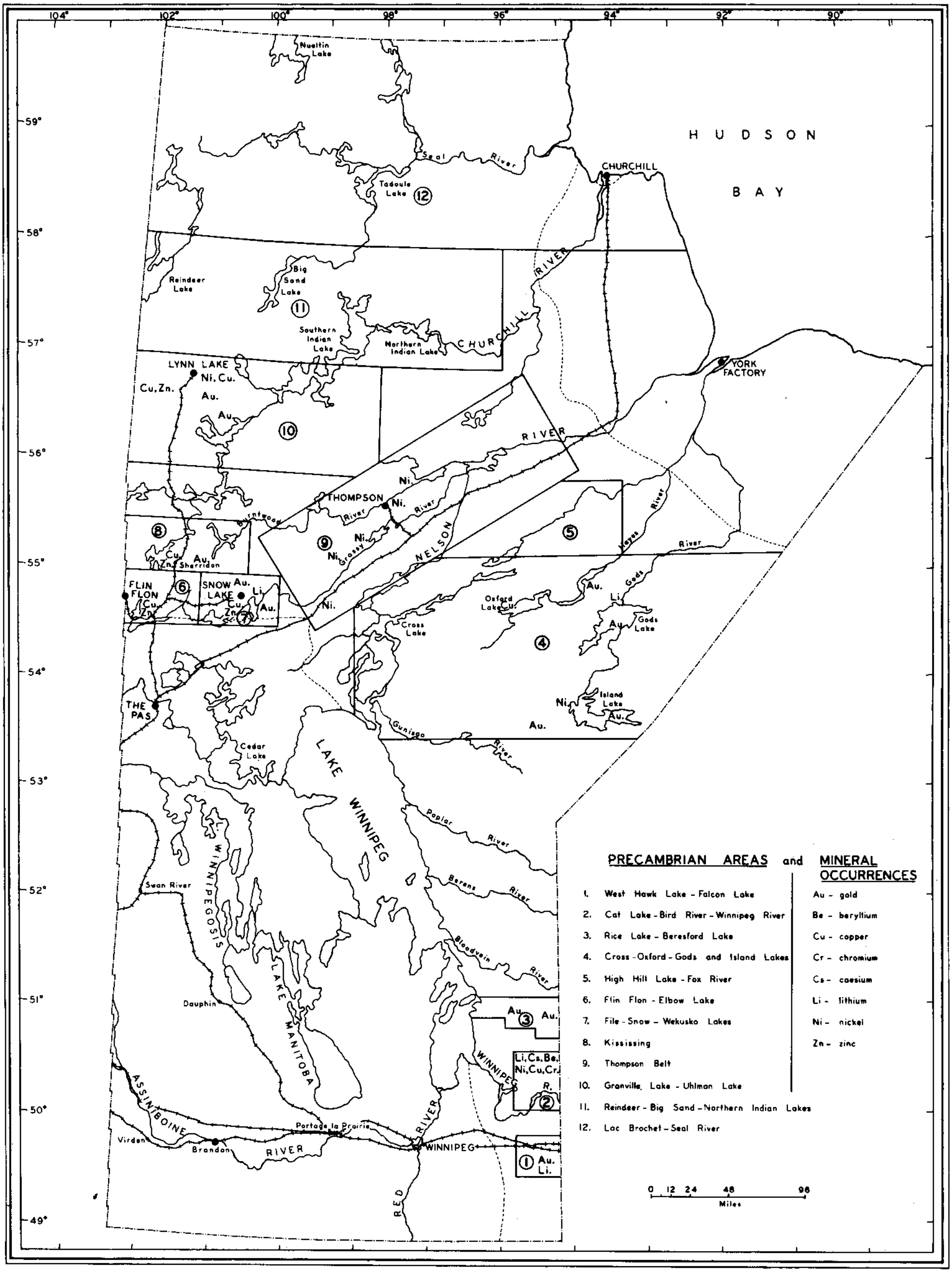


FIGURE 7 *Index to Principal Precambrian Areas*

Numerous gabbro bodies are distributed throughout the area and most of these have received some attention as possible loci for other copper-nickel deposits.

Sulphide deposits consisting largely of pyrrhotite with chalcopyrite and sphalerite occur in volcanic and sedimentary rocks in this district. At least one large deposit and several moderate-sized deposits carrying a few per cent copper and zinc have been outlined. This district warrants further investigation for copper-zinc occurrences.

Gold-bearing quartz veins are widespread but little work has been done on most of them. They occur in shear and fracture zones in volcanic and sedimentary rocks, quartz-feldspar porphyry, and diorite. At Last Hope Lake a vein at least 1,800 feet long occurs in a felsite dyke at the contact between quartzite and hornblende schist. Sulphides (pyrite, chalcopyrite, and galena) are sparse but the vein carries an average of 0.21 ounces gold per ton.

The general distribution of the various types of mineral occurrences in the Precambrian of Manitoba is shown in figure 7, which also outlines the various areas to be discussed in the following chapters.

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CHAPTER III

GEOLOGY AND MINERAL DEPOSITS OF THE SUPERIOR GEOLOGICAL PROVINCE OF MANITOBA

For purposes of the ensuing discussion the Superior province in Manitoba will be dealt with in 5 sections: (1) West Hawk Lake-Falcon Lake area, (2) Cat Lake-Bird River-Winnipeg River area, (3) Rice Lake-Beresford Lake area, (4) Cross-Oxford-Gods-Island lakes area, (5) High Lake-Fox River area.

WEST HAWK LAKE — FALCON LAKE AREA

The West Hawk Lake-Falcon Lake area, also known as the "Boundary area," lies east of Winnipeg along the Manitoba-Ontario boundary and forms part of the Whiteshell Forest Reserve. It can be reached conveniently by the Trans-Canada Highway. The area has been prospected for gold, tungsten, molybdenum, uranium, lithium, and base metals. Most of the mineral occurrences are in townships 8 and 9, ranges 16 and 17 EPM.

GENERAL GEOLOGY

Two separate northeast-trending belts of volcanic and sedimentary rocks occur in the area and are intruded by a number of granitic plutons (figure 8).

The volcanic rocks (1)[1] consist chiefly of older massive and pillowed basaltic and andesitic flows, fragmental and tuffaceous rocks, and minor slates. Predominantly sedimentary strata (2) consisting of greywacke, quartzite, argillite, and schists lie conformably above the volcanic sequence in the northernmost belt. The entire sequence of volcanic and sedimentary rocks belongs to the Keewatin Series as originally defined by Lawson for the Lake of the Woods district.

One of the oldest granitic rocks is a grey gneissic granodiorite and quartz diorite (3) probably at least partly formed by granitization of volcanic and sedimentary rocks. This rock contains numerous mafic inclusions.

Several stocks of quartz diorite, pink and grey granodiorite, porphyritic granodiorite, granodiorite and quartz diorite, and pink granodiorite (4) have been mapped separately by Springer (1952). The rocks have, in common, a massive character and may or may not be consanguineous. The rocks are fine- to medium-grained. They are cut by numerous pink dykes of granodiorite and quartz diorite. Microcline, forming large phenocrysts in the porphyritic rock, is conspicuous in the granodiorite.

A distinct, coarse-grained, almost pegmatitic microcline granite (5a) occurs about 5 miles northwest of Glenn. The rock is made up essentially of microcline and quartz, with less than 5 per cent oligoclase and biotite.

A small body of pink fine- to medium-grained granodiorite to biotite granite (5b) occurs west of Caddy Lake, the pink dykes that cut the older granitic rocks may be related to this intrusive rock.

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[1] Numbers in parentheses, when referring to rock types, correspond to numbered rock units on the appropriate maps; when referring to mineral deposits, they correspond to mineral localities shown on the maps.

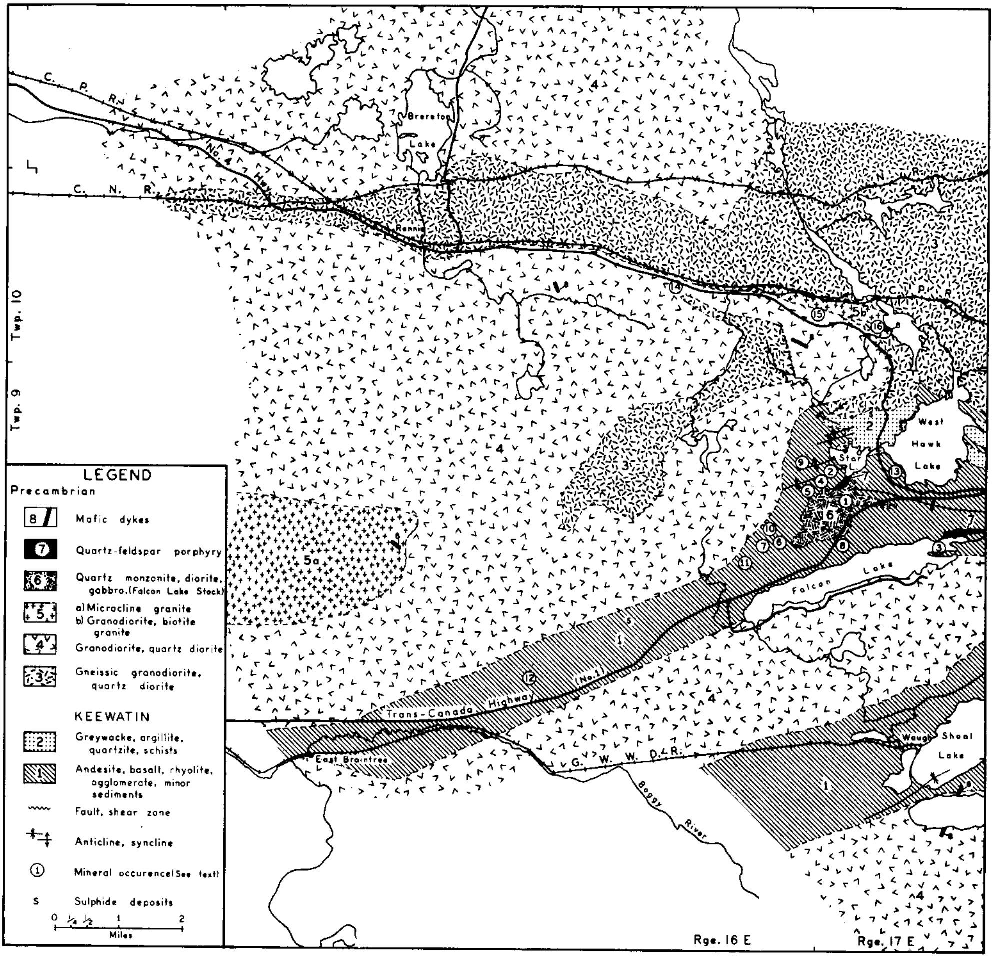

FIGURE 8 *Geology of West Hawk Lake-Falcon Lake Area*

The Falcon Lake Stock (6), north of Falcon Lake, has been extensively studied by several geologists because of its possible economic significance as a source of gold. Brownell (1941) showed that the stock consists of an outer margin of diorite and gabbro, an inner core of quartz monzonite, and an intermediate ring of syenodiorite and granodiorite. Angular and rounded inclusions of what appears to be the older diorite are found at the margin of the quartz monzonite core.

Brownell indicated that the acidity increases gradually towards the center of the stock. An hypothesis of simple multiple intrusion was discarded in favour of a theory that an acid magmatic differentiate rose from depth, forced out and replaced more basic interstitial fluids from already unconsolidated diorite, thus forming the inner core of quartz monzonite. Another hypothesis is that the basic outer part of the stock is the result of contamination by the surrounding volcanic rocks.

Two quartz-porphyry intrusions (7), one south of Star Lake, the other along the north shore of Falcon Lake are characterized by numerous stubby feldspar tablets. The porphyry is a massive to somewhat schistose rock. The relationship to the other plutons of the area is unknown.

A pyroxenite body (8) approximately 500 feet wide and ½ mile long is exposed west and slightly north of McGillivray Lake. The rock is composed almost entirely of hypersthene. The pyroxenite may be younger than the surrounding porphyritic granite.

Several diabase and lamprophyre dykes are scattered throughout the area. They commonly contain disseminated sulphides.

A moderate grade of metamorphism is characteristic of the volcanic and sedimentary rocks of the area. There is widespread evidence of alteration within all rocks. Carbonate is generally abundant in the volcanic rocks, especially near shear zones, and silicification is widespread both in the volcanic and sedimentary rocks. There is evidence that certain silicified rocks originally were tuffs. In the quartzo-feldspathic rocks it is impossible to determine how much of the quartz is introduced and how much represents primary quartz. Most commonly obscure bedding indicates their sedimentary origin but at places the rocks are massive or show irregular dark and streaky structures resembling flow structures.

An interesting result of metasomatic replacement is the development of "cherty" rocks along the north shore of Falcon Lake. Silicification of massive and minor pillowed andesite produced "rhyolite" and that of thinly bedded tuffs gave rise to "chert."

The volcanic and sedimentary rocks of the area are steeply dipping and trend east-northeast. A major anticlinal axis is situated south of West Hawk Lake and a synclinal axis, west of Shoal Lake.

Crumpling of the rocks west of Star Lake produced a series of minor anticlines and synclines plunging northeast. The crumpling may have accompanied or followed the intrusion of the granitic rocks as the strata appear to have been squeezed by or against the intrusion.

The foliation in the gneissic granitic rocks is usually parallel to the bedding of the volcanic and sedimentary rocks.

There is no indication of prominent faults in the area. Shears and fractures in which the mineral deposits occur strike in two general directions — east and northeast. Most of them dip steeply northward. These sheared and mineralized zones are numerous west of the Falcon Lake stock, around Star Lake, and around West Hawk Lake.

MINERAL OCCURRENCES

Gold

The search for gold in the West Hawk Lake district began shortly after the turn of the century. The attention of prospectors was directed first to numerous sulphide lenses in the Keewatin volcanic and sedimentary rocks. Later, quartz veins associated with the Falcon Lake stock were found to be more promising for the occurrence of gold. Most of the numerous trenches, pits, and prospect shafts found in the area date from between 1900 and 1920.

The veins occur either in the granodiorite ring or quartz monzonite core near the contact between the two main phases of the intrusion as well as in the volcanic rocks in the immediate vicinity of the Falcon Lake stock. There are no major, large-scale shear or fracture zones in the area. This lack of major structure which would localize gold-bearing solutions may be the principal reason for the widespread dissipation of gold mineralization and the absence of a producing mine in the area.

Homestake Explorations Limited. Gold-bearing deposits on the Sunbeam, Moonbeam, Waverley and adjacent claims (1)[1] have been investigated intermittently since the early part of the century. Between 1936 and 1941 Sunbeam Kirkland Gold Mines Limited drilled a deposit on the Sunbeam claim and sunk a shaft to a depth of 400 feet. In 1941 Goldbeam Mines Limited acquired the assets of the former company, did further diamond drilling, and outlined another deposit on the Waverley claim. In 1945 and 1946 a shaft was sunk to 500 feet on this deposit. In 1946 the combined reserves of the two deposits were estimated by the company to be 550,650 tons averaging 0.293 ounces gold per ton before dilution. Gold-bearing zones are also known to occur on the Moonbeam, Gold Coin, and Sunday claims.

No work has been done on any of these deposits since 1946. In 1950 the property was sold to Homestake Explorations Limited, and in 1960 it consisted of 21 leases.

The deposit on the Sunbeam claim consists of a pipe-like body of silicified quartz monzonite situated near the edge of the inner core. At surface the deposit is roughly circular in outline with an area of about 2,200 square feet. It increases with depth, and on the second level (at 200 feet) it has an area of over 3,000 square feet. The pipe plunges at angles of 55 to 65 degrees in a direction north 30 degrees west. Around the margins of, and concentric with, the pipe, the quartz monzonite exhibits faint banding. This led Brownell to suggest that the pipe-like channel which admitted the ore-forming fluids represents the last portion of the quartz monzonite core to consolidate. A flat-lying fault between the third and fourth levels of the mine displaces the lower part of the orebody northward for 65 feet. Several other northeast-trending fractures displace the deposit for distances of a few inches to several feet. Some of them are filled with quartz. The main sulphide mineral disseminated throughout the silicified quartz monzonite is pyrite. Pyrrhotite, arsenopyrite, sphalerite, galena, tennantite, and chalcopyrite occur in minor quantities.

On the Waverley claim several hundred thousand tons of material approaching ore grade are reported to have been outlined in three closely-spaced bodies which occur in the ring of granodiorite.

Star Lake Gold Mines Limited. This company holds a group of patented claims (2) formerly owned by Penniac Reef Gold Mines Limited. Before 1915 a shaft was sunk to 65 feet on the Moore claim and 100 feet of lateral work was done. Old company reports show high values in gold and small quantities of silver, platinum, and iridium. In 1938, Star Lake Gold Mines Limited did about 1,600 feet of diamond drilling and reported encouraging results. Since that time the property has been inactive. The deposit consists of scattered stringers of vein quartz in a zone of dark silicified and mineralized agglomerate.

Falnora Gold Mines Limited. This company holds a group of claims at the east end of Falcon Lake. On the Thompson 2 claim (3) there is a gold deposit on which

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[1] Numbers in parentheses, when referring to rock types, correspond to numbered rock units on the appropriate maps; when referring to mineral deposits, they correspond to mineral localities shown on the maps.

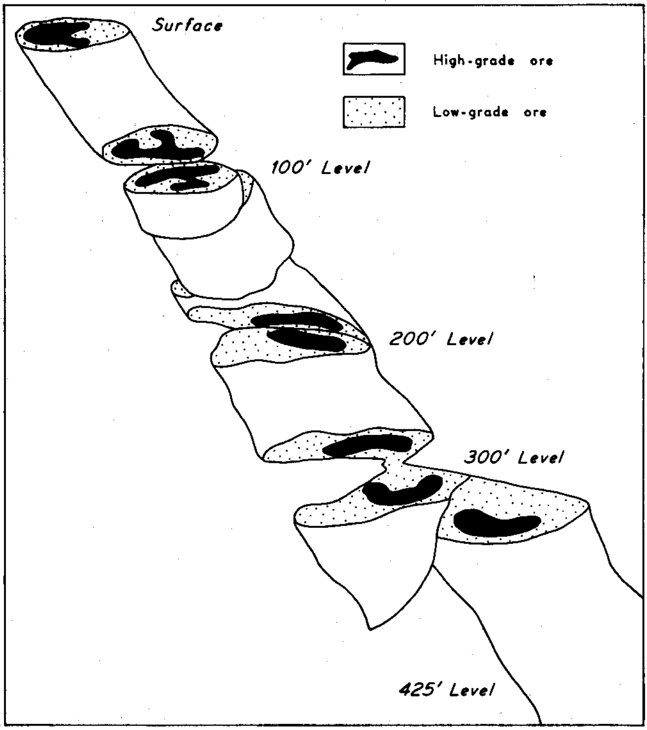

FIGURE 9 *Sunbeam-Kirkland Pipe-like Gold-bearing Zone*

considerable surface work and some drilling had been done prior to its acquisition by the present company. Falnora Gold Mines Limited drilled a few holes into the deposit in 1949.

The deposit occurs in a zone of sheared tuffaceous rock interbanded with andesite. A narrow porphyry dyke cuts the rocks a few feet north of the shear. The ore-bearing section consists of a hard, dense grey siliceous rock that may be a felsite sill or silicified volcanic rock. Very little vein quartz is present. The shear is up to 12 feet wide and the mineralized zone ranges in width from 2 to 4 feet and occurs along the western 500 feet of the shear. The eastern 250 feet of this zone is well mineralized with pyrite; sulphides are less abundant in the western part.

The easterly section of the deposit is reported to average 0.44 ounces gold per ton across a width of 2.1 feet for a length of 250 feet. Two shipments of ore taken from an open cut along the length of the deposit averaged 1.95 ounces gold per ton (38 tons) and 2.38 ounces gold per ton (18 tons). Some drill holes are reported to have intersected sections with high gold content.

Limited surface work has been done on several other gold occurrences in the area, in particular on the Gem-Sheba (4), Rad (5), Boyes (6), Jewel (7), and Four Leaf Clover (8) claims. About 1,500 feet of diamond drilling was completed on the Thor claims (9), in 1938. The gold content of most veins appears to be very erratic.

Tungsten

Scheelite occurs in shears and fractures along a northeast-trending zone (10) passing west of Barren Lake. Some occurrences were discovered in 1918 at which time a small amount of cobbed ore was shipped from the area. During the early part of World War II other deposits were discovered and in 1942 a thorough investigation of all the known deposits was made by J. D. Bateman of the Geological Survey of Canada and A. S. Dawson of the Manitoba Mines Branch.

Bateman's work (1943) indicated that the deposits known to date are of little economic interest, mainly on account of their small size. The deposits occur on claims M.G.T.3 and 4, Felsite 1 and Lake 10. The total tonnage "in sight" grading 1 per cent WO_3 was found to be 31 tons.

Scheelite is present in stringers and small lenses of sugary quartz. Where quartz stringers are absent the shear zone contains abundant secondary hornblende. The deposits are from 12 to 35 feet in length and 1 to 5 feet in width, with an average width of 2 feet. Some consist of single shear zones; others occur in en echelon arrangement with lenses successively offset northwest along the northeasterly strike. The deposits dip southeast and plunge northward at angles of 60 degrees or more. The scheelite is either disseminated or concentrated in small pods. Other minerals present are garnet, epidote, pale hornblende, and calcite.

Molybdenum

Molybdenite occurs in pegmatite dykes and quartz veins west and southwest of Barren Lake (11). Most of the mineralized bodies are found entirely within the Keewatin schist and greenstone. During the first world war, attempts were made to recover some molybdenite by hand-cobbing some of the pegmatites.

The main constituents of the dykes are pink feldspar and quartz. The molybdenite occurs as crystals varying from a fraction of an inch up to 3 inches in diameter. At places, it forms large clusters of radiating crystals. Native bismuth and gold have been reported to be associated with molybdenite.

Molybdenite in small hexagonal crystals is also found in equigranular granitic dykes. Small veinlets of molybdenite flakes are found traversing quartz veins.

The radioactive pegmatites along Highway No. 4 contain scattered small flakes of molybdenite.

Lithium and Beryllium

Two pegmatite dykes (12) containing lithium and beryllium minerals occur about 3 miles northeast of Glenn on the Greater Winnipeg Water District Railway.

On the Lucy No. 1 claim, the pegmatite is exposed in a trench 50 feet by 15 feet. The minerals of the dyke are pink and white feldspar in large crystals, granular albite, black tourmaline, blue acicular tourmaline, blue apatite, fluorite, pale silvery lithium mica, pyrophyllite, pale green beryl, and white spodumene in crystals up to 12 inches in length. Spodumene constitutes up to 25 per cent of the rock in the south portion of the dyke.

On the AD No. 2 mining claim a pegmatite is exposed for a length of 60 feet in an easterly direction and contains pink and white feldspar, smoky quartz, biotite, white to pale green beryl, and spodumene.

Another lithium deposit (13) occurs near West Hawk Lake.

Uranium

Uranium-bearing minerals occur in pegmatite zones (14, 15, 16), which lie near the porphyritic granodiorite and gneissic granodiorite near Highway No. 4 south of Bear Lake. The pegmatites are composed of microcline, albite or oligoclase, biotite, hornblende, apatite and garnet with minor pyrite, pyrrhotite, magnetite, and molybdenite. X-ray powder photographs indicate that uraninite mixed with some thorite is present.

The Whiteshell Uranium Syndicate carried out a scintillometer and sampling program on the deposits in 1950. Springer (1952) lists results of numerous assays done by the Radioactivity Laboratory of Ottawa from channel samples on the Found and Triangle groups of claims. The best selected sample contained 0.58 per cent U_3O_8.

Sulphides

Sulphides are widespread in the area west of West Hawk Lake. Some deposits occur in andesite but the majority are restricted to beds of sedimentary rocks (map-unit 2) and confined to shears that strike parallel to the bedding.

The sulphide bodies consist largely of pyrrhotite but some also contain considerable amounts of pyrite. They are either massive or disseminated and occur as stringers, lenses, and pods in the schists. Only very small amounts of nickel, copper, zinc, and tin have been reported from these deposits, and none are considered of economic significance.

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CAT LAKE — BIRD RIVER — WINNIPEG RIVER AREA

This district is well known for the pegmatite dykes containing deposits of lithium, beryllium, and (recently discovered) caesium, for the large chromite deposits within the Bird River gabbro-peridotite sill, and for the copper-nickel deposits along the lower contact of the sill. Although the area has been prospected for more than 40 years and many mineral deposits have been discovered, several in the past few years, no mines have yet (1962) been brought into production. However, shafts have been sunk and underground development was carried out between 1956 and 1961 on 3 deposits.

HISTORY OF EXPLORATION

The region along the Winnipeg, Bird, and Maskwa rivers has undergone several periods of exploration. During the first of these, beginning about 1920 and lasting until 1930, several copper-nickel and copper deposits, as well as numerous pegmatite dykes containing lithium, beryllium, and tin were discovered. Development work consisted largely of sinking shallow prospect shafts, although some underground development was carried out on two small tin deposits. During the 1930's several thousand feet of diamond drilling were done on a few sulphide deposits.

Chromite was discovered north of Bird River in 1942 and several deposits were drilled, as a result of which large reserves of low-grade chromite were outlined.

During the 1950's further drilling was done on some of the copper-nickel occurrences but the main activity, reaching a peak in 1955 and 1956, was the investigation of lithium deposits. This involved drilling of several deposits discovered many years ago as well as the discovery of a few new occurrences. Shafts were sunk in 1957 on two lithium deposits, (6) and (23) on figure 10.

Reconnaissance geological mapping was conducted along the main water courses in 1912 by the Geological Survey of Canada and during the 1920's the Survey mapped parts of the area at one mile to the inch. In 1948 and 1951 more detailed mapping, at ½ mile to the inch, was done by the Manitoba Mines Branch The most interesting parts of the area were mapped, at 1,000 feet to the inch, by the Mines Branch in 1954, 1955, and 1956.

GENERAL GEOLOGY

Figure 10 illustrates the geologic features of the area. Outcrops are widespread and well exposed in most parts of the district; glacial deposits (clay, sand, and gravel) are not thick. The Rice Lake group consists of a lower assemblage of volcanic rocks, mainly pillowed andesites and basalts, overlain by a series of greywacke, impure quartzite, and arkose, with minor conglomerate, slate and chert. The volcanic and sedimentary rocks are in part interbedded. Both are intruded by mafic and ultramafic rocks of the Bird River Sill, a differentiated complex composed of (from bottom to top) peridotite, narrow bands of pyroxenite and olivine gabbro, hornblende gabbro, and in places, anorthositic gabbro.

The sill is composed principally of a lower peridotite band and an upper hornblende gabbro band. The average thickness is 3,000 feet, with a maximum of 6,000 feet. The total length of the various intrusions and cross-faulted segments of the sill is about 20 miles along the Bird River belt, and 7 miles along the Euclid Lake-Cat Creek section.

The volcanic, sedimentary, and mafic intrusive rocks have all been invaded by granitic intrusions ranging in composition from quartz diorite to granite and pegmatite. Most of the granitic rocks (excepting the pegmatite) occur as large bodies enclosing the volcanic-sedimentary belts. However, in the eastern third of the area much pegmatitic granite and pegmatite occur well within the volcanic and sedimentary rocks. Apparently large bodies of granite lie not far below the surface, for many of these volcanic and sedimentary rocks are granitized. Grade of regional metamorphism also increases eastward; the rocks in the eastern part of the area have been recrystallized to quartz-feldspar-mica schists and hornblende-plagioclase schists.

The regional structure of the area, as determined from tops of pillow lavas and the sequence of rock types in the northern and southern occurrences of the differentiated Bird River Sill, is anticlinal (figure 11). However, an important synclinal structure occurs within the belt along the Bird River. Several cross-faults displace the volcanic and sedimentary rocks, the Bird River Sill, and granitic rocks. The horizontal displacement along some of these is more than a mile, and one is as much as 3 miles. A major longitudinal fault marks the contact between the sedimentary rocks and the Bird River Sill west of Bird Lake. Elsewhere the contact between the sediments and the sill is not exposed.

MINERAL DEPOSITS

Chromite

Chromite occurs as stratiform deposits within the lower, peridotite, part of the Bird River Sill. The chromite horizon lies parallel to and 175 feet or so below the gabbro-peridotite contact. Bands of dense and disseminated chromite are separated by layers of peridotite containing variable but small amounts of chromite.

The deposits are of two principal types, differing only in the thicknesses and distribution of chromiferous bands. Those on the Chrome and Page properties (21 and 18) consist of 3 zones. An upper main chromite zone, 6 to 10 feet wide, consists of alternating layers of dense ore, disseminated ore, and peridotite, all exhibiting sharp banding; about 30 feet below this is a narrow chrome band of dense

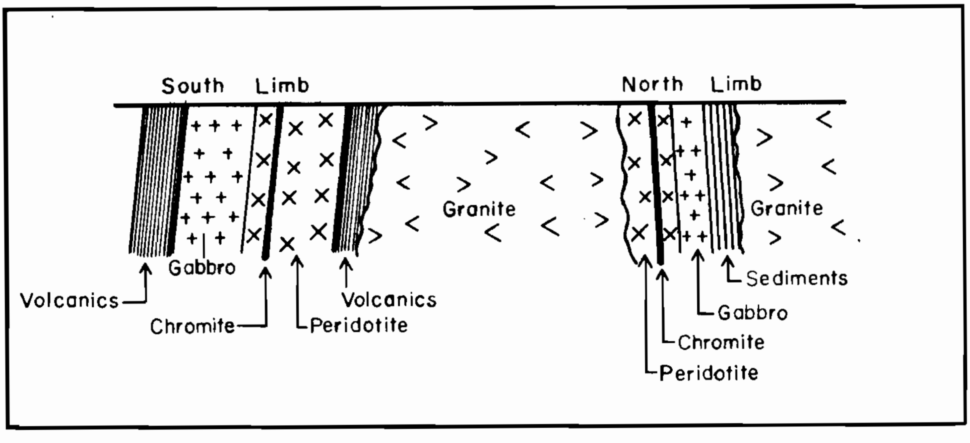

FIGURE 11 *Diagrammatic Section Bird Lake-Euclid Lake*

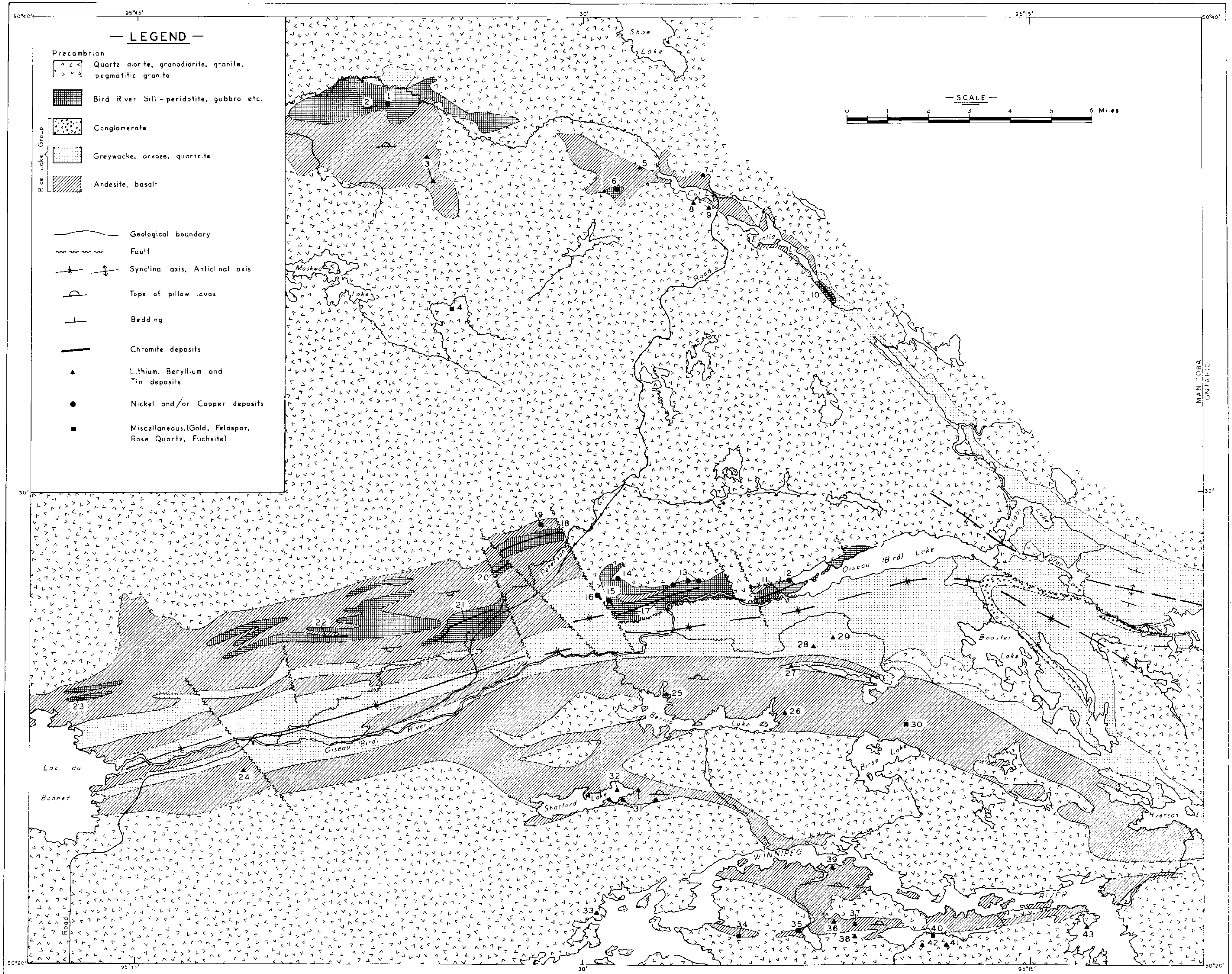

FIGURE 10 *Geology of Cat Lake — Bird River — Winnipeg River Area*

ore, and another 30 feet below that is a stringer zone. This type of occurrence is illustrated in figure 12 (A). In contrast to these are the occurrences (10 and 11)

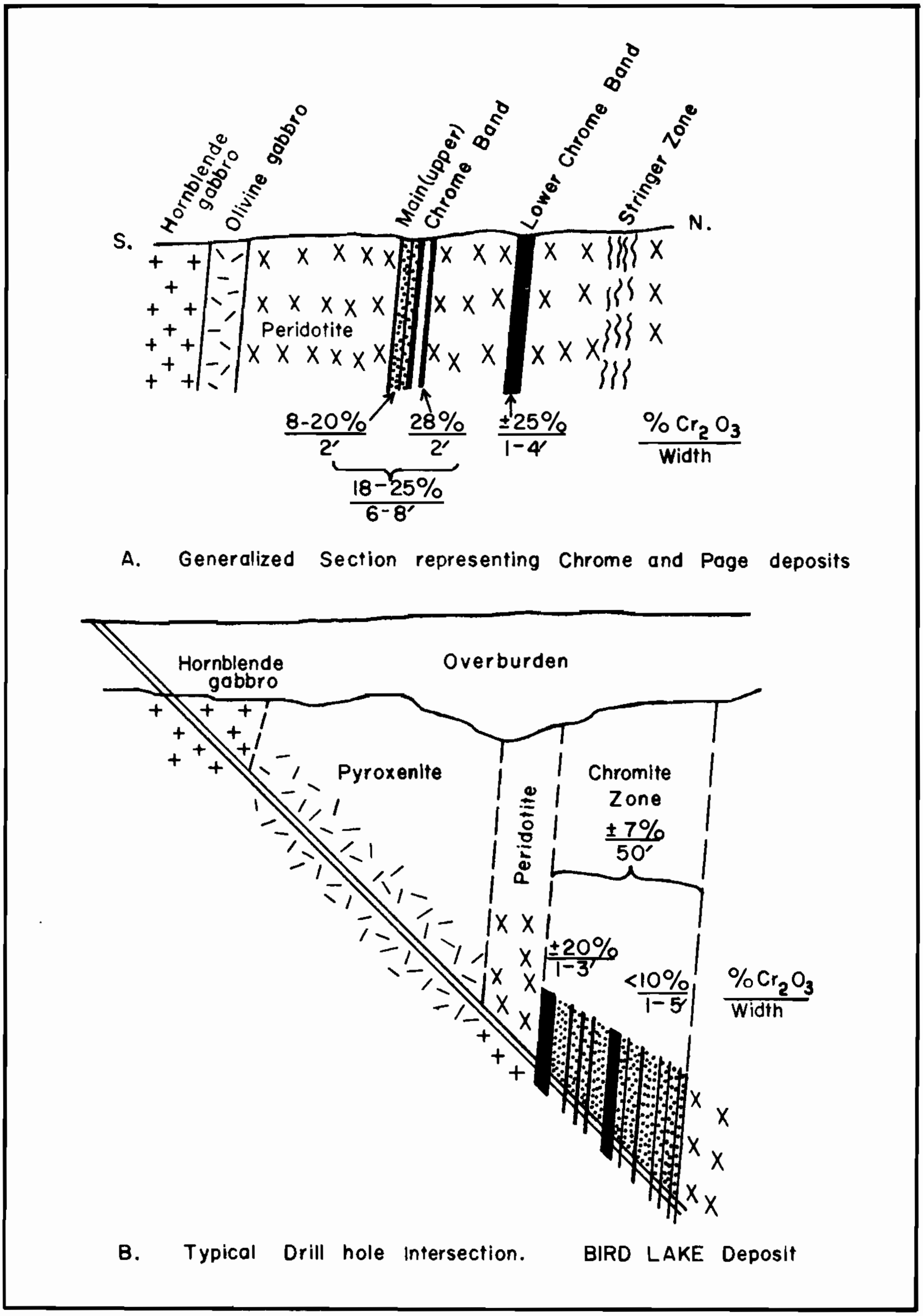

FIGURE 12 *Types of Chromite Deposits, Bird River Sill*

illustrated in figure 12 (B), which consist of alternating thin bands of about a foot thick, of dense ore and disseminated ore, across widths of 50 to 100 feet.

A large number of closely spaced transverse faults cut the chromite zones up into short blocks. In most places the displacement is only a few feet but in some cases the horizontal displacement may be as much as 300 feet.

Dense chromite ore contains 40 to 75 per cent chromite in small irregular to rounded and octahedral grains about 0.5 millimeters across. Typical disseminated ore contains about 25 per cent chromite. Many of the chromite crystals contain small silicate nuclei. The chromic oxide content of different bands varies from a few per cent for chromiferous peridotite to 30 per cent for dense ore. Average grades for individual bands and entire zones are shown on figure 12. The chrome:iron ratio is low, about 1:1 for low-grade disseminated ore to a maximum of 1.6:1 for dense ore. Tests indicate that little difficulty is encountered in obtaining concentrates of 40 per cent Cr_2O_3 but concentration produces only a slight improvement in the chrome:iron ratio.

Parts of the main chrome band have been drilled to a depth of 650 feet and indicated reserves are 874,000 tons grading 25.2 per cent Cr_2O_3 on the Page property (*Manitoba Chromium Limited*, locality 18), and 1,220,000 tons grading 18.2 per cent Cr_2O_3 on the Chrome property (*Gunnar Mines Limited*, locality 21). The actual reserves are probably many times these figures for only parts of each property have been drilled and the chromite bands are generally persistent. The deposit at Bird Lake (11) was drilled by Petra Chromite Limited to a depth of 200 feet and was estimated to contain 3,000,000 tons grading 7 per cent Cr_2O_3 to that depth. The occurrence at Euclid Lake (10) is similar to that at Bird Lake, and is reported by Gunnar Mines Limited to contain 11,000,000 tons averaging 4.6 per cent Cr_2O_3 to a depth of 1,000 feet.

Lithium and Beryllium Deposits

Pegmatite dykes containing lithium and beryllium minerals occur in volcanic and granitic rocks close to the margins of the large granitic intrusions. Most of the lithium dykes are in volcanic rocks; the beryllium dykes, if in volcanic rocks, occur closer to the granite than the lithium dykes. Many beryllium pegmatites occur within the granite. The most important dykes are those containing lithium minerals and these may be either vertical or nearly horizontal bodies.

The more or less horizontal dykes generally are zoned, though not simply, for particular bands are not necessarily repeated on both sides of the core. The result of the zoning is that the various valuable silicate minerals are concentrated in different bands or lenses. The main lithium minerals found in the flat dykes are spodumene, amblygonite, petalite, lepidolite, and triphylite; spodumene is most abundant. Although generally in separate bands or lenses, all of the lithium minerals occur in intermediate or core zones and are closely associated with quartz. The deposit on the north shore of Bernic Lake (25) contains lenses of pollucite as well as lithium minerals. Some of the flat-lying zoned dykes contain small amounts of beryl, tantalite-columbite, and cassiterite but these do not appear to be important constituents of any of the lithium-bearing pegmatites.

Most of the flat, zoned dykes are coarse-grained, containing crystals several inches to several feet across. Much of the spodumene, however, is intergrown with quartz and very large crystals of pure spodumene are rare. Besides lepidolite, which occurs as aggregates of small purple or yellowish green flakes, large flakes of grey or lilac coloured zinnwaldite and pale green lithium-bearing muscovite are present in the zoned dykes. These latter micas contain only minor Li_2O and occur in zones that are intermediate between the wall zone and main lithium zones and that are composed dominantly of feldspar (cleavelandite, microcline, or perthite) and quartz. The wall and border zones of the flat dykes are composed mainly of albite and tourmaline.

Excellent examples of nearly horizontal, zoned dykes are those occurring at Bernic Lake. *Chemalloy Minerals Limited* have done considerable underground exploration on the deposit (25) near the west end of Bernic Lake. Those at the east end of the lake (26) have been drilled and trenched by *Lithium Corporation of Canada Limited.* Zoning of the latter dykes is illustrated in figure 13. Spodumene, lepidolite, amblygonite and petalite are important constituents of these pegmatites.

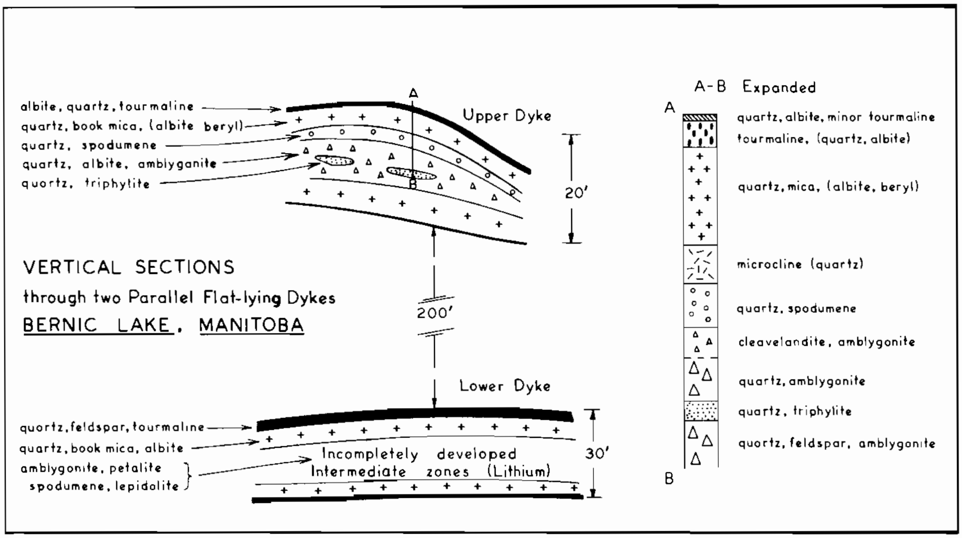

FIGURE 13 *Diagrammatic Vertical Sections Showing Zoning*

The steeply dipping lithium-bearing dykes are mineralogically much simpler than the flat-lying pegmatites; they consist of only two or three zones and contain spodumene but lack or contain only minute amounts of petalite, amblygonite, lepidolite, and triphylite. The border zones of the vertical dykes consist of fine-grained albite and quartz which grade into wall zones of coarser quartz and albite with minor spodumene. The central parts, which make up the bulk of the dykes, consist of medium-grained albite, quartz, and spodumene. The spodumene may occur in small closely spaced lenses composed of quartz-spodumene intergrowth or as crystals scattered throughout the quartz-feldspar aggregate. Examples of vertical dykes are those at Cat Lake (Irgon claim, locality 7) on which some underground development was done by *Lithium Corporation of Canada Limited*, and those (3) north of Maskwa Lake which were drilled by *Lithia Mines and Chemicals Limited.*

The following reserves have been reported for several lithium properties:

LOCALITY	TONNAGE	GRADE
3 (two dykes)	4,000,000 tons	1.28% Li_2O
5	600,000 tons	1.4 % Li_2O
7	1,200,000 tons	1.51% Li_2O
25	8,000,000 tons	1.85% Li_2O
26	800,000 tons	2.13% Li_2O

In addition the deposit (25) of *Chemalloy Minerals Limited* is reported to contain 300,000 tons of pollucite averaging between 25 and 30 per cent caesium.

Although beryl is present in small quantities in the outer intermediate zones of some lithium-bearing dykes, this mineral more commonly is concentrated in dykes lacking or containing only minor amounts of lithium. The beryl pegmatites are composed mainly of pink and flesh-coloured microcline (perthite), albite, glassy quartz, muscovite, biotite and/or zinnwaldite. Beryl is closely associated with quartz and books of zinnwaldite or pale yellowish green muscovite containing a few tenths of a per cent Li_2O. The beryl is usually distributed irregularly throughout the dykes as small to large crystals. The beryl dykes commonly contain small amounts of tantalite, columbite, topaz, uraninite, and monazite.

Pegmatite dykes containing beryl are common along the Winnipeg River, south of Shatford Lake, and around Cat Lake. A small pod of high-grade beryl (now removed) was present in a dyke (separate from the lithium dyke) on the property now held by *Chemalloy Minerals Limited* at Bernic Lake (23); a poorly exposed beryl pegmatite on which little work has been done was discovered in 1956 at the east end of Bernic Lake (26), also separate from the lithium dykes. The beryl content appears to be fairly high. The most important deposits appear to be those near Greer Lake (40) where, in 1957, *Dalhart Beryllium Mines and Metals Corporation* engaged in a program of stripping, trenching, and drilling. The work to date has outlined several lenses of material amounting to a few hundred thousand tons averaging about 0.5 per cent beryl. Large crystals of beryl (with some uraninite) also are present in the Huron dyke (37) south of the Winnipeg River. Little work has been done on the remainder of the beryl occurrences along the Winnipeg River.

During the early 1930's attempts were made to outline commercial tin deposits at Shatford Lake (32) and Bernic Lake (25) but these were unsuccessful. Shafts were sunk on both deposits and it was the drilling done at Bernic Lake after the operation was suspended that revealed the presence of spodumene on the property now held by *Chemalloy Minerals Limited.*

A few crystals of cassiterite occur in the wall zones of some dykes, in a coarse quartz-feldspar-mica aggregate in others, and in an albitite phase of one dyke (29). The latter is the largest of any known occurrence in the area. The surface zone averaged 0.35 per cent tin across an area 4.7 feet by 320 feet; drilling revealed narrower widths and lower grade at depth.

It is of interest to note that radioactive age determinations on uraninite from the Huron beryl deposit (37) and on lepidolite from the Bob (former Silverleaf) deposit (36) gave ages of 2,600 million years, which is regarded as a minimum age for the Superior geological province.

One other aspect of the pegmatite deposits requires comment. This is the difficulty frequently encountered in mineral identification. Most of the valuable silicate minerals (spodumene, amblygonite, beryl, petalite, pollucite) are white or nearly white in colour and may be easily confused with one another or even with quartz and feldspar.

Base Metal Deposits

Base metal deposits containing copper and nickel occur in or along the edges of gabbro and peridotite. The most important occurrences are those marked 1, 6, and 13, on figure 10. Some of the deposits in the area (for example, those cited above) contain both copper and nickel; others (14, 15, and 16) contain mainly copper.

The deposits north of Maskwa Lake (1) consist of pyrrhotite, pentlandite, and chalcopyrite disseminated throughout gabbro and peridotite adjacent to their contacts with basalt. These occurrences were discovered in 1917 and have been partly drilled several times, most recently by Maskwa Nickel Chrome Mines Limited. Small tonnages, averaging a fraction of a per cent nickel and copper have been outlined.

West of Cat Lake (6) sulphides are disseminated through a small gabbro plug in basalt adjacent to granitic rocks. *New Manitoba Mining and Smelting Company Limited* report reserves of 2,000,000 tons averaging 0.33 per cent nickel and 0.75 per cent copper to a depth of 425 feet. A shaft has been sunk on the deposit and development work has been carried out to the 500-foot level; a concentrator was erected on the property in 1957 but no production has yet been achieved (1961).

The deposits (12, 13, 14, 15) west of Bird Lake occur at the contacts between granite, and peridotite and gabbro. The largest of these (13) consists of a series of sulphide lenses composed of massive and disseminated pyrrhotite, pentlandite, chalcopyrite, cubanite, pyrite, and magnetite. The sulphides occur in fractured peridotite and basalt lying between peridotite and granite. Small stringers of sulphide penetrate the granitic rocks. Quartz and carbonate are common though not abundant in the sulphide zone. It appears that the sulphides (perhaps originally disseminated throughout the peridotite) have been "re-worked" and concentrated by the action of the intruding granite. The part of the sulphide zone covered by the Chance and Colossus 12 claims was drilled by *Maskwa Nickel Chrome Mines Limited* in 1953. Reserves to a depth of 500 feet are reported to be 1,213,000 tons averaging 1.23 per cent nickel and 0.37 per cent copper.

Small lenses of massive chalcopyrite occur on the Wento claim (15) in gabbro intruded by granite. Disseminated chalcopyrite and pyrrhotite on the Colossus claim (14) occur in a small lens of basalt intruded by peridotite and granite. South of the Winnipeg River (35) chalcopyrite and pyrrhotite are disseminated in a narrow gabbro sill intruding basalt and intruded by granite. The sulphides in this deposit occur both in the gabbro and in granite stringers cutting the gabbro. The deposit was drilled by *Lithium Corporation of Canada Limited* in 1956; low values in copper and nickel were encountered.

PLATE IV *Aerial view of Winnipeg River, looking south. High rock ridges (white, grey) are granitic rocks. The river follows a band of softer volcanic rocks.*

Miscellaneous Minerals

Besides the deposits discussed above, some attention has been paid to occurrences of fuchsite, rose quartz, feldspar, and gold. *Feldspar* is abundant in most pegmatite dykes in the area and a few dykes, or parts of them at least, are composed mainly of this mineral. Microcline and albite of ceramic grade were quarried from a large body (42) at the northeast corner of Greer Lake, between 1933 and 1939.

Chromium-bearing mica, *fuchsite*, occurs south of the Winnipeg River (34) in "pearl rock" (silicified basalt), at the contact between granite and basalt. Some of the bright green fuchsite-bearing material was shipped to Winnipeg in 1926 and used as stucco dash.

Rose-coloured quartz forms the core zone of a pegmatite dyke (30) north of Birse Lake. Much of the quartz is fractured but some pieces have been used as stones for jewellery. It may find wider use in the manufacture of aggregate tile. Some clear glassy quartz from Bernic Lake has also been used for this purpose.

Gold associated with sphalerite and galena was discovered between Maskwa Lake and Little Bear Lake in 1924 (4). Irregular quartz veins, cutting sheared lamprophyre dykes that intrude granite, are mineralized with pyrite containing gold; gold also occurs in the native state and as tellurides in the quartz. Although some material is very high grade, elsewhere the gold content is low. Surface indications are that the veins are very small. The property is owned by Bear Lake Mines Limited.

TABLE 6
MINERAL DEPOSITS
CAT LAKE — BIRD RIVER — WINNIPEG RIVER AREA

(See Figure 10 for locations of deposits)

1.	Copper, nickel	Mayville group	Maskwa Nickel Chrome Mines Limited
2.	Chromite	Pronto, Colossus claims	Maskwa Nickel Chrome Mines Limited
3.	Spodumene	Spot claims	Lithia Mines and Chemicals Limited
4.	Gold	Black Beaver group	Bear Lake Mines Limited
5.	Spodumene	Eagle claims	Lithium Corporation of America Limited
6.	Copper, nickel	Eagle claims	New Manitoba Mining and Smelting Company Limited
7.	Spodumene	Irgon claim	Lithium Corporation of Canada Limited
8.	Spodumene	Central claim	Cat Lake Consolidated Metals Limited
9.	Beryl	Mapetre claim	
10.	Chromite	Euclid claims	Gunnar Mines Limited
11.	Chromite	Wolf claims	Petra Chromite Limited
12.	Copper, nickel	Fisher claim	Petra Chromite Limited
13.	Copper, nickel	Chance, Devlin, Colossus 12 claims	Maskwa Nickel Chrome Mines Limited
14.	Copper	Colossus claim	Maskwa Nickel Chrome Mines Limited
15.	Copper	Wento claim	Wento Syndicate
16.	Copper	Colossus 3 claim	Maskwa Nickel Chrome Mines Limited
17.	Chromite	Queen, Annie claims	Maskwa Nickel Chrome Mines Limited
18.	Chromite	Page claims	Manitoba Chromium Limited
19.	Copper, nickel	Page claims	Manitoba Chromium Limited
20.	Chromite	Bell, Roy claims	Lac du Bonnet Chromium Limited
21.	Chromite	Chrome claims	Gunnar Mines Limited
22.	Chromite	National, Ledin claims	Howbay Gold Mining Company Limited

23. Chromite	Wards claim	Macroy Nickel Chrome and Exploration Limited
24. Spodumene	Matty claims	International Base Metals Limited
25. Spodumene, amblygonite lepidolite, pollucite (beryl)	Lith claims	Chemalloy Minerals Limited
26. Spodumene, amblygonite lepidolite, petalite (beryl)	Buck, Coe, Pegli claims	Lithium Corporation of Canada Limited
27. Cassiterite	former Rush claims	
28. Cassiterite	former Stannite claims	
29. Cassiterite	former Odd claims	
30. Rose quartz	Rose claim	
31. Beryl	Dyke claims	Contact Minerals Limited
32. Cassiterite		
33. Beryl	former Amazon claim	
34. Fuchsite		
35. Copper, nickel	Duck claim	Lithium Corporation of Canada Limited
36. Spodumene, lepidolite	Bob (former Silverleaf)	Lithium Corporation of Canada Limited
37. Beryl (uraninite)	Huron claims	Dalhart Beryllium Mines and Metals Corporation Limited
38. Beryl		Dalhart Beryllium Mines and Metals Corporation Limited
39. Beryl		
40. Beryl	Grace claims	Dalhart Beryllium Mines and Metals Corporation Limited
41. Beryl	Loon (former Top of the World) claim	Dalhart Beryllium Mines and Metals Corporation Limited
42. Feldspar		
43. Beryl		

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RICE LAKE — BERESFORD LAKE AREA

The first important discovery of gold in Manitoba was made during 1911 in a quartz vein on the north shore of Rice Lake. This was on the property now owned by San Antonio Gold Mines Limited which commenced production in 1932 and has operated continuously since that time. Central Manitoba Mines Limited started operations in 1927 on a deposit west of Beresford Lake and remained in production until 1937. Production at the property of Gunnar Mines Limited began in 1936 and ended in 1942. Ogama-Rockland Gold Mines Limited commenced operations in 1942 but remained inactive from 1943 to 1948 when the mine was re-opened; the mine finally closed down in 1951. At the Jeep Mine, controlled by San Antonio Gold Mines Limited, production began in 1948 and ended in 1950. The total recorded gold production from the Rice Lake area up to 1961 amounts to some $50,000,000 of which San Antonio Gold Mines Limited and its subsidiary, Forty-Four Mines Limited, account for about $40,000,000.

GENERAL GEOLOGY

The Rice Lake group of volcanic, sedimentary, and derived metamorphic rocks, forms a continuous belt from Lake Winnipeg to the Manitoba-Ontario boundary (Fig. 14). The volcanic rocks (basalt, andesite, dacite, rhyolite and associated pyroclastic varieties) are conformably overlain by a series of impure quartzite, greywacke, slate, and conglomerate. In the south part of the area these sediments have been altered to quartz-feldspar-mica schists. The Rice Lake group has been invaded by a series of calcic intrusions consisting of diabase dykes and sills, irregular sill-like bodies of gabbro, batholithic bodies of quartz diorite, and sills, dykes, and stocks of quartz-feldspar porphyry. The calcic rocks are largely massive and are confined mainly to areas underlain by the rocks of the Rice Lake group. Potash-bearing intrusions (microcline granite and granodiorite) form plutons enclosing both the Rice Lake group and the calcic intrusions. Unlike the latter rocks, the plutonic intrusions are in large part gneissic (granite gneiss).

Sediments of the San Antonio formation, conglomerate and feldspathic quartzite unconformably overlie the Rice Lake group and one body of quartz diorite. The rocks at the unconformable contact are heavily sheared and apparently faulted.

The Rice Lake group has been folded into anticlinal structures at Beresford Lake and Rice Lake. The limbs of these folds are steeply dipping. The area between

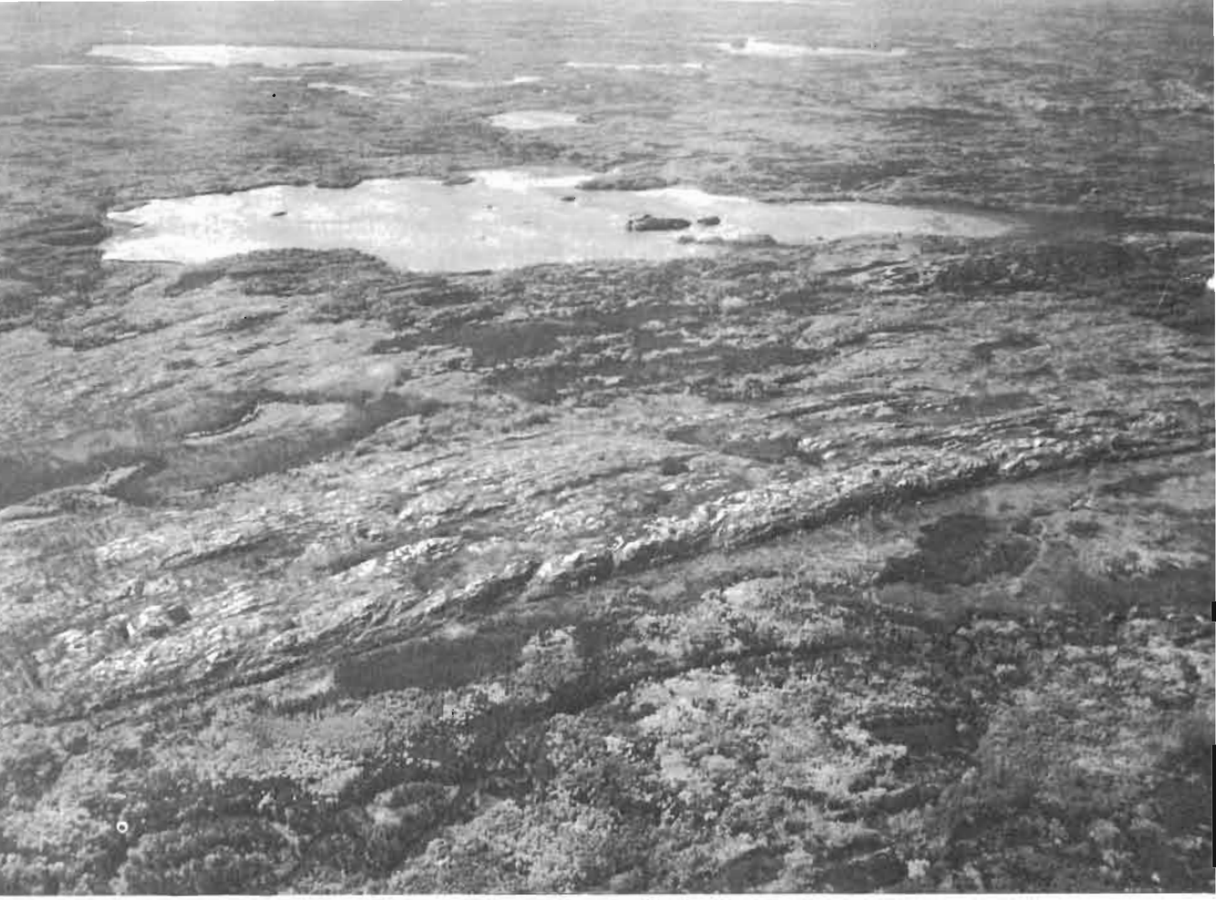


PLATE V *Aerial view, Rice Lake area, looking south. The ridge in the foreground is quartz-feldspar porphyry in contact with softer sedimentary rocks (treed area).*

Rice Lake and Beresford Lake is occupied by a large oval-shaped mass of quartz diorite. The San Antonio formation has been thrust over the Rice Lake rocks from the north and crumpled into a syncline and complementary anticline, the common limb of which is overturned. The folding of the San Antonio rocks appears to have accompanied invasion of the potash-bearing plutonic intrusions.

A number of longitudinal faults trending more or less east are present in the Rice Lake volcanic and sedimentary rocks. Numerous smaller shear and fracture zones trending northwest and northeast cut the Rice Lake rocks and calcic intrusions. Many of the shears and fractures are occupied by gold-bearing quartz veins. These shear and fracture zones are most common in massive brittle rocks such as diabase, gabbro, and unbedded non-pyroclastic and pyroclastic rocks. They are not well developed in the quartzose sediments and bedded tuffaceous rocks of the Rice Lake group. Only a few small shear and fracture zones are present in the San Antonio formation and these occur mainly close to the faulted unconformable surface separating the San Antonio formation from the Rice Lake group.

GOLD DEPOSITS

The distribution of gold deposits is shown on Figure 15 on which the more important occurrences are numbered. Table 7 lists the deposits under 3 categories: (1) those which have been important producers, (2) those on which considerable underground work was done but which produced little or no gold, although they

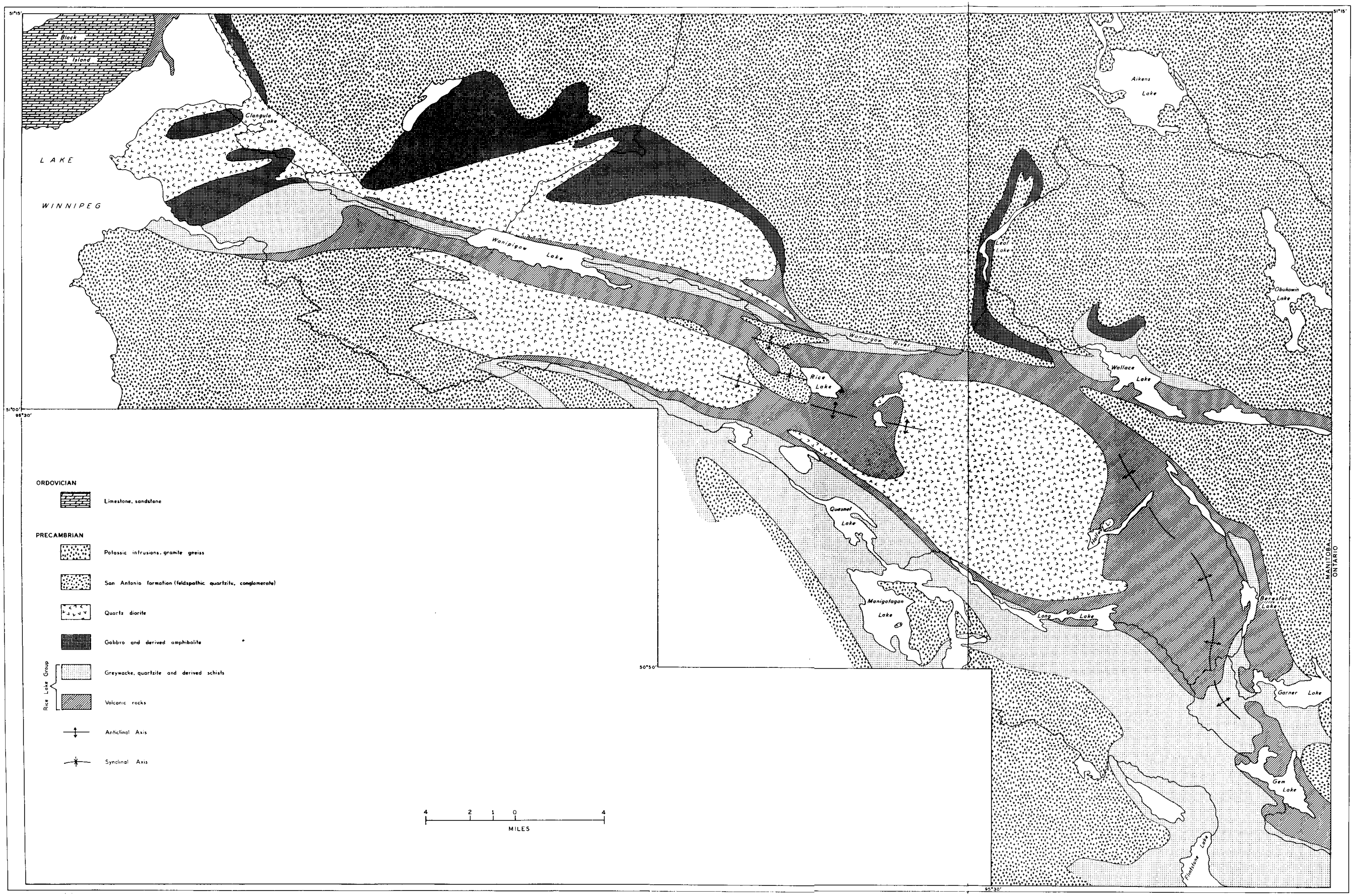


FIGURE 14 *Geology of the Rice Lake — Beresford Lake*

contained sufficient amounts of this metal to warrant underground exploration, (3) those on which prospect shafts were sunk but on which little or no underground work was done after the gold content was found to be low.

TABLE 7

WALL-ROCKS OF GOLD DEPOSITS

(Deposits in mafic rocks are marked by asterisks)

A. *Productive Mines*

1. San Antonio — diabase*
2. Jeep — gabbro*
3. Central Manitoba — gabbro (in part)*
4. Ogama-Rockland — quartz diorite
5. Oro Grande — gabbro*
6. Diana — gabbro*
7. Gunnar — gabbro*

B. *Underground Development — Little or no production*

8. English Brook — diabase and quartz diorite*
9. Poundmaker — diabase and quartz diorite*
10. Vanson — diabase and quartzite*
11. Wingold — porphyritic dacite
12. Gold Lake — diabase*
13. Packsack — diabase and dacite breccia*
14. Gold Pan — diabase and dacite breccia*
15. Moore — dacite breccia and quartz diorite

C. *Exploration Shafts — little or no underground development*

16. Grand Central — basalt*
17. Luana — dacite and quartzite
18. Eva — quartz diorite
19. Gilbert — diabase and dacite*
20. Wolf — diabase and dacite*
21. Ranger — rhyolite
22. Independence — rhyolite
23. Chicamon — dacite
24. Pendennis — quartz diorite
25. Gold Seal — dacite
26. Brooklyn — dacite
27. Cryderman — basalt*
28. Moore Lake — basalt*
29. Conley — basalt and quartz diorite*
30. Mandalay — gabbro*
31. Mirage — gabbro*
32. Onondaga — basalt and quartz diorite*
33. Elora — arkose
34. Valley Vein — quartz diorite
35. Eldorado — quartz diorite

It is evident that quartz veins are most abundant in the areas around Rice Lake and Beresford Lake where the volcanic-sedimentary belt is widest. These areas are also characterized by more numerous shear and fracture zones and diabase and porphyry dykes than elsewhere in the district. It is evident also, from Table 7 that, although gold-bearing veins occur in practically all rock types in the district the majority of those containing the largest amounts of gold occur in mafic intrusive and volcanic rocks. Of the dozens of veins that are not numbered on Figure 15 practically all occur in acid to intermediate rocks and contain little or no gold.

In the Rice Lake area diabase, because of its relative competency, has long been regarded as structurally favourable for the development of fractures. However, equally competent rocks comprise much of the Rice Lake group and indeed veins are numerous in these; however, generally they contain little or no gold. It appears that, besides being structurally suitable, diabase, gabbro, and basalt (all mafic rocks) were chemically favourable for the deposition of gold.

Many of the quartz veins consist of single bands or lenses of quartz, or series of stringers parallel to the length of the shear zones. Others consist of branching networks of stringers forming large angles with the long direction of fracture zones. Most veins and vein zones pinch and swell in an irregular manner.

The quartz veins are mineralized with pyrite and minor chalcopyrite, sphalerite, and galena. Veinlets and patches of ankerite are present in most veins, and grains of albite occur in many. The pyrite is in the form of small cubic crystals or as fine granular material in seams. Native gold is closely associated with the fine granular pyrite seams.

The wall-rocks of veins have been replaced by ankerite, pyrite, and albite. The degree of pyrite and ankerite wall-rock alteration appears to bear a direct relationship to the ferromagnesian content of the host rock, suggesting perhaps the derivation of Ca, Mg, and Fe from the original rock and addition of CO_2 and S from solution. The amount of pyrite in the vein quartz is more or less proportional to that in the wall-rock and similarly the gold content appears to vary according to the amount of pyrite in both the wall-rock and vein quartz. Hence the relative abundance of gold in veins in mafic rocks may be related to the development of pyrite and ankerite in the rocks; veins in the acid to intermediate types, which exhibit minor ankerite and pyrite wall-rock alteration, carry only minor gold.

The gold-bearing quartz veins in the *San Antonio* mine occur in the thickest part of a north-dipping diabase sill that has intruded tuffaceous rocks of the Rice Lake group. The veins occupy northeast shear zones and northwest fracture zones that, along with the veins, die out upon meeting the upper and lower contacts of the diabase. Other veins, however, appear down dip in the sill. The northeast veins are in shear zones dipping about 60° northwest; the wall-rocks are pyritized chlorite schists. The northwest veins occupy fracture zones that dip steeply northeast or are almost vertical; the wall-rocks are intensely albitized, carbonatized, and pyritized and the vein zones consist of networks of veins and stringers containing small pieces of grey altered wall-rock. Besides wall-rock alteration which usually extends a foot or less from the quartz, the veins are characterized by haloes of country rock alteration that may extend 200 feet or more on both sides of the veins. Country rock alteration is much less intense than that along the vein walls, and consists of diabase replaced by ankerite closest to the veins and by calcite farthest

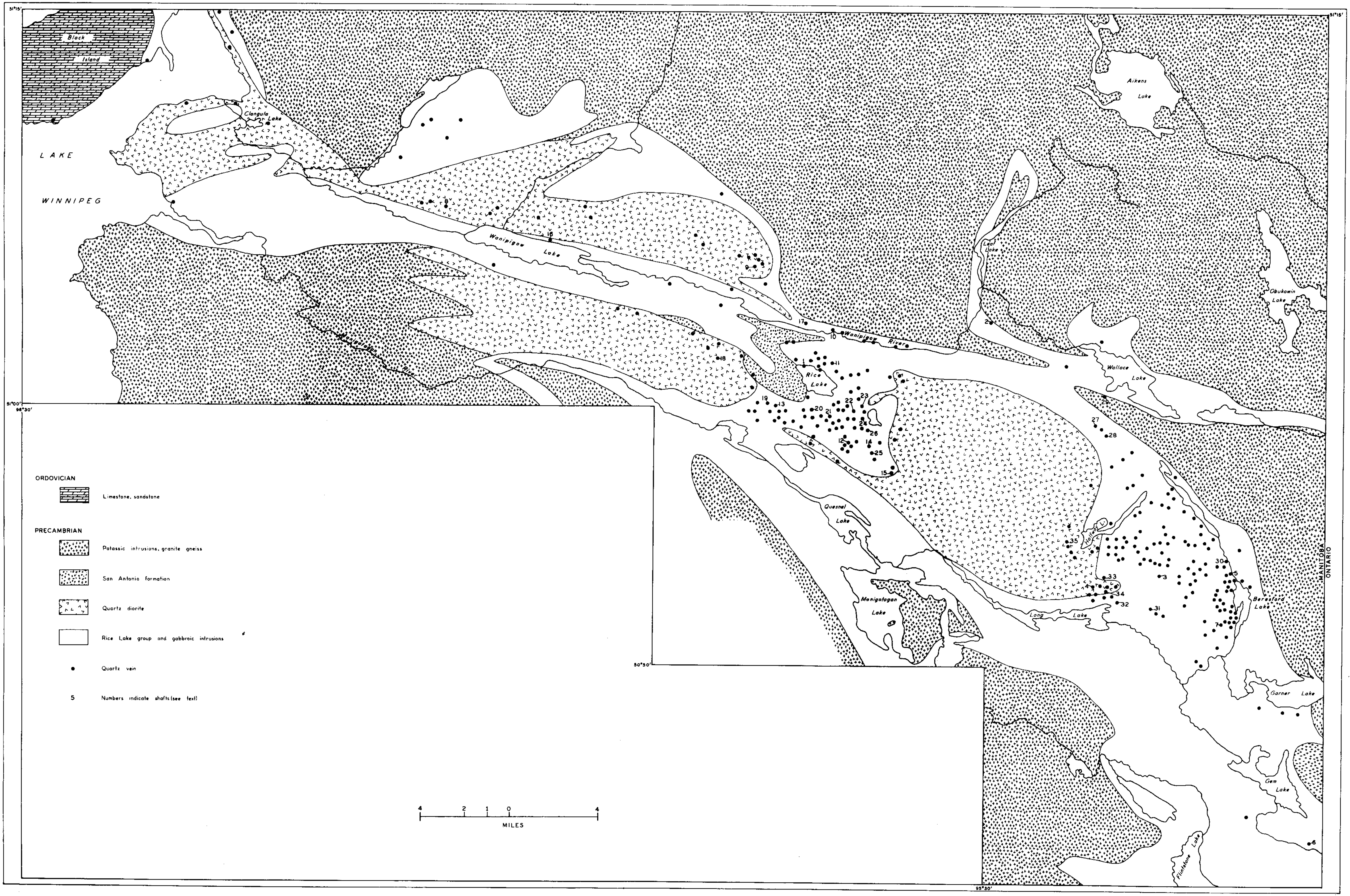
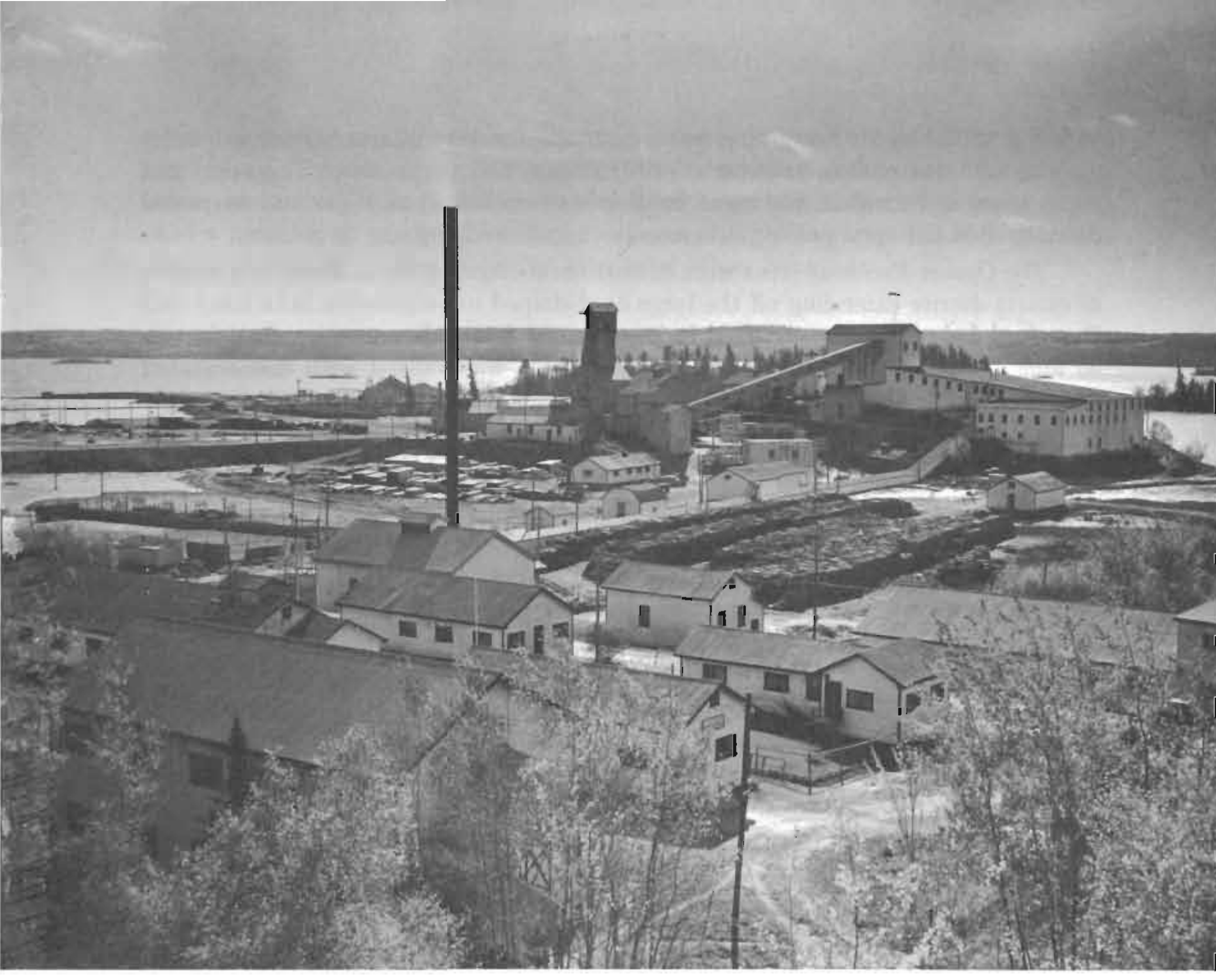


FIGURE 15 *Distribution of Quartz Veins Rice Lake — Beresford Lake Area*



View of San Antonio Gold Mine, Rice Lake, looking south. PLATE VI

from the veins. The average grade of ore milled to date has been approximately 0.27 ounces per ton.

Veins in the *Central Manitoba* mine occurred in a tuff band at its contact with a gabbro sill, and in meta-diorite. The veins lay end-to-end or en echelon in a zone trending diagonally across a wedge-shaped area of andesite, meta-diorite, and gabbro bounded by two long, wide, carbonatized shear zones. Only minor vein quartz and little gold occurred in the main carbonate shears. The subsidiary shears in which the quartz veins occurred were up to 2,400 feet long and from 1 to 25 feet wide. Quartz formed bodies as much as 2,100 feet long and commonly 4 or 5 feet (in places up to 20 feet) wide. However, the veins did not extend to any great depth, 750 feet or less, and practically all of the ore occurred at depths of less than 400 feet. Sulphides in the vein material consisted of pyrite, chalcopyrite, and pyrrhotite.

The Central Manitoba Mine operated from 1927 to 1937 and produced 160,034 ounces of gold from 435,737 tons of ore.

At the *Gunnar mine* the quartz veins occurred in east-striking sheared andesite and basalt near the end of an irregular granite dyke. The walls of the veins were altered to chlorite schist and chlorite-carbonate schist. The gold was most abundant in fine granular pyrite occupying seams in crushed sugary quartz. Other sulphides present included chalcopyrite, sphalerite, galena, and pyrrhotite. The veins and shear zones were widest and most continuous in pillowed andesite and narrowed down or died out upon passing into massive unpillowed andesite or granite.

The *Ogama-Rockland veins* were in northwest-trending shear zones in a tongue of quartz diorite extending off the large oval-shaped mass between Rice Lake and Beresford Lake. Quartz occurred in lenses a few feet wide and a hundred feet or so long. The veins and wall-rock were sparsely mineralized with disseminated grains of pyrite and chalcopyrite.

The *Jeep deposit* occurred in a northwest fracture zone in gabbro. The veins, though narrow, were high-grade. The ore was trucked to the San Antonio mill.

MISCELLANEOUS DEPOSITS

The metamorphosed sediments in the southern part of the area have been injected by numerous dykes, sills, irregular bodies, and stringers of pegmatite; much of the rock is a pegmatitic schist. In several places the schist, pegmatite, and pegmatitic granite bodies contain small quantities of pitchblende. Some work was done on these during the 1950's but the results were disappointing.

Bodies of peridotite and gabbro east of Clangula Lake and near English Brook (Russell, 1949) and south of Leaf Lake (Davies, 1950) contain small amounts of nickel. Some work was done on those near English Brook and encouraging results were obtained, although the deposits appear to be small.

A deposit of serpentinite east of Clangula Lake was worked many years ago as a source of ornamental stone. Deposits of silica on Black Island are suitable for glass sands, and foundry sands. Some of this material was shipped to Selkirk during the late 1950's.

A hematite deposit on Black Island has been investigated as a source for iron but the deposit, which overlies a Precambrian sulphide zone, is of very limited extent.

Iron formations, consisting of alternating bands of magnetite and "chert" are numerous near the Manitoba-Ontario boundary. These have received little consideration as a source of iron ore.

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CROSS — OXFORD — GODS — ISLAND LAKES AREA

This large area northeast of Lake Winnipeg covers over 25,000 square miles and is bounded by longitudes 92° 30′ and 98° 15′ and latitudes 53° 30′ and 55° 25′. It comprises several east-trending greenstone belts that form topographically low areas occupied by major lakes. The two northernmost belts at Utik Lake and Bear Lake are the smallest, each having a maximum width of 2 miles. The Oxford Lake-Knee Lake belt with its possible eastward extension through Gods, Edmund, and Little Stull lakes is the most prominent, being up to 14 miles wide at Knee Lake. The longest, almost continuous greenstone belt, extends for 240 miles from Cross Lake to Stull Lake by the way of the Echimamish River, Beaverhill, Gods lakes and Sharpe Lake. The Stevenson Lake-Island Lake belt is noteworthy for the nickel deposit that occurs near the west end of Island Lake.

Since 1956, when prospecting activity was renewed in this region, encouraging indications of metal mineralization have been found, and at least one nickel deposit of economic interest has been outlined in the Island Lake area. Prior to this period only sporadic prospecting for gold had been conducted, mainly between 1928 and 1933, in 1936, and in 1944-45. One former gold producer and six small prospects, where underground development was carried out are situated in this area. Gold to the value of almost six million dollars was extracted by God's Lake Gold Mines Limited between 1935 and 1943. In addition, over $200,000 worth of gold was recovered from other small deposits. Occurrences of lithium, beryl, tin, molybdenum, tantalum, columbium, asbestos, and iron ore have been reported from the area.

SUMMARY OF PROSPECTING AND MINING ACTIVITY

Although gold was discovered in the area in the early part of the century, it was not until 1928 when public interest was aroused by discoveries of high-grade gold at Island Lake, that the area was considered worthy of widespread prospecting. In 1932 Island Lake Mines Limited sank a shaft to a depth of 271 feet and in 1934 a 50-ton mill went into production. However, the mine operated only one year, and yielded almost 5,000 ounces of gold from ore assaying 0.61 ounces per ton.

In 1932, gold was discovered at Gods Lake. Rumours of the discovery were quick to spread and the Akers group of claims was soon staked. On this property God's Lake Gold Mines Limited sank a three-compartment shaft to a depth of 921 feet. During the life of the mine, from September 1935 to September 1943, 524,000 tons of ore were mined and bullion to the value of $5,925,844 was produced for an average grade of just over 0.3 ounces per ton. In 1941, a second shaft 6,000 feet to the west reached a depth of almost 2,000 feet in an attempt to find more ore, but without success. Jowsey Island Gold Mines Limited commenced development on another gold property located 6 miles west of the Gods Lake mine and sank a 214-foot shaft. Two small ore-shoots were outlined with values of up to 0.47 ounces per ton across a width of 5.5 feet. Operations were suspended in July, 1936.

In 1933, prospecting in the Knee Lake area resulted in the discovery of two gold occurrences. Johnston Knee Lake Mines Limited and Knee Lake Gold Mines Limited both carried underground development to depths of over 300 feet and, although some spectacular gold values were disclosed, they were erratic and operations were discontinued in 1936.

In the period between 1928 and 1938, the greenstone belts between Gods Lake and Sachigo River in Ontario were prospected and discoveries were reported from Stull Lake, Kistigan Lake and Little Stull Lake. Prospecting was also carried on around Stevenson and Bigstone lakes where a 50-foot shaft was sunk and some drifting carried out on a gold-bearing vein. During the same period prospectors worked the western part of Oxford Lake.

A large number of claims was staked during the summer of 1936 north of the Echimamish River following reports of gold and silver discoveries. High assays in gold were reported from many small occurrences, and a lead-silver prospect yielded assays of up to 500 ounces of silver per ton. Interest in the area subsided in 1937, when it became apparent that most of these occurrences were of very limited lateral and vertical extent.

In 1937 there was renewed interest in the Island Lake area when a shallow shaft was sunk on the property of Ministik Lake Gold Mines. Some prospecting continued around Gods, Island, and Oxford lakes in the post-war years of 1945-1947; however, no discoveries of importance were made. Recently, new gold finds were reported from Knee Lake.

Interest was shown in base metals in 1924 and 1928 when a copper-gold prospect at the eastern end of Hyers Island was drilled and in 1943 when God's Lake Gold Mines Limited optioned a copper prospect on Hyers Island at the western end of Oxford Lake. A geophysical survey of the deposit at the western end of the island yielded interesting results but subsequent diamond drilling, while uncovering sizable sulphide zones, gave no indication of either copper or gold in commercial quantities. In the same general area, Sherritt Gordon Mines Limited investigated occurrences of sulphides in 1949 and evaluated a lead-zinc showing on the south shore of Oxford Lake on a property optioned from Ventures Limited. Original work on this property had been done as early as 1922. Sulphide occurrences along Carrot River west of Oxford Lake were later examined by the Hudson Bay Exploration & Development Co. Ltd.

In 1952-53, prospectors reported base metal finds at Utik Lake, on claims subsequently held by Kay Lake Mines Limited. Following a magnetometer survey, one copper showing was drilled but no sizable body was outlined.

Allcop Mines Limited performed a ground geophysical survey on Hyers Island and diamond drilled several sulphide occurrences between 1955 and 1957. At the western end of the island, high-grade copper ore was indicated but is understood to be of limited extent.

In 1955 The International Nickel Company of Canada Limited started a systematic search for base metals in the map-area. Exploration followed a pattern, now common in Manitoba, of large-scale aeromagnetic and airborne electromagnetic surveys, systematic follow-up by ground geophysical surveys in conjunc-

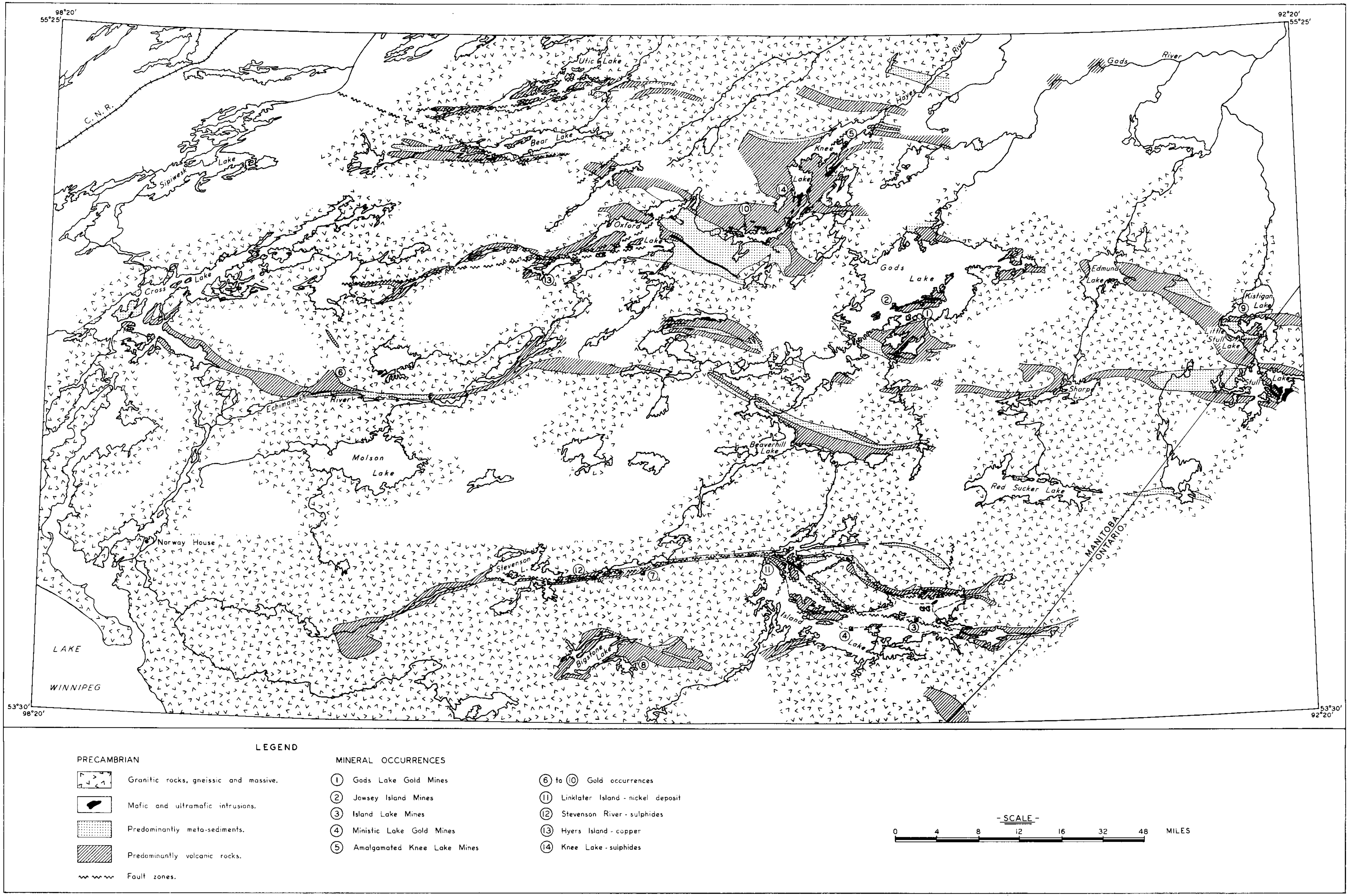


FIGURE 16 *Geology of Cross, Oxford, Gods and Island Lakes Area*

tion with geological investigations, staking or optioning of claims along the most favourable parts of greenstone belts, and finally diamond drilling of promising anomalies.

At first the search was concentrated in the north, where a large ultramafic sill along Fox River (immediately north of Figure 16) was investigated for possible nickel mineralization by the Canadian Nickel Company Limited. From there the company shifted its exploration program to Island Lake where it met with more success. Quinn (1960) gives the following summary: "In January 1956 two groups of 67 mining claims in the western part of Island Lake were optioned by the Canadian Nickel Company from the Rex Island Mining Syndicate. These long, narrow, southeasterly trending groups of claims cover discoveries of nickel made by (T.) Wass, mainly in ultrabasic sills of similar trend. An aeromagnetic survey in April 1956 showed many anomalies at Island Lake and led to the immediate staking of a few hundred additional claims there by the Canadian Nickel Company. The company began diamond-drill exploration of its optioned claims and of the magnetic anomalies early in 1956 and continued this work for 4 years. It is reported to have disclosed a body of low grade copper-nickel ore about 200 feet north of Rat Portage on Linklater Island."

Other major companies which, since 1958, have conducted airborne and ground geophysical surveys and some diamond drilling were the Phelps Dodge Corporation around Stull Lake near the Interprovincial boundary, and Canadian Longyear Limited in a narrow, 127-mile belt east and west of Stevenson Lake.

In 1959 and 1960, Noranda Mines Limited conducted exploration in the Cross Lake-Pipestone Lake area. Ground magnetic and electro-magnetic surveys were performed and several sulphide deposits diamond drilled.

In 1960, the Icon Syndicate, backed by several large mining companies, was granted a permit to conduct an airborne geophysical survey north of Knee Lake. This was followed by a ground geophysical study and a limited amount of drilling. It is understood that some massive sulphides were encountered.

GEOLOGY

The general geological setting of the map-area (Figure 16) shows a number of well-defined east-trending volcanic and sedimentary belts set in a predominantly granitic terrain consisting of gneissic and massive intrusions. The rocks are early Precambrian in age. Throughout the area the greenstone belts consist of an older series of intermediate (andesitic) volcanic rocks and derived schists with minor volcanic breccia, tuff, sediments, and minor conglomerate of the Hayes River group. This group is overlain unconformably by a younger, entirely meta-sedimentary series of conglomerate, greywacke, arkose, and micaceous schists variously termed Oxford, Cross Lake, and Island Lake series, depending on the locality. They may, or may not be, correlative units.

Bodies of gabbro, diorite, amphibolite and peridotite, mainly conformable to the known flows and sediments are abundant in almost every greenstone belt. Most of these are related to the period of volcanic activity. Many sulphide showings occur in the vicinity of these mafic intrusions.

Granitic rocks underlie the largest part of the area and in general are younger than the volcanic and sedimentary series and the mafic intrusions. Most are grey, faintly foliated tonalites and granodiorites and, in many places, the introduction of granitic material into schistose volcanic and sedimentary rocks has produced mixed gneisses and lit-par-lit gneisses. Some granitic rocks are contaminated by assimilated material and locally contain numerous xenoliths.

Pinkish massive granitic rocks approaching granite in composition and representing one or several distinct periods of intrusion are locally abundant and appear to be intrusive into older foliated types.

An intrusion of particular interest is the "quartz-eye granite" at Gods Lake. Field evidence strongly suggests that this pluton and its associated quartz porphyry and feldspar porphyry dykes are pre-Oxford in age, a suggestion first advanced but apparently later discarded by Wright. A genetic relationship between the pre-Oxford granite and porphyries and gold has been suggested by Baker (1935) for the Gods Lake mine. On the other hand, in the Little Stull Lake area to the east, gold has been reported in similar porphyries which cut the Oxford series. At Island Lake, quartz-feldspar porphyries occur mainly in the Hayes River group, but two bodies were also found in the Island Lake series. At Knee Lake the porphyries cut only volcanic rocks.

Diabase and lamprophyre dykes are the youngest intrusions. Most of them are small and trend northeast and north. In addition, several prominent dykes which are sufficiently large to be shown on aeromagnetic maps strike northwest.

Structure

Structurally, the Superior region of the Shield is characterized by an easterly or east-southeast trend of greenstone belts and gneissic granitic intrusions, in sharp contrast to the generally variable trend of the Churchill province of Manitoba. Absolute age determinations indicate that the older granite rocks range in age from 2,200 to 2,626 million years.

Within the map-area, some younger intrusions of more massive granitic rocks occur as batholiths elongated essentially parallel to this regional structural trend as, for example, at Island Lake and west of it. Others, however, occur as rather short plutons truncating the structure in a general northeast direction, as in areas north of Gods Lake, Knee Lake, and Bear Lake. The ages of two of these younger granitic rocks were determined to be 1,600 and 1,840 million years, corresponding generally to the age of synorogenic intrusions of the Churchill province. It is, therefore, possible that these younger granitic intrusions penetrated older rocks of the Superior province along northeast-trending zones of weakness at the time of the Churchill orogeny.

Drag-folds are common everywhere and in the wider parts of greenstone belts primary bedding structures are also locally abundant. At places it has been possible to determine the location of major fold axes. Dips within the older rocks of the Hayes River group are invariably steep to vertical but are moderate in some of the younger sediments. Secondary foliation is generally parallel to the bedding. The main greenstone belts appear to be remnants of synclines or synclinoria. Some of them are doubly plunging with younger meta-sediments exposed in the center as at Island Lake; others have a predominant plunge to the east as at Oxford, Knee, and Stull lakes. Near the extremities of some belts the rocks have been highly deformed into a number of isoclinal folds.

Fault zones and shear zones are numerous. Due to the scarcity of geological information, an over-all interpretation of their areal distribution is not yet possible. It is apparent, however, that sets of easterly-trending longitudinal faults exist in almost every greenstone belt. Some of these may be major thrust faults, generally dipping steeply to the north; others may be tear faults. The existence of a second major set of fault zones trending northeast is suspected from aeromagnetic data. They may be related to adjustments along the northeast-trending Churchill-Superior boundary. Locally, sets of north and northwest-trending faults have been outlined.

The majority of sulphide occurrences have been found in shear zones trending parallel to the foliation of the host rocks or in subsidiary shears and faults related to the longitudinal fault systems. Wall-rocks are commonly sericitized, chloritized, and/or carbonatized.

MINERAL OCCURRENCES

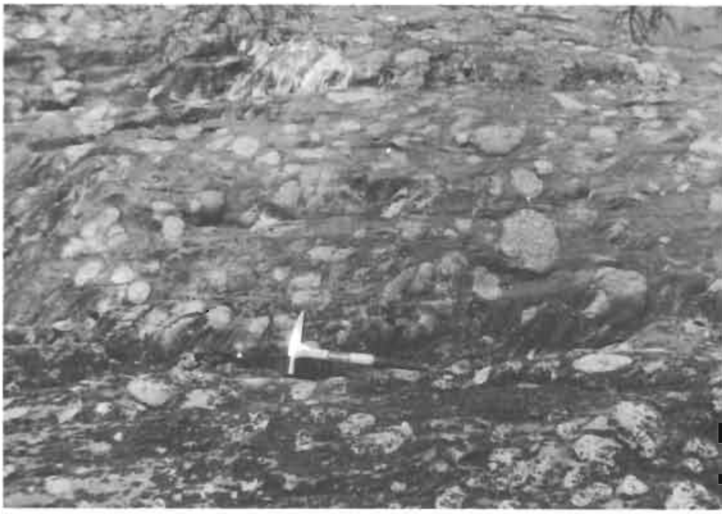
Mineral occurrences of the region are essentially of six types:

1. Gold-bearing quartz veins with associated sulphides.
2. Massive and disseminated sulphide replacement deposits in volcanic and sedimentary rocks.
3. Primary disseminated sulphides in ultramafic rocks.
4. Pneumatolitic minerals in pegmatites, aplites, and albitites.
5. Asbestos occurrences in ultramafic rocks.
6. Sedimentary iron-formations.

Only brief reference need be made to types 4, 5, and 6. At Cross Lake, spodumene, beryl, and apatite have been reported from numerous pegmatites. Molybdenum was found in a red pegmatite on Little Playgreen Lake near Norway House as early as 1898. Lithium-bearing pegmatites (spodumene) also occur south of Knee Lake and on the north shore of Gods Lake. The latter occurrence was drilled in 1959-60 and is reported to be of moderate size and grade. Tin occurrences in albitite at Red Sucker Lake were explored during the last war. Poor-quality asbestos was found in serpentinized peridotite bodies north of Knee Lake, in the Carrot River area west of Oxford Lake, and at Island Lake. Several iron-formations consisting of banded magnetite and chert were investigated on the surface and one, in the Cross Lake area, has been diamond drilled.

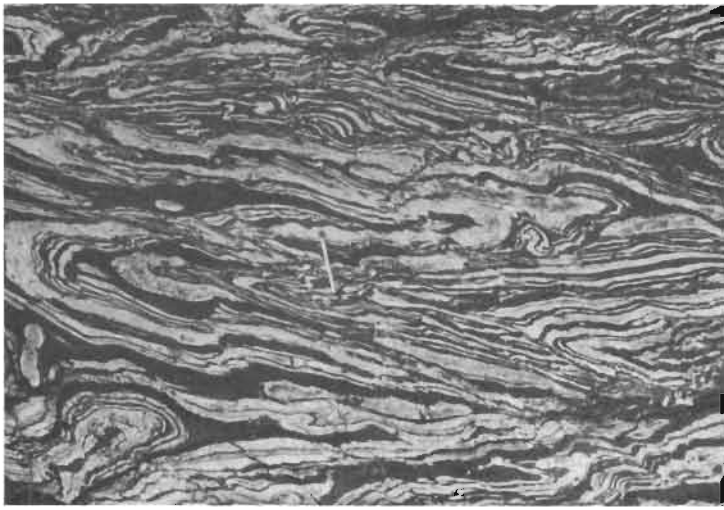
Gold is most widespread in quartz veins and stringers associated with light grey dykes of quartz porphyry and feldspar porphyry. Structural controls necessary for the emplacement of veins appear to have been of various types. In many places, these controls are horizons of tuff which provided easily permeable zones for ascending ore solutions, and easily replaceable media for gold-quartz mineralization. Shears in andesitic volcanic rocks, especially in the vicinity of small intrusions of porphyry, commonly carry mineralized quartz veins. Other types of control are shears within porphyry dykes or at the contact between lavas and porphyry intrusions trending in the general direction of the bedding or foliation of the country rocks. The lavas, tuffs, and sheared porphyry carry disseminated grains of pyrite; some carry disseminated pyrite, pyrrhotite, and arsenopyrite, and some are cut by bluish sulphide-bearing quartz stringers. Mineralized occurrences at Knee Lake, Gods Lake, and Little Stull Lake are of the latter type.

A. *Pillowed lavas, Oxford Lake.*



B. *Conglomerate, Oxford Lake.*

C. *Sediments in contact with volcanic rocks, Knee Lake.*



D. *Contorted iron-formation, Knee Lake.*

According to Baker (1935) the ore shoots at the Gods Lake Mine occurred in a tuff band lying between massive greenstones and an augite diorite sill. The sill, with an average width of 300 feet, extends for a length of over 10 miles and at its eastern end is cut by "quartz-eye granite." Along the north contact of the diorite the tuff is only 1 to 18 feet wide but is continuous for a length of more than 5 miles. The augite diorite, the tuff, and to a lesser extent the lavas are intruded by a great number of quartz-feldspar porphyry dykes which are irregular and discontinuous along strike. Baker explained that when the rocks were folded, the thick massive diorite was fractured more than the tuff and greenstone and that the cracks and fissures thus formed were subsequently filled by porphyry.

A number of cross-faults displace the augite diorite and the tuff and in all cases the west side was shifted to the north, with horizontal displacement of as much as 450 feet. All the ore shoots occur a few thousand feet to the east of these faults.

The tuff can be divided into three distinct types: a fine-grained slaty tuff, a mafic tuff (now a chlorite hornblende schist), and a coarser-grained, more felsic tuff in which all the ore shoots occurred. This tuff, found only in the widest parts of the band, shows well-defined bedding planes and is highly fractured and cemented by numerous, dark bluish or grey quartz stringers. The ore as a whole averaged not more than 25 per cent quartz. The tuff fragments and bands contained disseminated sulphides but most of the gold was found with the sulphides in the quartz. Pyrrhotite was prominent, with a considerable amount of pyrite, little chalcopyrite and sphalerite, and rare galena and arsenopyrite. Free gold was found locally underground. Baker (1935, p. 161) concluded that the "gold-bearing quartz veins and porphyries are no doubt genetically related to the 'quartz-eye' granite that probably underlies the whole [of Elk] island at depth."

At Oxford Lake, gold was found in small quartz stringers in sericitized, carbonatized and chloritized schist, commonly with indications of a green chrome mica, fuchsite. These schists are well mineralized with pyrite and scattered grains of chalcopyrite.

At Island Lake, Bigstone Lake, and on the Echimamish River gold occurs in quartz veins and stringers enclosed in feldspathic or chloritic schists mineralized with pyrite, pyrrhotite, arsenopyrite, galena, and minor chalcopyrite. Sections rich in galena, and with a high silver content, were also richest in gold.

At several places north of the Echimamish River, gold and silver occurrences have been found in sulphide-bearing felsitized zones. Some of these are quite extensive and usually follow shears parallel to the foliation of the country rocks, but they do not everywhere coincide with the structure of the enclosing strata. Tanton (1937) reports that they are of composite lithological character and consist chiefly of felsite, quartz porphyry, siliceous replacement bodies and inclusions of sericite and chlorite schist. Small lenticular sections along these zones gave very high assays in gold and silver.

At Utik Lake and in the vicinity of Gods Narrows, two occurrences of massive arsenopyrite with a few quartz stringers were found; samples assayed 0.2 and 0.1 ounces of gold per ton respectively.

Massive and disseminated replacement sulphide bodies in volcanic and sedimentary schists have been investigated in the area as a potential source of base metals. The most common type consists of pyrite or pyrite and pyrrhotite with minor copper and zinc sulphides. Generally the occurrences are small, up to several feet in width and several hundred feet in length, and contain disseminated sulphides grading into massive lenses in the center. The majority of the outcropping deposits are capped by 1 foot to 3 feet of gossan.

In several localities along the shores of Knee Lake and in the wider belt of volcanic rocks north of it, lenses of massive pyrrhotite and pyrite contain sparsely scattered grains of chalcopyrite and sphalerite. Several such deposits were located by drilling geophysical anomalies, but it is understood that none contained base metals in appreciable amounts. It is interesting to note that most of these deposits occur in schistose andesite in the vicinity of or at the contacts of gabbroic intrusions.

Small amounts of copper and zinc have been reported from similar occurrences on Carrot River, Gods Lake, and Little Stull Lake where some of the sulphides occur both in volcanic rock and silicified sediments.

On the property of Allcop Mines Limited at the western end of Oxford Lake, high values in copper were reported during a drilling program in 1956. The sulphides are in sheared and carbonatized sericitic and chloritic schist at the contact of a diabase dyke, and as observed in pits, consists of massive pyrite and disseminated chalcopyrite and a 2-foot lens of almost massive chalcopyrite in the center. This occurrence of sulphides appears to be associated with a flexure in the diabase dyke plunging 30 to 40 degrees to the west. The mineralized zone is also cut by a northeast-trending fault and there is evidence of sulphides along this structure to the north of Hyers Island.

In the Stevenson Lake area diamond drilling of several conductors by Canadian Longyear Limited in 1958-59 disclosed bodies of disseminated and massive sulphides, mostly pyrrhotite and pyrite, with some graphite and magnetite. The sulphides generally occurred in association with small mafic and ultramafic intrusions.

Several sulphide showings have been explored in the Cross Lake area. There, shears in volcanic rocks are well mineralized with pyrrhotite, pyrite, and grains of sphalerite and chalcopyrite.

In the Island Lake area, the low-grade nickel deposit outlined by the Canadian Nickel Company Limited is reported by Quinn to consist "mainly of disseminated millerite, pentlandite, nickeliferous pyrrhotite, pyrite, chalcopyrite and magnetite, in a sheared, serpentinized sill of peridotite and adjacent highly altered volcanic and sedimentary rocks of the Hayes River group."

The most favourable prospecting ground is probably along major longitudinal fault zones (strike faults) and sets of auxiliary faults. These extend over the entire length of some of the greenstone belts such as at Island, Oxford, Knee, Bear, Utik lakes, and possibly others. In prospecting, particular attention should be paid also to areas where greenstone belts are widest and, therefore, probably deepest, and where mafic and ultramafic intrusions are abundant; however, some long, narrow, intensively sheared belts may form important deep-seated structures.

Although considerable exploration has been carried out in this area for gold and base metals, an adequate investigation of a region of this size, comprising over 25,000 square miles, will take many years. Aeromagnetic sheets of the Wolf series, on a scale of 1 inch to 1 mile, released by the Mines Branch in 1960, should be a valuable guide for future exploration and useful in projecting greenstone belts into unmapped territory or into terrain overlain by a heavy drift cover. Parts of the area are covered by reconnaissance geological maps at a scale of 4 miles to 1 inch and a program of mapping some of the greenstone belts at a scale of 1 mile to 1 inch is now being conducted by the Manitoba Mines Branch.

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HIGH HILL LAKE — FOX RIVER AREA

This area northeast of Lake Winnipeg is bounded by longitudes 94° 00′ and 96° 00′ and latitudes 55° 25′ and 56° 00′. It has been mapped on a scale of 4 miles to 1 inch. Approximately 80 per cent of the terrain is underlain by granitic rocks. The High Hill Lake greenstone belt is about 40 miles long and up to 8 miles wide. The Fox River belt is also known to extend for approximately 40 miles but may be much longer towards the east where it trends into unmapped and heavily drift-covered territory.

The volcanic rocks consist chiefly of basalt and andesite with minor rhyolite and dacite. Many of the flows are characterized by elongated pillows. Chert, iron-formation and thin beds of meta-sediments occur locally. Bands of flow breccia, agglomerate and tuff occur at a few places. Beds of slate, slaty argillite, quartzite, graphitic schist, phyllite and chlorite schist were encountered in drill holes in the greenstones south of Fox River. The meta-sediments which outcrop north of Fox River lie stratigraphically above the volcanic rocks. They consist of nodular cordierite schist, garnetiferous plagioclase-biotite-quartz gneiss and schist and staurolite-garnet-mica-quartz schist.

Mafic and ultramafic rocks form sills in the mafic to intermediate volcanic rocks. A layered sill at least 2,500 feet thick outcrops along Fox River. Although most of this sill consists of serpentinite and serpentinized pyroxenite and peridotite, some bands 25 feet or more thick are composed of unaltered peridotite and pyroxenite. One band of serpentinite at least 20 feet thick near the base (south side) of the sill probably was derived from dunite. Dunite was encountered in some drill holes south of the main sill. Veinlets and disseminated grains of magnetite occur throughout the sill. A few microscopic veinlets of cross-fibre serpentine (asbestos) were noted at one locality.

Except for the Fox River ultramafic sill, the area has been only very lightly prospected. There is no information available on the nature of the gold and sulphide occurrences east of High Hill Lake, shown on Figure 17.

Large angular boulders containing 1 to 3 per cent disseminated pyrite, pyrrhotite and chalcopyrite in massive greenstone, rhyolite, and agglomerate or breccia, were found along Fox River, 3 miles above the mouth of Bigstone River.

The extent of the ultramafic body found along Fox River was investigated by the Canadian Nickel Company Limited, in 1956. A group of 1,279 claims was explored. The same year and in 1958 drilling was conducted on several claims north and south of the river. In 1956 and 1957 Sherritt Gordon Mines Limited carried out an electromagnetic survey covering almost the entire central part of the greenstone belt. This company also performed a limited amount of drilling.

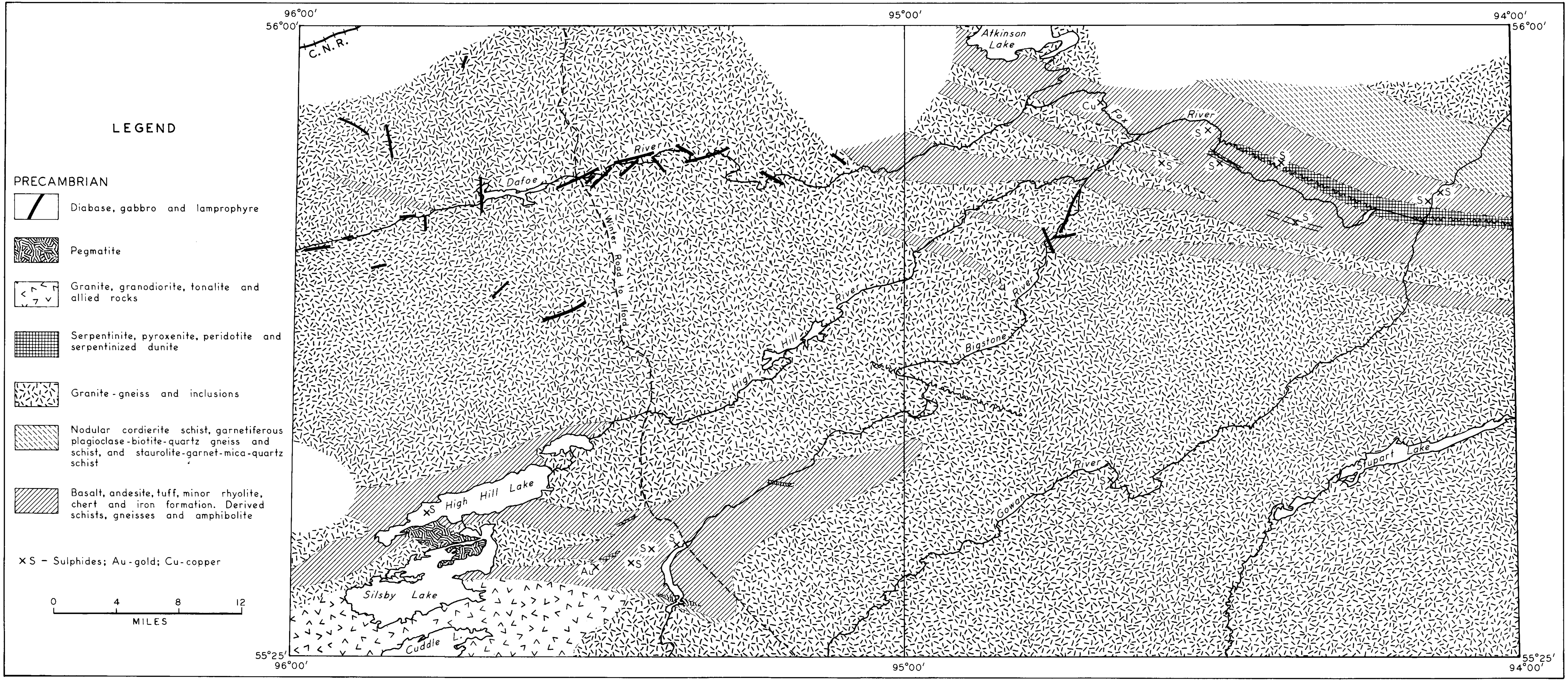

FIGURE 17

Geology of High Hill Lake — Fox River Area

Although no deposit of economic value was indicated in the area, many drill intersections encountered sulphides in serpentinized peridotite, dunite, and greenstone. Some zones bear up to 20 per cent disseminated pyrrhotite with lesser amounts of pyrite. Chalcopyrite, sphalerite and galena were also reported. The drilling indicated the presence of several ultramafic sills in the greenstones south of Fox River.

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CHAPTER IV

MINERAL AREAS OF THE CHURCHILL GEOLOGIC PROVINCE OF MANITOBA

From the standpoint of known mineral occurrences and value of mineral production the Churchill geologic province greatly surpasses the Superior province of the southern and eastern parts of Manitoba. It ranks as one of the outstanding mineral areas of the Canadian Precambrian Shield. Within the boundaries of this area are situated: the copper and zinc deposits of the Flin Flon district; similar sulphide deposits, gold-bearing quartz veins, and lithium-bearing pegmatite dykes of the Snow Lake-Wekusko Lake district; the copper-zinc deposits of the Sherridon area; the nickel-copper, copper-zinc, and gold deposits of the Lynn Lake district; and, along the southeast border of the Churchill province, the numerous large nickel deposits of the Thompson belt.

Little is known about the geology and mineral potential of the area north of latitude 57° 00′ but there is no reason to suppose that this northern part of the province will not eventually be as productive as the southern part of the Churchill block, containing the deposits referred to above.

Mineral exploration in the Churchill block should not be guided solely by experience in the Superior province where particular attention is directed toward "greenstone" belts to the relative exclusion of sediments, sedimentary gneisses, and granitic gneisses. There is ample evidence of important base metal deposits in sediments and gneisses of the Churchill province (Sherridon, Chisel Lake, Stall Lake, Osborne Lake, Thompson) and rocks of this type may eventually prove to be more important hosts for mineral deposits than the greenstones of this part of the Precambrian Shield.

THE FLIN FLON REGION

The Flin Flon region, as defined here, forms the western half of the large volcanic belt extending from Flin Flon to Snow Lake. Although the entire belt forms a single natural geologic entity bounded on the south by Palaeozoic limestones and on the north more or less by the Kisseynew lineament, it has been divided into two parts for convenience in describing geologic features and mineral deposits. The dividing line coincides with the central part of a north-trending batholith, which forms a natural division between the two parts of the greenstone belt.

For several decades the Flin Flon region was the main metal producing area of Manitoba. The first production of metals in the province, from the Mandy Mine, dates back to 1917. The mine yielded copper, gold, and silver from high-grade sulphide ore that was shipped to the smelter at Trail, B.C.

The large copper-zinc deposit of Flin Flon was discovered in 1915 but production was delayed until 1930 when a satisfactory metallurgical process for extraction of the metals was finally worked out.

The oldest rocks of the district have been named the Amisk group. They are chiefly lava flows (andesite, basalt, dacite, porphyritic andesite, quartz porphyry, flow breccia), with associated pyroclastic breccias, and minor amounts of tuff, sediments, and gabbroic intrusive rocks. These rocks have been invaded by "quartz-eye" granite, known locally as the Cliff Lake granite porphyry. The Missi series of conglomerate, greywacke, and arkose unconformably overlies the Amisk group and the "quartz-eye" granite. Other bodies of granitic rocks, younger than the Missi series are abundant in the area. These include tonalite, tonalite gneiss, diorite, granodiorite, granite, granite gneiss. There are also some post-Missi mafic intrusions including a group of predominantly gabbroic rocks known as the "Boundary" intrusions.

The various stratigraphic classifications suggested for the Flin Flon region are shown in Table 8. Bruce (1918) considered the Cliff Lake granite porphyry to be older than the Missi sequence because of numerous pebbles of a similar rock found in the Missi conglomerate. Alcock (1923) found no such evidence and further noted that the porphyry cuts mafic dykes of a kind similar to dykes found cutting the Missi. However, other writers (Wright, Buckham, Stockwell, Bateman and Harrison) subsequently found good evidence that a pre-Missi "quartz-eye" granite porphyry exists.

The Missi was divided by Bruce into the upper and lower parts because he found pebbles of sedimentary rocks, and a boulder of conglomerate, in the Upper Missi. However, he considered that the unconformity was questionable, and that perhaps the Missi strata actually formed a conformable succession. As no other evidence was found for this interpretation, it was abandoned by all later writers. Wright and Buckham considered that Bruce's Lower Missi was part of the Amisk. The Amisk group was thus found to contain mappable amounts of sedimentary material. Pre-Missi schistose and highly metamorphosed rocks, chiefly sedimentary in origin, were also found in the Flin Flon area.

Tanton (1941) considered that a widespread "greenstone" assemblage in the Flin Flon area was younger than the Missi series. These "greenstones" are massive, fine-grained rocks, chiefly composed of chlorite, hornblende, sericite, and zoisite. Where observed in contact with the Missi series they exhibit the relationships of intrusive bodies, and Tanton believed that they were mainly of intrusive origin. An alternative view, held by other geologists who have examined these "greenstones," is that they are volcanic rocks.

The rocks of the Amisk group were closely folded and deeply eroded before the deposition of the Missi series, which lies with marked angular unconformity upon the older, volcanic rocks. The Missi series itself was then folded, and no doubt the structures already existing in the Amisk group were further deformed. As a rule, fold axes in both the older formations and the younger sedimentary series trend a few degrees west of north. In the Missi series the limbs of the folds are commonly overturned towards the west, but in the volcanic rocks overturning is only locally present.

The relatively unaltered Amisk and Missi-type rocks pass abruptly northward into Kisseynew-type rocks along an east-northeast trending boundary (near the northern boundary of Figure 18). Originally it was suggested that the contact

TABLE 8

COMPARATIVE STRATIGRAPHIC SUCCESSIONS

Flin Flon Region

BRUCE (1918)	ALCOCK (1923)	WRIGHT AND STOCKWELL (1934)	TANTON (1941)	BUCKHAM (1944), BATEMAN AND HARRISON (1944)	STOCKWELL (1946)	HARRISON (1951)
Amisk-Athapapuskow Lake district	Flin Flon mine area	Amisk Lake area	Flin Flon and Schist Lake areas	Athapapuskow and Mikanagan Lakes area	Flin Flon-Mandy area	Flin Flon district
Kaminis granite Granite and allied rocks	Diorite Granite and allied rocks Basic intrusions	Granite and allied rocks Basic intrusions	Granite and allied rocks Basic intrusions	Boundary-type Intrusions Granite and allied rocks Basic intrusions	Kaminis granite Boundary intrusions Granite and allied rocks Basic intrusions	Kaminis granite Boundary intrusions Granite and allied rocks Basic intrusions
Intrusive Contact	*Intrusive contact*	*Intrusive contact*	*Intrusive contact*	*Intrusive contact*	*Intrusive contact*	*Intrusive contact*
Upper Missi series: conglomerate, clastic sediments	Upper Missi series: conglomerate, clastic sediments	Missi series: conglomerate, clastic sedimentary rocks	Greenstone complex—mainly intrusive (includes Amisk of most authors)	Missi: conglomerate; clastic sedimentary rocks	Missi: conglomerate; clastic sedimentary rocks	Missi series: clastic sedimentary rocks; local volcanic rocks; derived schists and gneisses
Unconformity ?			Missi: conglomerate; clastic sedimentary rocks			
Lower Missi series: clastic sediments						
Unconformity	*Unconformity*	*Unconformity*		*Unconformity*	*Unconformity*	*Unconformity*
Cliff Lake granite porphyry		Granite, quartz-feldspar-porphyry		Granite-gneiss ? 'Quartz-eye' granite ?	Cliff Lake Granite porphyry	'Quartz-eye' granite
Intrusive contact		*Intrusive contact*		*Intrusive contact?*	*Intrusive contact*	*Intrusive contact*
Amisk series basic volcanic rocks; some acidic rocks	Acidic volcanic rocks, basic volcanic rocks (not named but equal to Amisk of Bruce)	Wekusko group: basic and acidic volcanic, and clastic sedimentary rocks (includes Amisk and part of Lower Missi of Bruce)	Schists derived from volcanic and sedimentary rocks	Basic and acidic volcanic rocks; some clastic sedimentary rocks (not named but equals Amisk, and includes part of Lower Missi of Bruce)	Amisk group: basic and acidic flows and pyroclastic rocks	Amisk series: mainly basic volcanic rocks; some acidic lavas; some clastic sedimentary rocks (includes Wekusko group of Wright)
			Pre-Missi sedimentary rocks			

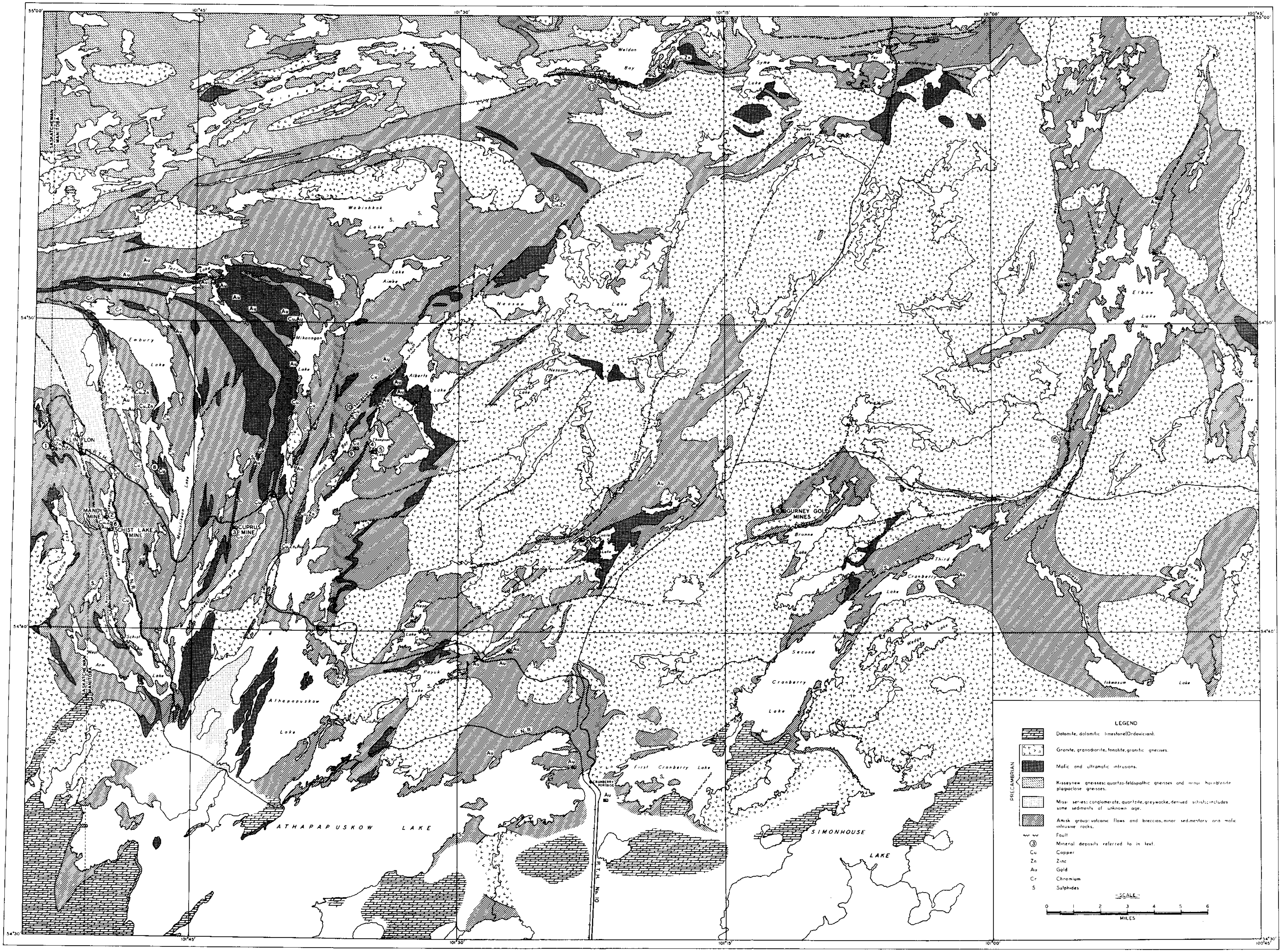

FIGURE 18 *Geology of Flin Flon — Elbow Lake Area*

between these rocks in the File Lake map-area, about 75 miles east of Flin Flon was faulted. Later a major fault trending northeast, north of Wekusko Lake, was interpreted by Frarey (1948) to be the eastward continuation of the Snow Lake fault, the entire structure representing a southward-protruding lobe along the Kisseynew lineament (see Figure 22). Kalliokoski (1952) determined that the Kisseynew complex at Weldon Bay is separated from the Amisk rocks by a fault and Robertson (1953) found a similar relationship about 14 miles to the east at Nokomis Lake. The type of mineral deposits found in the area also appears to change abruptly at the lineament. Stockwell, as reported by Harrison (1951), suggested that pyrrhotite-rich sulphide deposits occur north of the assumed Kisseynew lineament and pyrite-rich sulphide deposits south of it, and that the line indicating their respective boundary coincided closely with the lineament. Finally, Harrison (1951), compiling all the evidence, considered the lineament as a major structural feature and believed that it may be a fault zone along which the Kisseynew rocks were thrust over Amisk volcanic rocks. According to Harrison excellent structural evidence that the Kisseynew lineament marks a fault zone is provided in the area north of Mikanagan Lake. There, an elongated dome in the Kisseynew gneisses is overturned to the south, and its south limb is in contact with the north flank of an elongated dome of Amisk volcanic rocks. No syncline has been found between the two anticlinal structures, so it appears that the contact is along an unconformity, or a fault. However, the presumably younger Kisseynew rocks are overturned to the south so that they lie face down on the north-dipping flank of the Amisk dome, a position impossible to achieve except by faulting. Local discontinuities and irregular surface traces along the lineament may have been caused by granitic intrusions and deformation. Harrison also suggested that the mineral deposits of the Flin Flon-Snow Lake belt are related to faults that extend north and south from the Kisseynew lineament.

Robertson (1951), however, endeavoured to show that the lineament, as such, does not control the mineralization and is not the trace of a thrust fault but an accentuated break between two dissimilar rock types.

Haites (1960) considered that the lineament is one of several major transcurrent fault zones in the Precambrian Shield along which the direction of movement seems to be mainly left-handed. He points out that according to Van Hees (1958) the western extension of the Kisseynew lineament is on strike with the Meadow Lake escarpment in Saskatchewan and that the total length of the Meadow Lake-Kisseynew lineament may exceed 400 miles.

Other faults of the area some of which are related to the Kisseynew thrust, are numerous. Most of these faults trend a few degrees west of north, but some strike northeast; others are curved, with a general easterly trend. The Ross Lake fault, east of Flin Flon, forms one of the prominent lineaments, extending south of the Kisseynew lineament and offsetting the main structure. The Flin Flon and Mandy mines are probably related to the Ross Lake fault. East of the Cuprus mine at Manistikwan Lake strong shearing was noted by Harrison (1951) and major faults were mapped by Bateman and Harrison (1944) and by Buckham (1944) through Mikanagan and Whitefish lakes, the north part of Athapapuskow Lake, and through Schist Lake. An extensive northeast-trending fault passes through Fay and Vamp lakes and was noted much farther south by Podolsky (1957) in the vicinity of

Lucille Lake. Podolsky also shows a northeast-trending fault through the First, Second and Third Cranberry lakes; this fault may be continuous with faults passing through the center of Elbow Lake (McGlynn, 1959).

Geological mapping of the area has progressed recently to the detailed stage. The Geological Survey of Canada has published 9 maps covering 1,575 square miles at a scale of 1 inch to 1 mile. The Flin Flon-Mandy area was mapped by Stockwell (1960) at a scale of one inch to 1,000 feet. The area is also probably the most thoroughly prospected ground in the province. Hudson Bay Exploration and Development Co. Ltd., a subsidiary of the Hudson Bay Mining and Smelting Company Limited, and other major and minor companies have conducted systematic ground geophysical investigation since 1948. The following areas have been covered by ground electro-magnetic surveys, largely at line intervals of 400 feet or less: Embury and Mikanagan lakes and the entire area between these lakes; an area northwest of Embury Lake; Manistikwan Lake; the Northeast Arm of Schist Lake; the central, north part of Athapapuskow Lake; Neso, Payuk, Lucille lakes; an area north of Cranberry Portage; an area extending from Naosap Lake to Weldon Bay; the Third Cranberry Lake and Grass River; an area north and east of Elbow Lake.

PLATE VIII *Flin Flon, looking west. Behind the mine area is Flin Flon Lake, now filled with tailings from the mill.*

Some of the above ground was covered by two or three ground electro-magnetic surveys as well as magnetic surveys. For most of the areas, however, the ground geophysical exploration must be considered as of a preliminary nature. Extensive parts of some greenstone belts have yet to be covered by ground geophysical work utilizing improved techniques, before the full potential of the Flin Flon region is appraised.

Drilling of sulphide occurrences has been concentrated mainly in the area west of longitude 101° 30′; only limited drilling has been performed near Weldon Bay, the Second and Third Cranberry lakes, along Grass River, north of Brunne Lake, and at Elbow Lake.

MINERAL DEPOSITS

Copper-zinc

Flin Flon Orebody (1)[1]

The most important mineral deposit in the map-area is that containing the complex copper-zinc-gold-silver ore being mined by the Hudson Bay Mining and Smelting Company Limited at Flin Flon, astride the Manitoba-Saskatchewan boundary.

In addition to the ore extracted from the main mine, the company has produced copper and zinc from several small deposits: Schist Lake, Birch Lake (Sask.), Cuprus Mine, Coronation Mine (Sask.), North Star Mine, and the Don Jon Mine, all situated within trucking distance from Flin Flon.

Since 1930 over 47 million tons of ore have been extracted from the Flin Flon mine. In 1961 the mill at Flin Flon treated 1,682,693 tons of ore, operating at an average daily capacity of 4,610 tons. The mine workings extend to the 3,750-foot level.

At Flin Flon the ore occurs in six lenticular to irregular bodies within a zone 500 feet wide. These bodies average 900 feet long, 70 feet wide, 1,500 feet in vertical depth, and 2,500 feet in length along the plunge. They were formed by replacement of the country rock and include ore of two types, solid sulphides and disseminated sulphides. Seventy per cent of the total known ore is of the solid sulphide type. This consists mainly of pyrite, with included remnants of the host rock, and additional quartz and carbonate. In places, the ore exhibits banding, inherited from pre-existing structures. The disseminated ore usually occurs on the footwall side, and along the lower edge of the plunging solid sulphide bodies. Disseminated ore represents a partial replacement of the host rocks. Metallic minerals in the usual order of deposition include magnetite, pyrite, pyrrhotite, arsenopyrite, sphalerite, chalcopyrite, cubanite, galena, gold, tetrahedrite, tennantite, electrum, sylvanite, tetradymite, and altaite.

Rocks in the immediate vicinity of the mine include quartz porphyry intruded along a contact between lava flows on the northeast side and more easily sheared pyroclastic rocks and flow breccias on the southwest. These formations form a southeast-pitching anticlinal fold on the southwest limb of a major syncline. On the northeast side of the anticline drag-folds, forming minor anticlines and synclines,

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[1] Numbers in parentheses refer to localities on Figure 18.

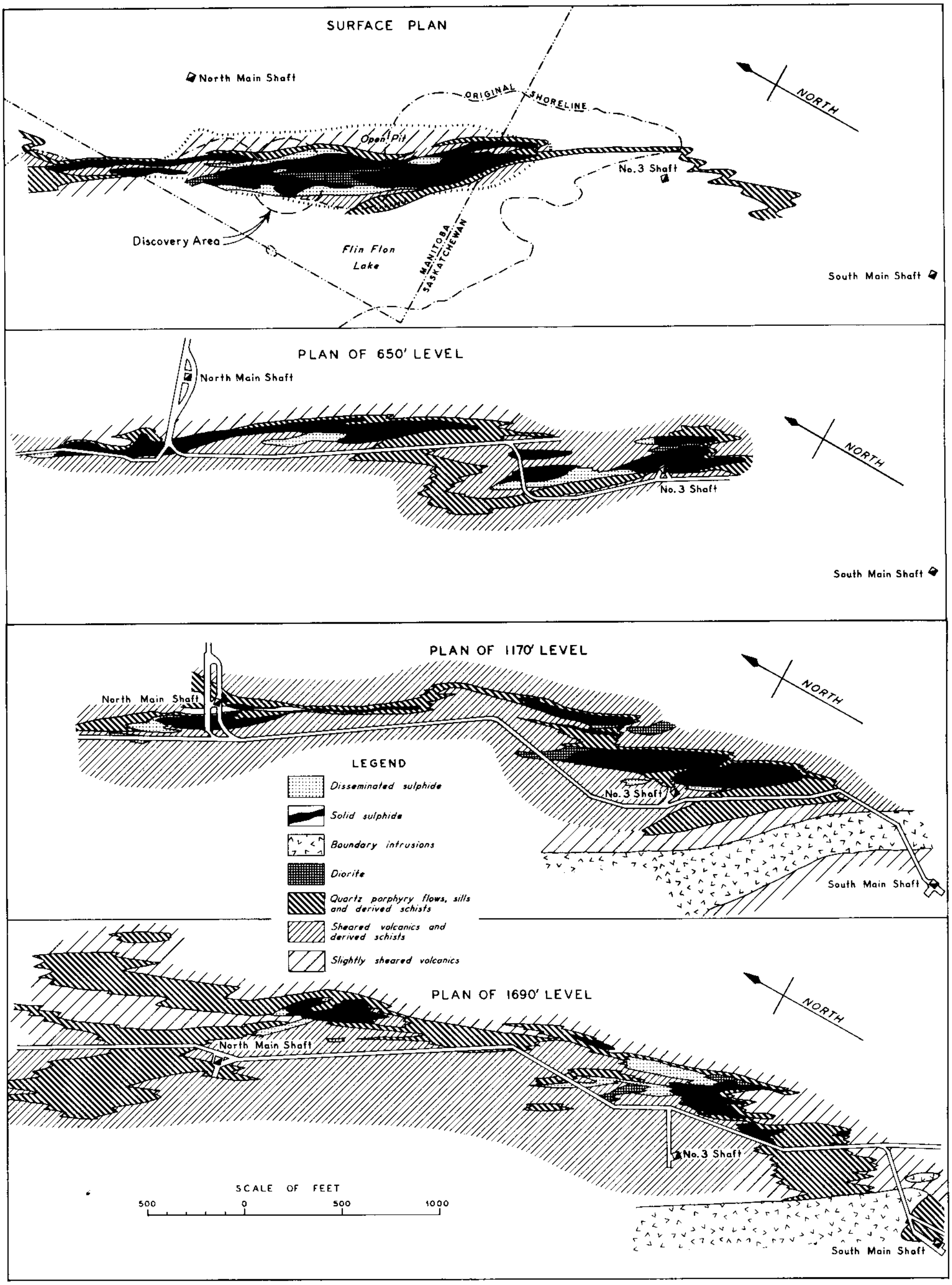
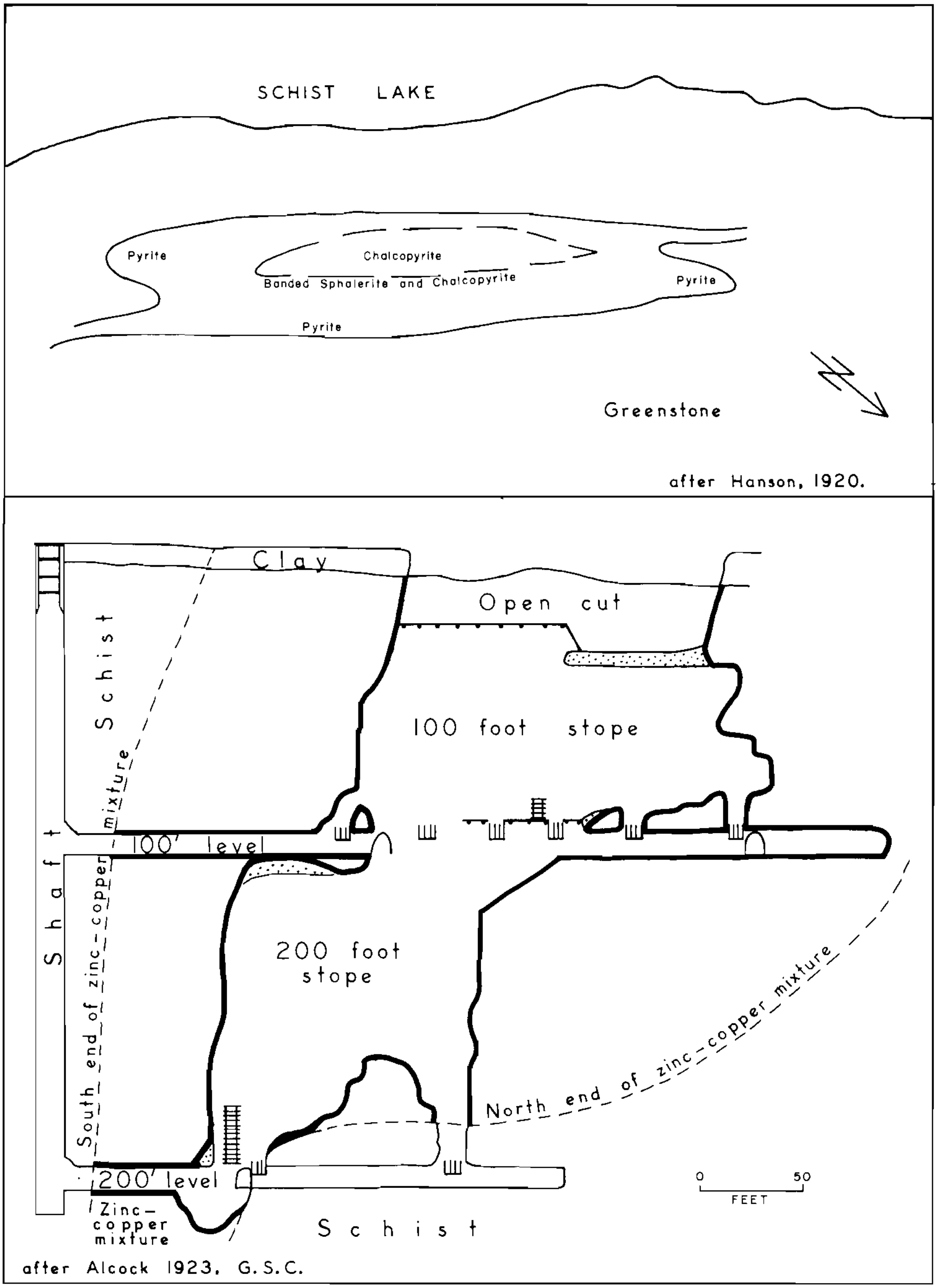


FIGURE 19 *Surface and Level Plans, Flin Flon Orebodies*

have resulted from upward and southward movement of the formations on the northeast side with respect to those on the southwest side. Crumpling occurs in the crests and troughs of these folds. The orebodies occur along the northeast limbs of these structures and terminate against their crests and troughs, plunging southeast



after Hanson, 1920.

after Alcock 1923, G. S. C.

FIGURE 20 *Plan and Section — Mandy Orebody*

with them (Figure 19). Some orebodies occur en echelon beneath subsidiary folds, with right-handed offset along strike, and some are hook-shaped along parts of their crests. The hook-shaped structures are open downward and to the northwest and reflect the shape of the crests of the anticlines.

The rocks within the ore zone and on the footwall side are in very large part altered to chlorite schists, with lesser amounts of talc and sericite schists, across widths of as much as 1,000 feet. In addition they are to some extent silicified and carbonatized. Intense shearing terminates at the contact between the competent lavas and the folded quartz porphyry. The shearing is thought to have developed as a result of movements accompanying folding. Lineation is well developed in the schists and plunges southeast with the folds and the ore. The diorite sills within the ore zone are only partly altered to schist and replaced by ore; more massive parts of the diorite remain as "horses."

Four coinciding structural features thus control the deposition of the ore. These are: the contact between the competent and incompetent beds, folding, schistosity and lineation. The ore-bearing solutions have been derived from either the same source as the Boundary intrusions or a younger granite that lies south of the mine area.

Although most workers favour the replacement theory for the origin of the orebodies, Bichan (1960) has advocated a direct magmatic theory. He suggests that magmatic injections penetrated the drag-folded contact between underlying incompetent tuffs and overlying highly competent rhyolite porphyry. Both the quartz porphyry and the ore masses were introduced during the same phase of the geologic history of the area.

The Mandy Orebody (2)

The Mandy was the first deposit in the entire area to undergo development. The first diamond drilling program in northern Manitoba was conducted there in 1916 and revealed an orebody containing 25,000 tons of massive chalcopyrite averaging about 20 per cent copper and containing gold and silver to the value of about $5.00 per ton. These reserves were mined out between 1917 and 1920 and yielded 9,866,328 pounds of copper. The ore was shipped to Trail, B.C. for smelting.

Additional reserves of lower grade ore were outlined on the property between 1928 and 1929 when the shaft was deepened to 1,025 feet. Due to wartime requirements in copper the mine again went into production between 1943 and 1944 when 125,021 tons were extracted averaging 5.47 per cent copper, 16.5 per cent zinc, 0.095 oz. gold and 1.9 oz. silver per ton.

The Mandy deposit was in a shear zone in volcanic breccia (Figure 20). It was situated in the same synclinal fold as the Flin Flon mine, but on the opposite and overturned limb. The strike and dip of the ore was parallel to the enclosing formations, and the plunge was steeply south. The ore replaced a tight drag-fold in the sheared rocks which acted as an incompetent member lying between more competent rocks. The chief minerals were pyrite, sphalerite, chalcopyrite, and minor amounts of galena and arsenopyrite.

The orebody was 100 feet long, 12 feet wide, and tapered downwards to a depth of 200 feet. The orebody exhibited zoning. Surrounding the central chalcopyrite-rich part of the deposit was a zone of mixed and banded sulphides in which sphalerite predominated and this in turn was surrounded by a zone in which pyrite was the abundant sulphide.

In 1962 drifting at the 1,100- and 1,300-foot levels was in progress from the adjacent Schist Lake mine towards mineralized zones in the Mandy mine.

Cuprus (3), North Star (4), and Don Jon Mines (5)

Several small sulphide deposits near Flin Flon have been mined out by the Hudson Bay Mining and Smelting Company in the past few years. The ores were trucked to Flin Flon for treatment. The Cuprus mine, on the northeast arm of Schist Lake, 7½ miles southeast of Flin Flon, was in production between 1948 and 1954. It yielded 509,152 tons of zinc and copper ore.

The Cuprus deposit (Figure 21, D) occurred on the west limb of a major syncline which plunges 10 to 20 degrees to the north. Rocks encountered in the mine workings were graphitic schist, graphitic tuff and chert, andesite with derived schists and diorite. The formation of the major syncline created minor drag-folds in the graphitic bands. The intrusion of the diorite intensified the folding and produced subsidiary synclinal drag-folds in the graphitic schist band. The ore was invariably associated with the graphitic rocks and was localized in the troughs and eastern limbs of these subsidiary synclines. The orebodies consisted of massive sulphides, partly or completely replacing the graphitic schist.

The North Star mine, (Figure 21, C) 12 miles east of Flin Flon, produced a total of 218,847 tons of copper ore between 1955 and 1958. The orebodies occurred in a cherty (silicified) chlorite schist. The adjoining rocks are andesite, dacite and a quartz porphry flow or sill. The shape of the orebody and the thickening of the quartz porphyry adjacent to it point to drag-folding as a cause of the fracturing and shearing of the cherty chlorite schist. The orebody consisted of massive sulphides and sulphide-filled fractures.

The Don Jon mine (Figure 21, A) operated between 1955 and 1957. Copper was recovered from 69,811 tons of ore. The mine was situated 1,600 feet east of the North Star. The deposit consisted of two lenses of massive sulphides which occurred in a drag-folded band of chloritic dacite bounded by a quartz porphyry and a derived siliceous sericite schist.

In addition to zinc and copper, all three mines yielded some values in gold and silver.

Schist Lake Mine (6)

The Schist Lake mine (Figure 21, B) is situated only 3.5 miles southeast of Flin Flon. From 1955 until the end of 1960 the mine produced 501,766 tons of copper and zinc ore. The main shaft was deepened to 2,281 feet in 1958 and production now comes from the lower levels of the mine.

The ore occurs as tabular to lens-shaped bodies which strike northwest, dip vertically and plunge at 60 degrees to the southeast. The ore zone is 800 feet long and has been traced for a distance of over 2,000 feet along the plunge. The maximum length of continuous ore within this zone is 200 feet. Widths of individual ore lenses vary from a maximum of 35 feet to a minimum of 2 feet. The ore consists of three types: massive sphalerite-pyrite, massive chalcopyrite-sphalerite, and disseminated chalcopyrite-pyrite, all in a sericite-carbonate schist.

The controlling structure is a strong northwest-trending shear up to 140 feet in width which consists predominantly of carbonatized sericite schist. This schist zone contains northwest plunging flexures and small drag-folds and cherty patches of rock that have failed by fracturing. These structures formed channels readily available for ore-forming solutions. The massive sulphide ore is a replacement of

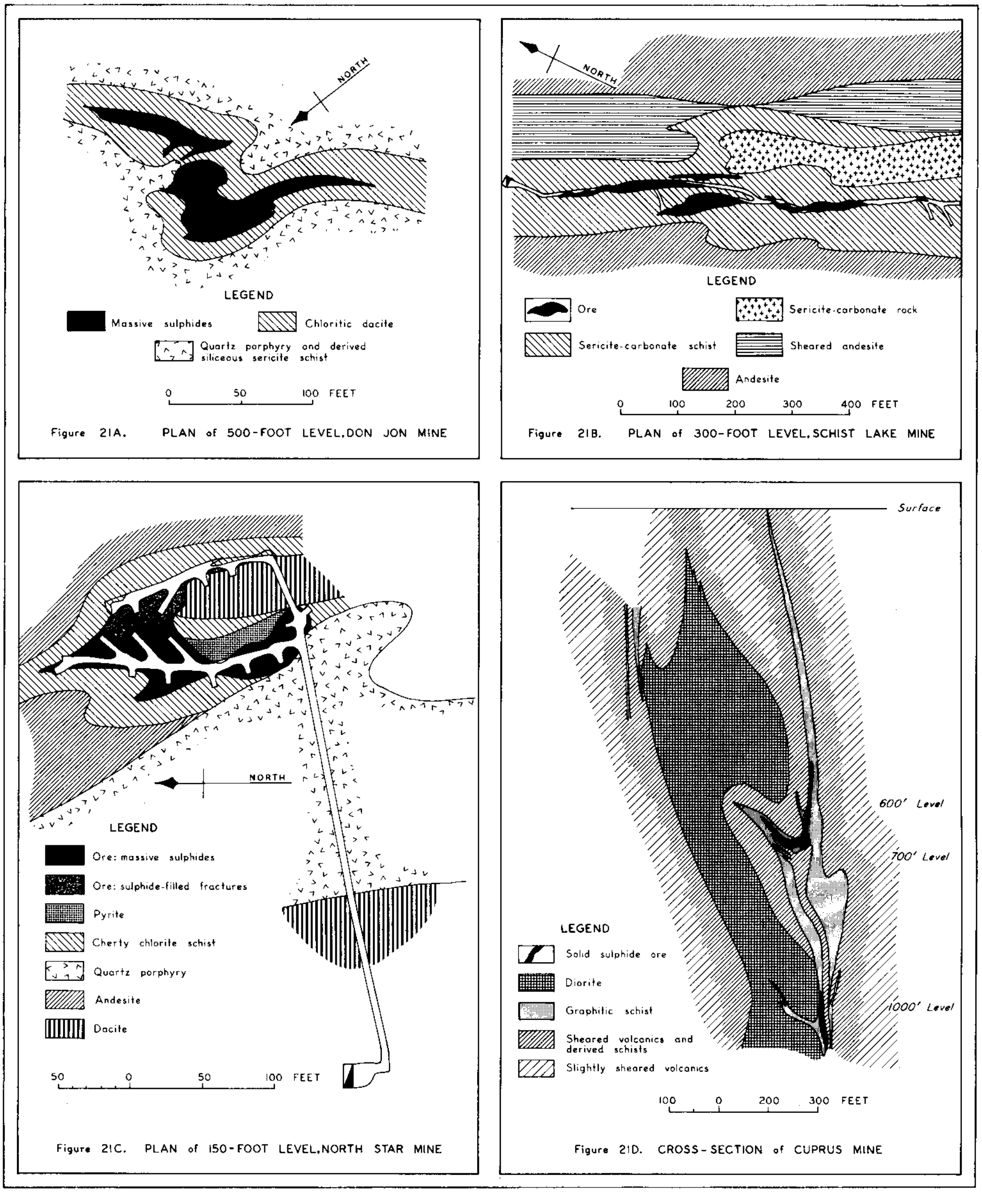


Figure 21A. PLAN of 500-FOOT LEVEL, DON JON MINE

Figure 21B. PLAN of 300-FOOT LEVEL, SCHIST LAKE MINE

Figure 21C. PLAN of 150-FOOT LEVEL, NORTH STAR MINE

Figure 21D. CROSS-SECTION of CUPRUS MINE

FIGURE 21 *Plans of Don Jon, Schist Lake and North Star Mines and Section of Cuprus Mine*

the schist and a disseminated type of ore was produced by fracture filling in the cherty rock. Local thickening occurs near the crests of drag-folds. Finely disseminated pyrite occurs in the sericite schist near the boundaries of the orebodies.

Other Sulphide Occurrences

Small replacement bodies of copper and zinc sulphides have been found near Embury Lake (7), Manistikwan Lake (8), Thompson Lake (9), localities 4 and 5, Athapapuskow Lake (10), Lucille Lake (11), Blueberry Lake (12), Weldon Bay

(13), locality 14, and Grass River (15). They usually occur in rocks of the schist and greenstone complexes in the vicinity of intrusive bodies of quartz porphyry and felsite. Some deposits occur in strongly schistose rocks derived mainly from siliceous volcanic rocks such as the Don Jon (4) and Amulet (10) deposits.

The deposits found south of Weldon Bay consist of pyrrhotite and pyrite; some of these contain chalcopyrite and sphalerite. They occur in strongly schistose rocks: garnetiferous gneisses and schists, amphibolites, and hornblende gabbro in the vicinity of alaskite granodiorite bodies which have intruded along east-trending fault zones; some of the faults coincide with the Kisseynew lineament, locally known as the Weldon Bay thrust.

Small showings of sulphides containing disseminated or massive pyrite and pyrrhotite, and at places minor chalcopyrite, are numerous. Most of these occurrences have been found in shear zones in volcanic rocks. Surface work, sampling and limited diamond drilling have been performed on many of these prospects.

Gold

Gurney Mine (16)

Besides the gold that has been recovered as a by-product from the base metal deposits near Flin Flon, the Gurney mine located about 25 miles east of Flin Flon produced 25,164 ounces of gold between October, 1937 and November, 1939.

The orebodies occurred in shear zones in tuff and to a lesser extent in silicified hornblende basalt. The gold occurred in light grey to white quartz veins. Gold and sulphides (pyrite, pyrrhotite, chalcopyrite, sphalerite, galena) were concentrated in fractures in the veins. Ruby silver and telluride have been reported. Pyrite was also disseminated in the tuff and schists. The amount of gold usually was proportional to the amount of sulphides present in the veins.

Replacement bodies, consisting largely of pyrite and pyrrhotite lenses paralleling the bedding of the sedimentary rocks have been found in the general vicinity of the mine. Although numerous, none of these carry gold; chalcopyrite is present in some of these sulphide bodies. Thus two stages of mineralization have been outlined in the vicinity of the mine. The first, represented by iron sulphide deposits typical of high temperature conditions, was followed by a later, lower temperature stage during which deposits carrying galena, gold, and silver were formed. Galena is not everywhere an indicator of gold, but good values usually are obtained from quartz where galena is present. The light grey vein quartz of the area is believed to have formed later than the dark quartz associated with the iron sulphides.

Other Gold Occurrences

Gold occurs in many localities of the Flin Flon district. It is associated with arsenopyrite, pyrite, and other sulphides in quartz veins cutting greenstone schists, quartz feldspar porphyry and sometimes other granitic rocks.

Throughout the district many deposits contain little vein quartz but consist of disseminated sulphides in sheared and sometimes silicified rocks; these may also contain gold. The silicified gold-bearing bodies include masses of either chloritic or sericitic schist with varying proportions of vein quartz, pyrite, arsenopyrite, pyrrhotite, iron carbonate and sometimes tourmaline. Stockwell (1944) divided the gold-bearing sulphide deposits into three types, according to the dominant sulphide, pyrite, pyrrhotite or arsenopyrite. Some of the deposits contain one sulphide with only traces of the others. Small amounts or traces of gold were found in a number of these deposits but many have been found to be completely barren.

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THE FILE — SNOW — WEKUSKO LAKES AREA

Geographically this area extends from 54° 30′ to 55° 00′ north latitude and from 99° 30′ to 100°45′ west longitude. The center of the area is about 65 miles east of Flin Flon. Snow Lake and Chisel Lake are connected by road to Wekusko Station, at Mile 81 on the Hudson Bay Line of the Canadian National Railway. A branch line from Optic Lake to the Chisel Lake mine was opened in 1960.

The area was first regarded as promising prospecting territory by Tyrrell during his exploration in 1896. Subsequently the area has been examined in varying detail by officers of the Geological Survey of Canada. Since 1939 the entire area has been mapped at a scale of 1 inch to 1 mile by the Survey. In addition the areas about Snow Lake and Chisel Lake have been mapped in greater detail.

GEOLOGY

Precambrian rocks, which underlie the area, are bordered on the south by Ordovician dolomite. The Precambrian rocks may be divided into four main groups. Probably the oldest group comprises mafic and felsic lava flows with associated intrusions and beds of tuff, volcanic breccia and agglomerate; at some localities the lavas are interbanded with mainly argillaceous sediments and their metamorphic derivatives. This group is correlated with the Amisk group of the Flin Flon region and is locally referred to as of Amisk age or Amisk type, or simply Amisk "volcanics."

The second group consists mainly of conglomerate, arkose, greywacke interbedded thin slaty members, and minor schists. The rocks underlie small areas within, and generally considered to have been deposited unconformably upon, the Amisk-type lavas. Although the stratigraphic position of the sedimentary rocks is uncertain, locally they have been named the "Missi series." The third group, known as the Kisseynew gneiss, is widespread in the northern third of the area. It consists chiefly of highly metamorphosed sedimentary material: garnetiferous gneisses and schists, staurolite-sillimanite gneisses and schists, feldspathic sedimentary rocks, minor mafic pyroclastic rocks, mafic lavas, and gneisses derived from arkose. It has been suggested that these rocks are in part the metamorphic equivalents of the sediments and volcanic rocks of the Missi-type found to the south. However, this age relationship is very uncertain.

The fourth group of rocks is intrusive and consists of predominantly granitic rocks of various ages but the largest batholitic bodies appear to be generally younger than any volcanic and sedimentary rocks in the area. Some of these granitic rocks postdate the structural deformation of the area and may be younger than the Kisseynew lineament.

Bodies of quartz-eye granite and associated porphyries have attracted much interest because of their postulated genetic relationship with gold-bearing quartz veins. Similarly, base metal mineralization is thought to be related to various mafic intrusions (pyroxenite, amphibolite, meta-gabbro, meta-diorite). Many of these intrusions, predominantly small stocks, have been outlined in the area. Although numerous sulphide occurrences have been found in the vicinity of these stocks some sulphide deposits bear no evidence of a relationship with the mafic intrusions.

On Figure 22 the sediments grouped together as map-unit (2) are of different ages. At Morton Lake, Woosey Lake and west and north of Wekusko Lake they consist mainly of fresh-looking greywacke, arkose, and conglomerate that have been shown on map-legends as unclassified rocks whose stratigraphic position is unknown. West of Morton Lake, the northerly-trending sediments are interbedded with volcanic rocks and have been classified as Amisk. Similar rocks have been outlined 2 miles east of Crowduck Bay.

The widespread sedimentary formations that trend northeast, in the area east of Wekusko Lake, consist chiefly of arkose, greywacke, conglomerate, biotite schist, garnet-staurolite schist and some volcanic members. Armstrong (1941) included this group in his "Laguna series" (along the east shore of Wekusko Lake). Frarey (1950), mapping their eastward continuation believed that the lithology of the sedimentary members and their unconformable relation with the older volcanic rocks strongly suggested that they are of Missi age. Possibly the term Missi-type would be more appropriate for these formations.

In almost the entire map-area the Kisseynew gneisses fall north of the assumed Kisseynew lineament. However, north of Crowduck Bay Frarey mapped lithologically similar schists and gneisses on both sides of the fault. Harrison (1951), on the other hand, states that a fault separates the Kisseynew-type rocks from others in this area. It is possible that in places the Kisseynew lineament consists of a zone of composite lineaments or that mylonitized granitic rocks may have been mapped as Kisseynew gneisses.

The general trends of folded structures in the area is north and north-northeast. Folds plunge south in the File Lake area and west of there, and generally north in the Snow Lake area, except near Squall and Morgan lakes. East of Wekusko Lake sets of doubly plunging synclines and anticlines trend northeast. The most prominent fold of the area is the Threehouse syncline. Near Snow Lake it plunges about 40 degrees north, but south along the axis the plunge gradually steepens to 80 or 85 degrees north. The Herblet Lake syncline is a broad, basin-shaped fold underlain to the south by an overturned anticline. The entire structure possibly is due to folding and subsequent deformation caused by the southward thrust along the Kisseynew lineament (locally referred to as the McLeod Road thrust.)

The McLeod Lake syncline is a warped fold, and the direction of warping is congruent with assumed thrusting to the south along the Kisseynew Lineament.

The Squall Lake Dome is elongated somewhat in a north to south direction, and is marked by beds dipping outward in all directions around a granite stock. The crest of a similarly trending fold, the File Lake Anticline, is occupied by a gneissic granite which has been interpreted as a granitized rock of sedimentary origin. Farther to the west the Loonhead Dome is marked by an eastward trend and low dips. A set of tightly folded and warped synclines and anticlines has been outlined between the File Lake Anticline and Loonhead Dome.

Large, well-defined, doubly plunging, folds lie east of Wekusko Lake. The axes of these folds generally strike 10 to 45 degrees east of north, and the beds are commonly overturned.

Faults and shear zones are numerous. The most prominent faults are those which coincide with the Kisseynew lineament. The File Lake fault follows roughly the south shore of the lake. To the west, it curves north up Dummy Bay and is continued by a fault system paralleling the south shore of Loonhead Lake. The Kisseynew lineament is also represented by the Snow Lake fault, the McLeod Road thrust, and its eastern continuation into the Crowduck Bay map-area. Harrison (1951) points out that if it is assumed that the Kisseynew lineament marks a fault, there is contradictory evidence regarding the direction of movement. Regional structures in the Kisseynew gneisses suggest that the fault marks a thrust from the north and northeast. However, minor structures within the fault zone at Snow Lake indicate that the north side has moved down, that is, the faulting was normal; at Loonhead Lake they indicate thrusting from the south. It is possible that movements may have occurred at more than one time, and that the fault may itself have been deformed by later folding and intrusions. However, it must be remembered that this structural relationship is open to criticism, inasmuch as some geologists maintain that the boundary between Kisseynew gneisses and the volcanic and sedimentary rocks to the south is not a well-defined fault zone but rather represents a rapid change across a metamorphic front with only local faulting.

The most prominent northeasterly-trending fault is the Berry Creek fault, which has a total length of over 30 miles, and merges into the Kisseynew lineament. It is marked by a broad zone of fissile schists that dip steeply or vertically. This fault may provide the structural control for some ore deposits in the area. Other northerly-trending faults such as the Varnson Lake fault, the Woosey Lake fault, the Morton Lake fault, and a set of faults west of Morton Lake, do not appear to continue northward past the Kisseynew lineament.

MINERAL DEPOSITS

The File-Snow-Wekusko lakes area, formerly a gold-producing region, has now gained importance as a base metal belt. A zinc-lead-copper mine at Chisel Lake commenced production in September, 1960. Two other deposits, the Stall Lake mine and the Osborne Lake mine are in the development stage. In addition, several small sulphide bodies have been outlined in the central part of the area. Exploration for base metals and gold is continuing in all the greenstone and sedimentary belts of the area, including the Kisseynew gneisses.

The Nor-Acme mine at Snow Lake and the Laguna (Rex) mine at Wekusko Lake are former gold producers. In addition, several hundred ounces of gold were recovered from numerous properties during development projects. A promising lithium-bearing prospect is situated north of Wekusko Lake.

Gold

The known gold deposits of the area occur in three regions: the area underlain chiefly by sediments east of Wekusko Lake, the area northwest of Wekusko Lake which comprises Snow and Squall lakes, and the area west and north of Morton

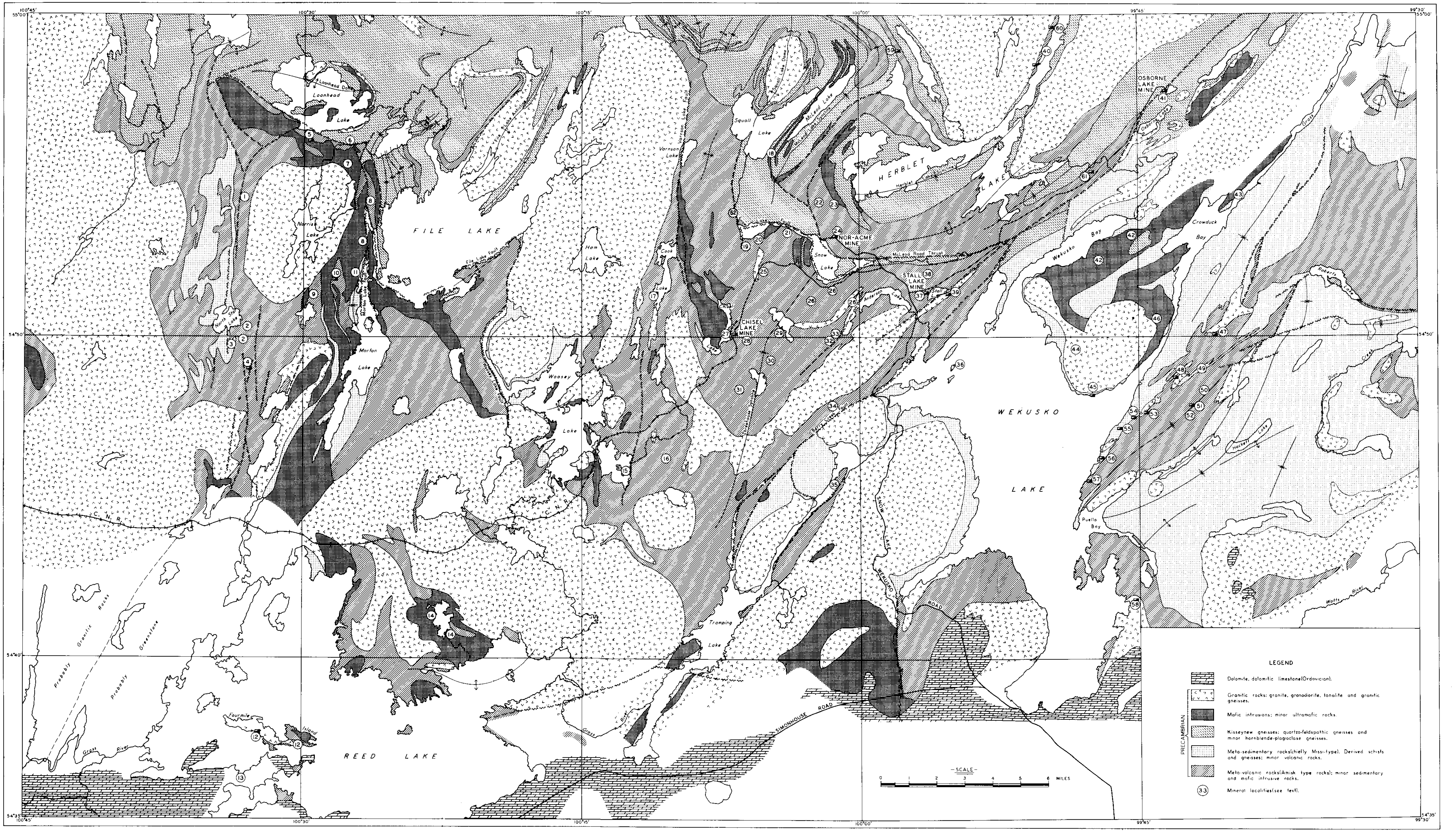

FIGURE 22 *Geology of File — Snow — Wekusko Lakes Area*

Lake. A few gold-bearing veins have been found near Loonhead Lake and on Fourmile Island on Reed Lake.

Most of the deposits are quartz veins that occur along shear zones in lavas and that locally cross dykes of fine-grained quartz diorite, dacite porphyry, and quartz feldspar porphyry cutting the greenstones. The shear zones either cross the structure at various angles (these probably mark faults) or follow the regional cleavage of the rocks. Some quartz veins follow zones in sheared dykes of rhyolite, diorite, "quartz-eye" granite, and quartz porphyry. Many of the quartz veins lie near large or small bodies of "quartz-eye" granite or near dykes of porphyry or rhyolite that are related to the granite. The association with these soda-rick rocks is so common that Stockwell concluded that the deposits are genetically related to these intrusions. East of Wekusko Lake most of the known deposits occur along two northeasterly-trending belts, one lying along the northwest limb of a synclinal basin of sediments and lavas, the other lying along and near the axis of the syncline. This belt has a length of nearly 6 miles and a width of less than ½ mile. Of the 24 gold deposits occurring in the area over half lie wholly or partly in porphyry and the remainder are in other rocks less than 1,200 feet from the edges of porphyry bodies. In the Morton Lake area the gold deposits lie in lavas and sediments north of a large body of "quartz-eye" granite. Small "quartz-eye" granite stocks and feldspar porphyry dykes are abundant in this area.

The association between these intrusive bodies and gold mineralization is not so apparent near Snow Lake. In the Nor-Acme mine the ore occurred at the contact between feldspathic sedimentary and volcanic rocks and mafic pyroclastic rocks on the crests of anticlines that have been subjected to faulting. Porphyry dykes are absent and the closest body of "quartz-eye" granite outcrops 2 miles to the southwest.

On broad mineralogical grounds, Harrison (1949) divided the deposits into four main groups: (a) those in which pyrrhotite is the most abundant sulphide; (b) those in which pyrite is the most abundant; (c) those that contain noticeable amounts of galena and sphalerite, usually in addition to pyrite; and (d) those in which arsenopyrite is the main sulphide. The last two groups are commonly gold-bearing.

Nearly all of the pyrrhotite-rich deposits carry some chalcopyrite. They contain only small amounts of vein quartz and little gold; in many of them pyrrhotite is reported to be nickeliferous. These pyrrhotite deposits are numerous north of Morton Lake and have been investigated for base metals. Some were found southwest of Snow Lake and in the vicinity of Crowduck Bay.

The pyritic deposits are concentrated mainly southwest of Snow Lake toward Morgan Lake, though a few are known west of File Lake, and on Fourmile Island on Reed Lake. These were prospected for gold but low assays were obtained except from the Morgan Lake gold deposit (15)[1] and some gold-bearing zones on Fourmile Island (12).

The deposits which carry noticeable amounts of galena and pyrite are near Snow Lake and at Morgan Lake. These deposits are characterized by milky white quartz (which is partly vuggy), pyrite, galena and sphalerite. The Camwe "A" showing at

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[1] Numbers refer to localities on Figure 22.

Snow Lake Narrows (21) is of this type and also contains some tennantite. The Morgan Lake gold deposit contains much more sphalerite and chalcopyrite than galena, and does not seem to be typical of either this or the preceding group.

The gold deposits characterized by arsenopyrite are the most important in the area. They are widely distributed between Snow and Squall lakes, close to the Morton Lake Fault, and east of Wekusko Lake. All these deposits are associated with quartz veins contained in rocks that have been intricately folded, faulted, and sheared. Arsenopyrite is the most abundant metallic constituent and occurs in the veins and in scattered small crystals disseminated in the wall-rocks. Other minerals present include pyrite, galena, sphalerite, chalcopyrite, pyrrhotite, native gold, tourmaline, and carbonate. Most of the gold is contained in silicified wall-rocks or inclusions, or at the contacts between veins and wall-rocks or inclusions. In the Nor-Acme mine, no gold was found in the vein quartz itself. Carbonate is a common though not abundant constituent of the ore at the Nor-Acme mine, and appears to have exerted a strong influence on localization of gold there. Similarly, carbonate occurs in other deposits near Snow Lake, Squall Lake, and east of Wekusko Lake.

Numerous sulphide deposits near Snow Lake and east of Wekusko Lake are marked on the surface by extensive gossan zones from which gold can be panned, but the underlying solid rock yields only small amounts of gold. Harrison shows that in many localities the gossans formed prior to deposition of glacial material but in other deposits the gossan is the product of post-glacial weathering.

Nor-Acme Mine (24)

The Nor-Acme mine was situated near the northeast shore of Snow Lake, about 75 miles east of Flin Flon. The mine was opened by the Howe Sound Exploration Company Limited[1] (later named the Britannia Mining and Smelting Company Limited) and from June, 1949 to September, 1958, when it closed, yielded 511,816 ounces of gold and 41,406 ounces of silver valued at $19,354,819. Although the ore in the ground averaged close to 0.17 ounces per ton, the difficulties in treating arsenopyrite ore were such that the net recovery was only 0.106 ounces per ton. Tests carried out in 1961 on a 250,000 ton stockpile of arsenical concentrates at this property had an average grade of better than 0.28 oz. gold per ton. Plans for recovery of this gold are in progress.

The ore occurred along a fault zone approximately paralleling the contact between feldspathic sedimentary and volcanic rocks of the footwall and coarse mafic pyroclastic rocks of the hanging wall. These rocks are cut by irregular mafic intrusions that vary in composition from diorite to hornblendite, and by small felsic dykes.

Gold occurred with arsenopyrite, pyrrhotite, and pyrite in replacement-type orebodies which had an easterly trend, dipped approximately 45 degrees to the north, and raked north 30 degrees east. The ore was distributed along the Howe Sound fault for a length of nearly 2,000 feet, but it was convenient, especially on the upper levels of the mine, to divide it into two main orebodies, the Dick and the Toots. The Dick orebody was both wider and richer; the Toots was much smaller and was about 1,000 feet west of the Dick.

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[1] Under lease-royalty agreement with Nor-Acme Mines Limited.

The orebodies were quite irregular in outline, varying from widths too narrow to be mined up to widths of more than 100 feet. The character of the ore gangue varied with the type of host rock. In acidic volcanic rocks the ore was siliceous; in basic volcanic rocks it was a grey replacement consisting mainly of quartz and calcite; in hornblendite, calcite containing pinkish bleached biotite constituted most of the gangue. In all rocks, however, a highly siliceous replacement, which approached vein quartz in appearance, generally occurred along the Howe Sound fault. Vein quartz constituted less than 5 per cent of the orebodies and was generally barren.

The structural features influencing the concentration of gold and sulphide minerals included: faulting, folding, contacts between rocks of different competency and regional foliation. All mineable ore was found adjacent to the Howe Sound thrust fault. Other structures influenced the deposition of the ore only in that they created favourable conditions for mineralization along the fault zone. The Dick orebody was situated on the nose of a minor anticlinal fold which was truncated by the Howe Sound fault. The fault had been deflected into a gentle crescent-shaped roll, and the acidic wall-rocks had been shattered and sheared over much greater than normal widths, resulting in the expansion of the orebody to widths of more than 100 feet in some places. In places where the Howe Sound fault formed the contact between acidic and basic rocks, small variations in the attitude of the fault plane produced shattering in the acidic rocks or zones of low pressure in the sheared basic rocks, favourable for the deposition of sulphides and gold. The influence of regional foliation, with trends at large oblique angles to the fault zone, is indicated by the development of "spurs" of ore along this direction.

The Laguna (Rex) Mine (55)

The Laguna mine was situated on the east shore of Wekusko Lake (Figure 22) on the Rex group of claims. Two shafts were sunk on a quartz vein in 1918 and Herb Lake Gold Mines Limited recovered 1,377 ounces of gold from the deposit. In 1924-25, Manitoba Metals Mining Company Limited produced 5,517 ounces of gold from the same workings.

No further work was done until 1934 when the property was acquired by Laguna Gold Mines Limited. Production between 1936 and 1939 amounted to 52,462 ounces of gold and 6,117 ounces of silver with a total value of $1,872,808.

The oreshoots were developed in a quartz vein striking north-northeast and dipping 70 to 75 degrees southeast. The vein had a minimum total length of 2,100 feet and was mined down to the 1,000-foot level.

The vein trended parallel to the long axis of a body of quartz-feldspar porphyry. At the surface it occurred almost entirely within the porphyry and followed very closely the western contact between the porphyry and sediments. With depth it gradually dipped away from the contact towards the center of the porphyry. The vein averaged about 2½ feet wide but in places was up to 6 feet wide. The quartz generally continued unbroken for distances of several hundred feet but locally pinched out or abruptly passed into several closely spaced stringers. The wall-rocks on both sides of the main vein were cut by many small quartz stringers that trended somewhat more easterly than the vein and lay parallel to the cleavage of the por-

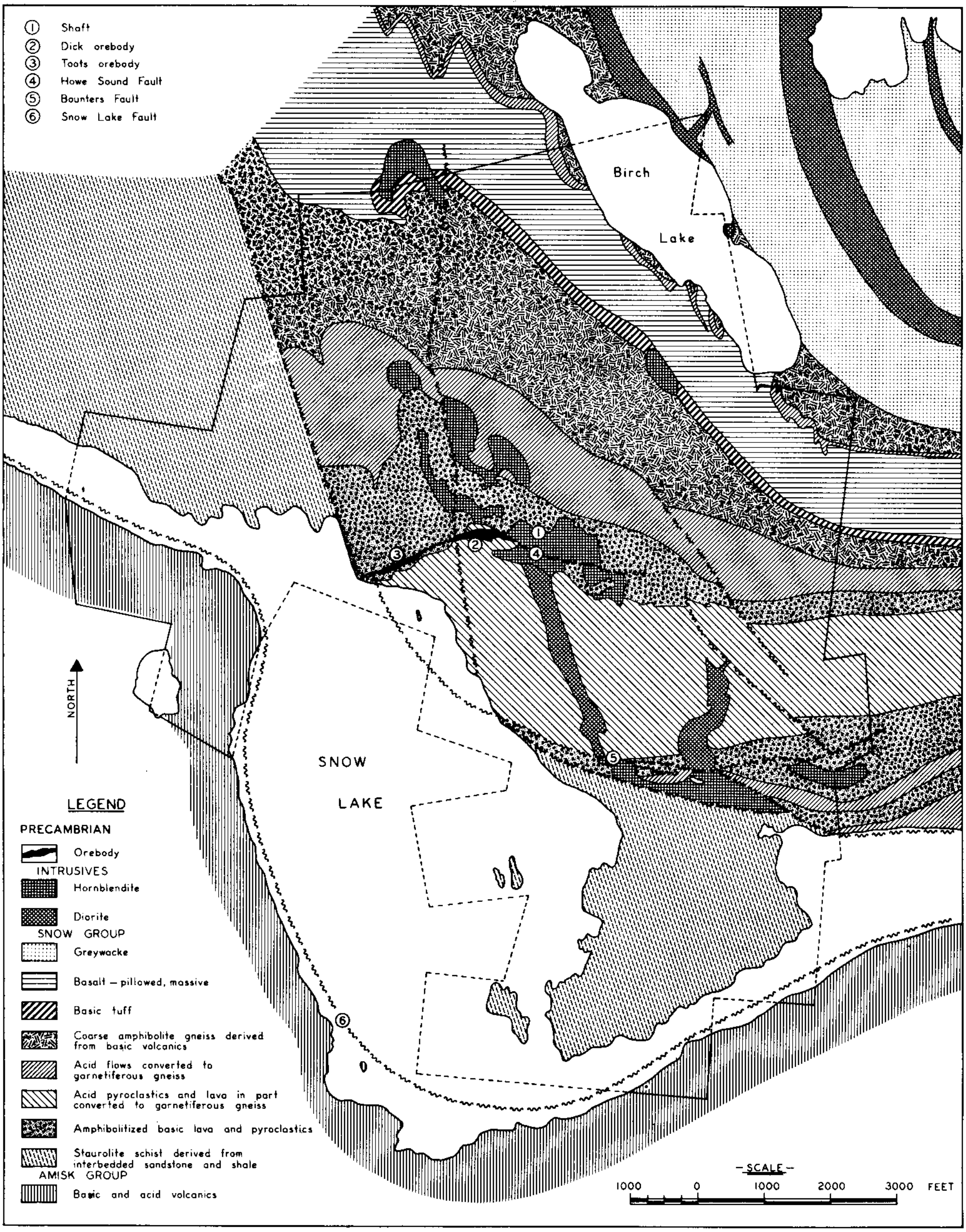

FIGURE 23 *Surface Geology, Nor-Acme Mine*

phyry. The quartz of the main vein varied from white to bluish and from coarse-grained to sugary. Finely crystallized arsenopyrite, disseminated in the quartz and wall-rocks, was abundant. Small amounts of galena, sphalerite, pyrite, and native gold were mixed with the arsenopyrite. Pyrrhotite associated with chalcopyrite was plentiful in the lower levels but was not reported from the upper levels.

Base Metals

Several deposits of massive sulphides and numerous occurrences of disseminated sulphides are distributed throughout the area.

Davies (1960) divided the massive sulphide deposits of Manitoba into seven different types, of which four are found in the File-Snow-Wekusko lakes region:

1. pyrrhotite — pentlandite — chalcopyrite — pyrite
2. pyrite — pyrrhotite — chalcopyrite — sphalerite
3. pyrite — pyrrhotite — chalcopyrite
4. pyrite — pyrrhotite — sphalerite — chalcopyrite — galena

The Hudson Bay Mining and Smelting Company Limited conducted extensive investigations in the area and outlined numerous mineralized zones and eight massive deposits of actual or potential commercial value. These are the Chisel Lake Mine (27) and the Ghost Lake deposit (28), both of type 4; the Stall Lake Mine (37), the Rod deposit (39), the Osborne Lake deposit (41), the Bomber deposit (17), and the Pot Lake deposit (16), all of type 2; and the Joannie deposit (32) of type 3. In addition, several small occurrences of massive sulphides of type 1 are known at Wekusko Lake on Rice Island (36) and east of Wekusko Bay (42). The nickel content of these deposits is too low to make them of economic value at present.

Although in a general sense the most common deposits, types 2 and 3, are similar mineralogically, the relative proportions of chalcopyrite and sphalerite vary from one to the other. In this regard it is significant that those deposits which contain sphalerite considerably in excess of chalcopyrite also contain notable quantities of galena; those in which the amount of chalcopyrite greatly exceeds sphalerite contain little or no galena. Both gold and silver are present in the ores; the amount of silver varies more or less directly with the amount of sphalerite and galena.

The deposits are tabular to lenticular and vary from 4 to 10 feet wide and from 200 to 1,800 feet long; the known depths vary from 300 to 1,200 feet. Two of the narrowest deposits (4 feet and 6 feet wide) are the longest — both 1,800 feet; the widest deposit (80 feet) is 800 feet long.

Unlike the Flin Flon deposits which occur in typical Precambrian "greenstone," most of the Snow Lake-Wekusko Lake sulphide deposits occur in gneisses and schists such as quartz-hornblende gneiss, garnetiferous quartz-biotite gneiss, chlorite-garnet-biotite schist, chlorite-garnet-actinolite schist and hornblende-plagioclase gneiss. Also in contrast with the Flin Flon deposits, those in the Snow Lake-Wekusko Lake area appear to lack well-defined structural control, although this may in part be due to less complete investigation. A further difference in the two areas is the absence of, or presence of only limited macroscopically visible wall-rock alteration in the Snow Lake deposits.

Grades of the deposits as determined from diamond drilling vary from 11.6 per cent zinc and 0.42 per cent copper to 4.64 per cent copper and 0.4 per cent zinc. The maximum gold and silver content is 0.060 and 1.96 ounces per ton respectively.

Production at the Chisel Mine started in September, 1960. The Stall Lake mine and the Osborne Lake mine are under development with workings reaching a depth of 2,660 and 52 feet respectively (September, 1961).

Disseminated sulphide deposits are abundant in the area. Most contain only small amounts of base metals and their locations are not shown on Figure 22. West of File Lake the majority of these deposits occur in schistose mafic lavas, especially in local shear zones in highly faulted volcanic rocks near younger gabbroic intrusions; some occur in sedimentary rocks. In the vicinity of Snow and Wekusko lakes the deposits occur in volcanic rocks, in Kisseynew gneisses, sediments and schists. The amounts of sulphides vary considerably between different deposits. For the most

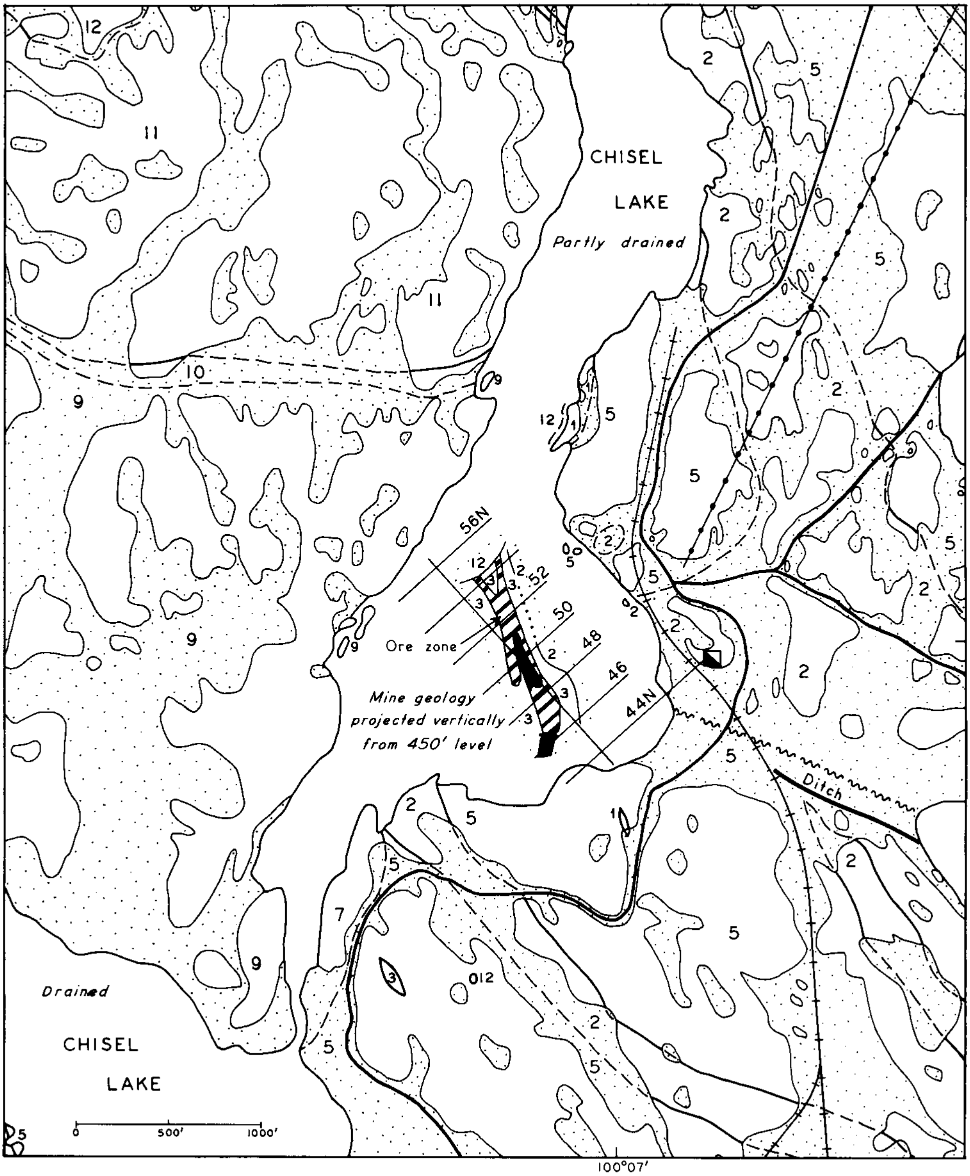

FIGURE 24 *Surface Geology, Chisel Lake Mine Area*

2 — Massive amphibolite flow rocks. 3 — Staurolite-garnet Schist. 5 — Pyroclastic rocks. 9 — Meta-peridotite. 10 — Meta-gabbro (more than 80% green amphibolite). 11 — Meta-gabbro; amphibole-plagioclase rock. 12 — Meta-diorite. Black — Introduced tremolite-carbonate material of ore zone. Stippled — Drift-covered area.

part the sulphides are sparsely disseminated and account for 5 to 20 per cent of the rock; however, small masses of solid sulphide commonly are found in the central parts of the deposits. Most deposits contain either pyrite or pyrrhotite; some carry both sulphides. Chalcopyrite and sphalerite occur locally but only in small quantities. Chalcopyrite is usually localized in stringers, veinlets, or irregular patches in the iron sulphides, usually in parts of the deposits consisting chiefly of massive sulphides. Most of the deposits were sampled for gold content, which is usually low. Very little copper is present in the disseminated deposits; nickel is reported from some of the pyrrhotite-rich deposits.

Chisel Lake Mine (27)

Detailed geological investigations were conducted by Williams (1960) at the Chisel Lake mine. The orebody is 800 feet long and up to 80 feet wide. It extends to a depth of over 1,000 feet. The ore reserves were reported (in 1959) as 3,832,400 tons averaging 11.0 per cent zinc, 0.42 per cent copper, 0.91 per cent lead and 0.060 oz./ton of gold and 1.96 oz./ton of silver. The main shaft reaches a depth of 1,163 feet and a raise from the 1,050-foot level was converted to a production shaft in 1960.

The Chisel Lake mine, near Snow Lake. This is one of several mines supplying zinc and copper ore to the Flin Flon operation. PLATE IX

Production at the mine began in September, 1960. The ore is shipped directly to the Hudson Bay Mining and Smelting Company Limited smelter at Flin Flon.

The orebody occurs along a structural discontinuity that strikes northwest and runs from Lost Lake to Chisel Lake, presumably extending beneath the latter (Figure 24). Immediately north of the discontinuity, the pyroclastic and flow rocks form the nose and east limb of a syncline whose axis lies to the west and plunges towards the north. South of the discontinuity, on the southern shore of Chisel Lake, is a thick sequence of pyroclastic rocks with interlayered flows and minor discontinuous staurolite-bearing beds. This sequence strikes northwest and dips fairly steeply to the northeast, conformable with the regional structure of the Threehouse syncline. These structural trends are truncated to the west by the differentiated mafic intrusive lopolith.

The ore zone is sheet-like in form, striking northwest and dipping approximately 45° NE. The southeast end of the orebody appears to rake to the northwest. A meta-diorite intrusion cuts off the ore zone to the northwest before it reaches the meta-peridotite on the west shore of Chisel Lake. The footwall rocks of the ore zone consist of siliceous schists that are commonly staurolite-bearing; the hanging wall rocks are also garnet- or staurolite-bearing schists succeeded outward by massive amphibolite, presumably of flow origin.

Within the main ore zone there is a close relationship between the ore minerals and a coarse massive green tremolite-carbonate rock. It is in this secondary material that the widest and highest grade intersections of massive sulphide were obtained. Disseminated sulphides and stringers of more massive sulphides occur in the footwall rocks; in places sulphides are abundant enough to bring the siliceous schists up to ore grade.

The main ore mineral is sphalerite, but pyrite, pyrrhotite, chalcopyrite, galena, and arsenopyrite are also present. Gold values encountered in the massive tremolite rocks of the zone are probably due to a gold telluride disseminated through them. Carbonate is a common gangue mineral in the granular sulphide ore. Other minerals of lesser importance are tourmaline, gahnite, and apatite.

The Osborne Lake Mine (41)

The Osborne Lake mine is located 13 miles northeast of the town of Snow Lake. A road and a power transmission line were completed to the mine in 1961. By the end of 1962 surface construction had been completed and a shaft collared and sunk to a depth of several hundred feet.

Diamond drilling has indicated that the tabular orebody has an average width of 12 feet and is 500 feet long and 600 feet deep. Ore reserves have been reported at 443,000 tons averaging 4.01 per cent copper and 1.7 per cent zinc.

The ore occurs entirely in quartz-biotite gneiss of the Kisseynew type.

The Stall Lake Mine (37)

The Stall Lake mine is located 4 miles southeast of the townsite of Snow Lake. A shaft was sunk to depth of 2,660 feet and lateral development has been carried out on several levels between the 900 and 2,550 elevations (December, 1961).

The ore reserves as of December, 1959 were established at 783,200 tons grading 4.54 per cent copper and 0.4 per cent zinc. The gold and silver content is 0.02 and 0.27 oz./ton respectively. The ore occurs in quartz-hornblende gneiss at the contact with quartz-biotite-hornblende gneiss (footwall) in several tabular steeply plunging bodies. The main sulphides are chalcopyrite, sphalerite, pyrite and pyrrhotite.

Ghost Lake Deposit (28)

The Ghost Lake deposit is situated approximately 1 mile east of the Chisel Lake mine.

The orebody as outlined by drilling in 1959 is 300 feet long, 300 feet wide and up to 40 feet in width. It is lenticular in shape and contains some 260,700 tons of ore averaging 11.6 per cent zinc, 1.42 per cent copper, 0.7 per cent lead and 0.013 oz./ton of gold and 1.14 oz./ton of silver. The ore occurs in quartz-biotite-(garnet) gneiss at the contact with andesite (hanging wall). The structural control was probably exercised by regional and local folding.

TABLE 9

Mineral Deposits, File-Snow-Wekusko lakes area

1. Gold	Arcana claim	Morton Lake Gold Mines Ltd.
2. Gold	Gold Rock, North Star	File Lake Gold Mines, Limited
3. Copper, nickel	Snow claim	
4. Gold	Jupiter claims	Morton Lake Gold Mines Ltd.
5. Copper, gold	Loonhead Lake deposit	
6. Gold	G.M. claims	International Mining Corporation (Canada) Limited
7. Gold	Senior group	
8. Nickel, copper, gold	Doe & Pilot claims	
9. Copper	R.O.E. claims	Dickstone Copper Mines Limited
10. Gold	Gordon Lake sulphide deposits	
11. Copper, nickel, gold	Morton Lake sulphide deposits	
12. Gold	Fourmile Island gold deposits	Reed Lake Mines Limited
13. Gold	Ono M.C.	
14. Copper, nickel	New Colony group	
15. Gold	Dot 5 claim	Northern Canada Mines Limited and Pioneer Gold Mines Limited
16. Copper, zinc	Pot Lake deposit	Hudson Bay Mining and Smelting Company Limited

17.	Copper, zinc	Bomber deposit	Hudson Bay Mining and Smelting Company Limited
18.	Gold	Margaret & K. claims	Squall Lake Gold Mines Limited
19.	Gold	J.M. claims	Sherlynn Mines Limited
20.	Gold	N.O. 3 claim	Tern Lake Mines, Limited
21.	Gold	S.D. claims	Camwe Snow Lake Mines Limited
22.	Gold	Snow group	Koona Lake Mines Limited
23.	Gold	Birch Lake showing	
24.	Gold	Nor-Acme Mine	Nor-Acme Gold Mines Limited
25.	Gold	How 4 claim	Tern Lake Mines, Limited
26.	Gold	Groundhog, Angus, etc., group	International Mining Corporation (Canada) Limited
27.	Zinc, copper, gold	Chisel Lake Mine	Hudson Bay Mining and Smelting Company Limited
28.	Copper, zinc, lead, silver	Ghost Lake deposit	Hudson Bay Mining and Smelting Company Limited
29.	Gold	Ern 5 claim	
30.	Gold	Con claims	The Consolidated Mining and Smelting Company of Canada Limited
31.	Tungsten (*Scheelite*)	Wow, Chance claims	
32.	Copper	Joannie deposit	Hudson Bay Mining and Smelting Company Limited
33.	Copper, gold	W.J. 2, 3 claims	
34.	Gold	Grant 3 claim	
35.	Nickel	Tramping Lake sulphide deposit	
36.	Copper, nickel	Rice Island deposit	The International Nickel Company of Canada Limited
37.	Copper, zinc	Stall Lake Mine	Hudson Bay Mining and Smelting Company Limited
38.	Gold	Gold Hill group	Hudson Bay Mining and Smelting Company Limited
39.	Copper, zinc	Rod deposit	Stall Lake Mines Limited
40.	Gold	Sask-Mani deposit	Sask-Mani Precious Metals Mining Company Limited

41.	Copper, zinc	Osborne Lake Mine	Hudson Bay Mining and Smelting Company Limited
42.	Copper, nickel		
43.	Molybdenum	Crowduck Bay showing	
44.	Gold		
45.	Gold		
46.	Lithium	Spodume, Beryl claims	Sherritt Gordon Mines Limited
47.	Gold	King George, King Edward claims	Wm. S. Barclay
48.	Gold	Bino, Nemo, Peter Roy claims	Kusko Exploration Syndicate
49.	Gold	Molly claim	Copper Lake Mining Company Limited
50.	Gold	Rainbow group	Hackett Gold Mining Company, Ltd.
51.	Gold	Ferro Mine	Explorers Alliance Limited
52.	Gold	Pocohontas claim	
53.	Gold	Elisabeth, Dauphin claims	The Pas Consolidated Mines Limited
54.	Gold	Bingo Mine	Bingo Gold Mines Limited
55.	Gold	Laguna (Rex) Mine	Homesite Mines Limited
56.	Gold	Moose, Horn, Ballast, claims	Kiskoba Mining Company Ltd.
57.	Gold	Kiski, Wekusko, claims	McKenzie Oil and Gas Company Limited
58.	Gold	Royal 146 claim	Wekusko Mines Limited
59.	Gold		
60.	Gold	Cyclone claim	
61.	Silver, lead	Bill 8 claim	
62.	Tungsten	Juliana claim	Northern Tungsten Limited

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THE KISSISSING AREA

This district, bounded by latitudes 55° 00′ to 55° 30′ and longitudes 100° 15′ to 102° 00′, is well known for the complex structures and base metal deposits occurring in Kisseynew gneisses of sedimentary origin. Although the area has been extensively prospected, especially in the vicinity of Sherridon, the Sherritt Gordon mine has been the only producer, operating for parts of 1931 and 1932 and continually from 1937 to 1951. Mineral occurrences are not numerous but are widely scattered throughout the region; several known gold and base metal prospects are of potential value. A considerable amount of exploration has been carried out on some properties since 1958.

GENERAL GEOLOGY

The area is underlain for the most part by discontinuous belts of Kisseynew gneisses. These rocks were derived mainly by regional metamorphism and granitization of stratified rocks. The widespread and intense granitization has converted a great proportion of the paragneisses to granitoid gneiss, granite gneiss, and ultimately into migmatite. Approximately 25 per cent of the area is underlain by intrusions of granite, granodiorite, tonalite, and some granite gneiss. Less metamorphosed, Amisk-type greenstones have been mapped at one locality only, southeast of Sherridon, along the southern boundary of the map-area. These rocks lie in faulted contact with the Kisseynew complex to the north and evidence of dragfolds indicate that the south side (Amisk) has moved upwards relative to the Kisseynew gneisses.

Metamorphism has obliterated almost all primary bedding structures of the original rocks, so that age relationships throughout the area cannot be determined with certainty. The stratigraphic sequence indicated on the legend (Figure 25) is extrapolated from the Sherridon and Batty Lake areas where detailed mapping was carried out.

Bateman and Harrison (1946) divided the Kisseynew gneisses into three divisions: the Pre-Sherridon, Sherridon, and Post-Sherridon groups; the basis for this classification was the distinct quartz-rich character of the Sherridon group, correlation of the Sherridon group with quartzites at Weldon Bay which overlie Archaean greenstones, and structure. The Sherridon structure was interpreted as a complexly folded anticline with Pre-Sherridon rocks outcropping in the center. These Pre-Sherridon rocks consist of stratiform quartz-oligoclase-biotite gneiss which weathers buff and which contains many garnetiferous beds overlain by dark green hornblende-plagioclase gneiss that is locally garnetiferous. The hornblende gneiss is generally massive and without visible structure but in many places it is thinly foliated. The Sherridon group consists of distinctive white to grey quartzites interbedded with dark green to black hornblende-plagioclase gneisses. The different beds contain abundant quartz and various minor amounts of feldspar, biotite, hornblende, and garnet. They have a distinctive gneissic structure that is typically emphasized by the quartz, which stands out in relief on weathered surfaces. The Sherritt Gordon orebodies occurred in the Sherridon group near the contact with hornblende-plagioclase, gneiss, which Bateman and Harrison (1946) classified as Post-Sherridon but which Robertson (1958) classified as Nokomis (equivalent to Pre-Sherridon).

According to Bateman and Harrison the Sherridon group is overlain by dark green hornblende-rich gneiss that is in sharp contact with the distinctive Sherridon quartzites. The hornblende gneiss is succeeded by widespread metamorphic types characteristic of the prevailing Kisseynew gneisses of the district. These consist chiefly of stratified biotite-rich quartz-feldspar-garnet gneiss but may include some conglomerate. The stratified gneisses invariably grade into rocks that have been so injected by granitic material and pegmatite that the bulk of the rock is intrusive and for mapping purposes, is classified as "granitized" gneiss. In addition, there are granitoid gneisses that resemble granite or granodiorite in hand specimen, but they have a stratiform structure similar to bedding and probably represent sedimentary gneisses in an advance state of granitization.

The Kisseynew gneisses of the Batty Lake area[1] are structurally similar to those of the Sherridon area, and distinctive rock types can be traced continuously from one area into the other. Robertson (1953) was thus able to determine that Moody Lake lies within a major north-trending anticline. Going in the directions, north, west, or east, off the crest of this anticline into younger rocks one passes into typical Sherridon formations. He thus called the older rocks Nokomis group. In this case undoubtedly the Sherridon is post-Nokomis, and structure indicates that it occupies synclinal areas within the Nokomis. The same relationship was found elsewhere in the area. The Nokomis rocks, however, can be traced into "post-Sherridon" rocks of the Sherridon map-area[2], where apparently the stratigraphy should be reversed and the Sherridon structure considered synclinal, as also postulated by Sherritt Gordon geologists (Farley, 1948). No post-Sherridon sedimentary rocks have been found in the Batty Lake area. It seems probable that the rocks at the center of the Sherridon structure, formerly regarded as pre-Sherridon, are domed Nokomis rocks. Robertson states that the constancy of the Nokomis character of the rocks lying along the Amisk contact is maintained at least as far west as Annabelle Lake in Saskatchewan. This is corroborated by Pollock (personal communication) who, in mapping the area between Kississing Lake and the Manitoba-Saskatchewan boundary, found Nokomis-type rocks overlain by Sherridon-type rocks. The Sherridon there, however, is chiefly a quartzo-feldspathic paragneiss derived from arkosic sediments with minor quartzites. The large exposure of complexly folded Sherridon rocks west of Kississing Lake may represent a basin-like structure. West and south of Duval Lake (southwest of Kississing Lake) parts of the Nokomis rocks are not the typical biotite-rich quartz-feldspar gneiss but consist chiefly of semi-pelitic schistose meta-sedimentary rocks, with intercalated garnetiferous and staurolitic schists. These rocks appear to occupy a synclinal position in the Nokomis and did not attain the higher metamorphic grade typical of most of the Kisseynew gneisses.

The rocks shown as "Nokomis-type" north of latitude 55° 15′ on figure 25 are undifferentiated sedimentary gneisses as taken from Geological Survey of Canada Map 970A.

Several features have been described as unique to the Nokomis-Sherridon boundary. The most characteristic is the occurrence, at the base of the Sherridon group, of a variable width of limestone and limy rocks which grade laterally into pure quartzites. These narrow limestone-quartzite bands can be found in almost all parts of the Batty Lake area. The limestones grade into the overlying quartz-rich sedimentary gneiss of the Sherridon group and into the underlying fine-grained commonly graphitic, garnetiferous quartz-biotite gneiss or hornblende gneiss of the Nokomis group. Commonly the limestones have been converted to "hornblende-plagioclase-gneisses." Under the microscope these rocks are chiefly distinguished as an assemblage of quartz, calcite, diopside, tremolite, hornblende, plagioclase, scapolite, clinozoisite, sphene, and apatite. Calcite may form up to 80 per cent of the rock.

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[1] G.S.C. Map 1006A.
[2] G.S.C. Map 862A.

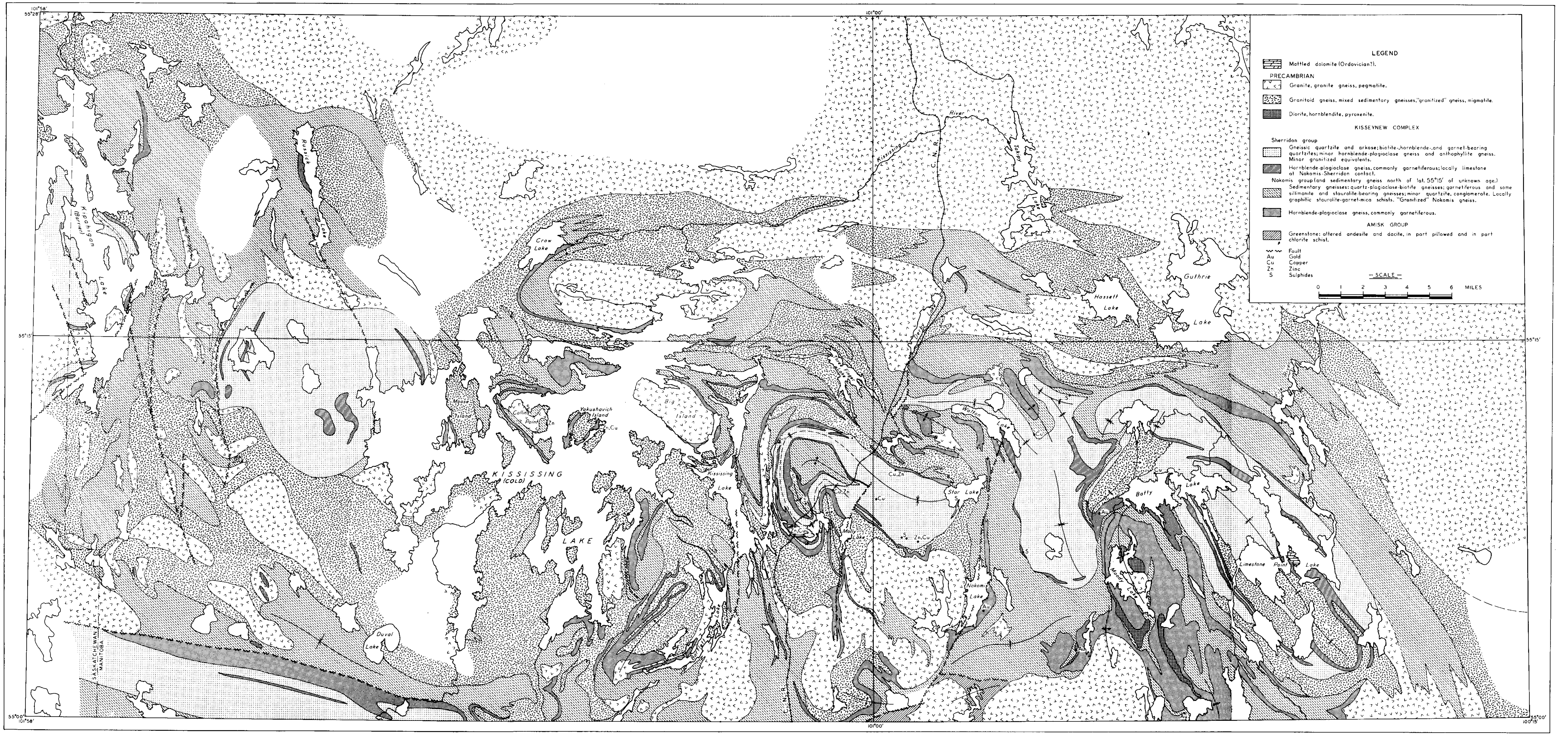

FIGURE 25

Geology of the Kississing Area

Aerial view, Kisseynew gneisses, west of Sherridon. These banded gneisses are characterized by complex open folds.

TABLE 10

Correlation between Sherridon and Batty Lake Map-areas
(*after Robertson*)

Sherridon area Bateman and Harrison (1946)	Equivalent to	Batty Lake area Robertson (1953)
Post-Sherridon	↘	
Sherridon group	→	Sherridon group
Pre-Sherridon	→	Nokomis group
		— (Fault contact) —
		Amisk series

Robertson (1961) came to the conclusion that "The division of the Kisseynew into two groups can evidently be more suitably based on the distinct change of sedimentation expressed by the development of the limestones and their intertonguing orthoquartzites than on the more general quartz-rich character of the Sherridon, even though this character is quite distinctive."

"Orthoquartzites and interbedded limestones are sorted rocks characteristic of the 'stable platforms' or 'Foreland Facies' (Pettijohn, 1943, 1948). These succeeded as they are by sandstones trending towards true quartzites, are a definite sedimentary feature of a type of sedimentation that probably characterized a large area at the time of deposition. Mapping in other areas of Kisseynew-type rocks should anticipate the possibility of stratigraphic markers of this type and level in the stratigraphic column."

Re-examination of critical areas of the Sherridon fold by Robertson led to the conclusion that similar contact relationships between the Nokomis and Sherridon groups exist there and led to the re-interpretation of the structure of the entire area.

There is also preliminary evidence that hornblende-rich gneisses occur near the base of the Sherridon group in the area west of Kississing Lake. Specifically, some bands of "hornblende-plagioclase gneiss" north of the northwest corner of Kississing Lake, east and west of Kipahigan Lake and at the base of the small occurrence of Sherridon rocks in the southwest corner of Kipahigan Lake, are finely stratified and commonly grade into or are intercalated with quartzo-feldspathic paragneiss.

Inasmuch as the Sherridon of this area contains much gneiss probably derived from arkose, it is not quite characteristic of the "stable platform" type of deposit described above but may well represent a facies variation. Whereas the depositional environment of orthoquartzite-carbonate is neritic to intertidal, for this arkosic facies it would be terrestrial to intertidal.

A band of anthophyllite-rich rock occurs in the Sherridon group at Sherridon and east of there. It varies in width from 50 to 100 feet and occupies a relatively constant stratigraphic position 500 to 800 feet above the base of the Sherridon. The character of its mineral assemblage suggests iron metasomatism of an aluminum-rich sediment or tuff. This possibility is favoured because of the wide lateral development and apparent continuity of the band. A tuff band would probably provide the necessary high permeability to ascending metasomatic solutions.

Another feature of the Nokomis-Sherridon contact is the presence of graphitic gneiss (Robertson, 1953). Graphite occurs in quantity only near the top of the Nokomis group where it may form as much as 50 per cent of the rusty weathered parts of the gneiss; its absence elsewhere indicates some stratigraphic control. It may possibly be of organic origin. Pollock (personal communication) found graphitic bands in the Nokomis, in places bordering Sherridon rocks; elsewhere the exact stratigraphic position of the graphitic bands has not yet been determined.

Detailed work has been done on the "Cree Lake Intrusive Rocks"[1] by Davies (1948) who found that the existing rocks do not form an intrusive complex, as reported by Bateman (1944); he found that the only distinctly intrusive rock in the area was a pyroxenite. A similar conclusion was reached by Robertson (1961). Davies states in his summary that: "No anorthositic intrusives are present, these rocks actually being altered calcareous sediments. A rock unit previously mapped as meta-gabbro is almost certainly another sedimentary hornblende-plagioclase gneiss. A pyroxenite intrusion is present on the shore of Cree Lake. However, its presence does not justify the concept of a related series of intrusives (from pyroxenite to granite), the Cree Lake 'Intrusives,' since the anorthosite and meta-gabbro are no longer recognized." Robertson further points out that the "oligoclase granite" does not exist, at least, not to the mappable extent shown on Map 862A, and that the rocks outcropping in this area, are typical of the Nokomis-Sherridon contact.

Metamorphism

As a result of regional metamorphism, rocks of the Kississing area are chiefly represented by mineral assemblages characteristic of the amphibolite facies together with great volumes of "granite-like" material. Most of the rocks fall into the staurolite-kyanite or diopside-almandine-hornblende subfacies, depending upon their

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[1] As shown on the Geological Survey of Canada Map 862A.

derivation. The pronounced structural overturning, slickensiding, and excellent foliation and lineation support the concept that the staurolite-kyanite subfacies is characteristic of assemblages formed under high pressure and shearing stress. A notable exception to this regional grade of metamorphism was found in an area southwest of Kississing Lake where some Nokomis rocks exhibit a lower grade of metamorphism, up to the albite-epidote-amphibolite facies.

Structure

There is no evidence of a major break between the Nokomis and Sherridon groups and recent workers (Robertson, Pollock) suggest that the contact is transitional. On a regional basis it appears that rocks of the Kississing area underwent two periods of folding. These, however, were not necessarily separate and unrelated tectonic movements. The simplest explanation would be a change in the stress conditions during a single orogenic cycle possibly due to the injection of plutonic rocks (synorogenic intrusions). First the rocks were folded in an east to slightly north-of-east direction, the Sherridon rocks forming continuous or almost continuous eastward-trending synclinal belts. Directional stress resulted in overturning to the south. The second period of folding, in a north to slightly northwest direction, produced cross-folding and pronounced warping characteristic of Kisseynew folded structures. Much of the Sherridon group of rocks was eroded from the domed areas, accounting probably for their present discontinuous occurrences.

According to Hogg[1] folds in the Batty Lake area resemble typical "nappe" structures developed by overthrusting from the northeast.

The most prominent fault is that southeast of Sherridon, near the southern boundary of the map-area, separating the Kisseynew meta-sedimentary gneiss from Amisk rocks. Pronounced shearing is evident, with development of augen-gneiss, flaser-gneiss, and mylonite. Drag-folds in the Nokomis quartz-biotite gneiss and in the Amisk "greenstone" indicate that the fault is of normal character with north side down (Robertson, 1953). The observations made by Robertson are not consistent, however, with the idea that thrusting occurred from the north. It is possible that the nature of the main movement was obscured by the emplacement of the granite adjacent to the fault.

According to Robertson, the Amisk-Kisseynew fault is displaced to the left by a fault trending north through Nokomis Lake to Walton Lake.

Two other northward-trending faults exist on both sides of the Sherridon structure, the Molly Lake fault and the Kississing Lake fault. The Molly Lake fault displaces the Sherridon-Nokomis contact north of the lake but most probably tapers out, as there is no evidence of similar displacement on the opposite limb of the Sherridon syncline.

Very pronounced lineaments trend south-southeast at Kipahigan Lake. The nature of displacement along these breaks is unknown.

Figure 26 after Robertson (1961) shows his concept of the development of the Sherridon structure. In the first stage of deformation the Sherridon was folded into a west-northwest trending syncline with a small anticlinal welt of Nokomis rocks

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[1] Hogg, W.: Company report in Manitoba Mines Branch files of assessment work on cancelled claims.

in the center. Cross-folding in a northerly direction resulted in warping and production of small secondary synclines and anticlines as shown on Figure 26 (b and c).

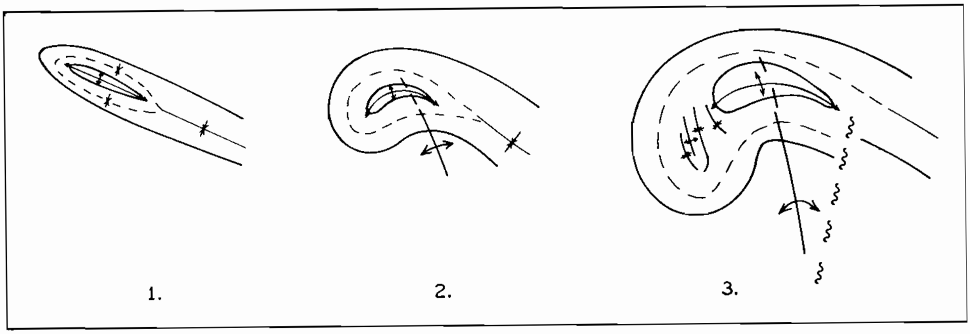

FIGURE 26 *Development of Sherridon Structure*

MINERAL DEPOSITS

General Statement

The area has been prospected for base metal deposits, chiefly copper-zinc, and for gold.

Bateman and Harrison (1946) state that "In contrast with the Flin Flon district, where the copper-zinc ores are associated with pyrite, copper and zinc mineralization in the area of Kisseynew gneiss is accompanied by pyrrhotite. There are two types of mineral deposits in the area: (1) barren sulphide deposits consisting of pyrrhotite with a little pyrite and insignificant amounts of chalcopyrite and sphalerite; and (2) copper-zinc orebodies consisting largely of pyrrhotite, but with appreciable amounts of chalcopyrite and sphalerite and a little pyrite. These two types have close structural and genetic relationships, and as pyrrhotite and pyrite are the earlier-formed minerals, it is likely that both types were identical at one stage in their evolution; whereas at a later stage some of the pyrrhotite deposits were sufficiently mineralized with chalcopyrite and sphalerite to form orebodies." Although it may be generalized that the chief sulphide throughout the entire map-area is pyrrhotite this was not observed to be the case by Farley (1948) in the Sherritt Gordon mine where the ratio of pyrite to pyrrhotite is 2 to 1.

The greatest number of sulphide deposits has been found in the Sherridon group especially near the contact with the Nokomis rocks where hornblende gneisses are abundant. Shearing and fracturing have been localized near such contacts especially where the strata are folded, because the rocks on either side have offered different degrees of resistance under stress, and in this way fractures and channelways were provided that guided and confined the sulphide deposition derived from some igneous source beneath.

There is a close association between pegmatite and many of the sulphide deposits. Pegmatite intrudes all members of the Kisseynew gneisses of the district but is more prevalent along zones of weakness, such as contacts between hornblende gneiss and quartzite of the Sherridon group. The Bob Lake deposit, 3½ miles southeast of the Sherritt Gordon mine, is almost completely enclosed in pegmatite and there was much pegmatite in the Sherritt Gordon mine also. Pegmatite is also present, although in lesser amounts, in some of the barren pyrrhotite deposits. The pegmatite is usually shattered where it is associated with the sulphides.

In the Batty Lake area several deposits related to the Nokomis-Sherridon contact were described in detail by Robertson (1953). These and others are shown on Figure 25. Most of the sulphide deposits contain some chalcopyrite, sphalerite and galena. Low and erratic values in gold and silver were reported.

Hornblende-plagioclase gneisses of the Nokomis group appear to be particularly favourable host rocks for quartz veins and gold mineralization. On the Simpson prospect, east of Nokomis Lake, Nokomis gneisses are mineralized along a north-trending zone for a length of over 3,000 feet. The deposit consists of quartz veins and stringers along a fault in garnetiferous hornblende plagioclase gneisses. Parts of the zone, where deformation was most intense, carry abundant pyrite, pyrrhotite, arsenopyrite. Gold is associated with the arsenopyrite. A considerable amount of trenching and drilling has been carried out on the property.

During the time the Sherridon mine was in operation, Sherritt Gordon Mines Limited conducted prospecting and much geophysical work in the vicinity of Sherridon. In the Nokomis, Moody, Batty, and Walton lakes areas electro-magnetic surveys were conducted in 1957-1959 by the Hudson Bay Exploration & Development Co. Ltd. Numerous conductors were drilled in scattered localities, some in the vicinity of surface prospects already known, such as the Bob Lake deposit which contains some 2,380,000 tons of material averaging 1.33 per cent copper and 1.18 per cent zinc. The most recently discovered Jungle Lake deposit (5 miles northeast of Sherridon) contains some 3,700,000 tons grading 1.42 per cent copper and 1.1 per cent zinc. It occurs within quartzose sedimentary gneiss at its contact with hornblende-plagioclase gneiss (Nokomis-Sherridon contact), and in this respect is similar to the former Sherritt Gordon orebodies.

The most common type of sulphide deposit is one related to the Nokomis-Sherridon contact. Unfortunately, because of the presence of graphitic schists near the top of the Nokomis group, a great number of electrical conductors investigated by diamond drilling were of that nature. Koffman et al. (1962) compared the costs of exploration efforts in regions of gneissic rocks and volcanic rocks. For this purpose tabulations of drilling results of conductors for two sample areas of equal size, one east of Sherridon (132 conductors) and one in the vicinity of Flin Flon (39 conductors), were discussed. The authors found that there are over three times as many conductors in the gneissic area, but, that the volcanic area contains almost four times as many conductors of favourable massive sulphide type.

Near Nokomis Lake, east of Sherridon, a promising gold occurrence was drilled in 1961. According to reports by the company doing this work, a vein zone some 500 feet long and 10.9 feet wide was outlined. The gold-bearing material consists of a silicified bed within the Kisseynew sedimentary gneisses. The occurrence is significant in indicating the presence of an unusual type of gold deposit within the gneisses which were formerly considered unlikely host rocks for gold deposits of any kind.

Very few prospects of interest are reported from the Kississing Lake area west of Sherridon. Several occurrences containing chalcopyrite and sphalerite, galena, and iron sulphides lie in various sheared rocks on Yakushavich Island and Collins Point (Figure 25).

The area is covered by four aeromagnetic maps published by the Mines Branch: Kississing, Sherridon, Kisseynew and Bartlett. Airborne electro-magnetic surveys have been conducted by companies over large areas east and west of Sherridon.

The Sherritt Gordon Mine

The Sherritt Gordon mine was located 100 miles north of The Pas. Copper-zinc ore was discovered on the property in 1922. Production began in 1931 and continued to June 1932, when operations were suspended because of the low price of copper. Mining was resumed on August 1st, 1937, and was carried on continuously until the ore reserves were exhausted and milling stopped in September, 1951. The mine equipment and many of the town buildings were then moved to the new mine at Lynn Lake. The production of metals from the mine was: copper 366,244,801 lbs., zinc concentrate (50 per cent) 148,961 tons; gold 101,026 oz., silver 3,218,324 oz. The total value of production was $58,732,366, from 8,531,352 tons milled.

The East and West orebodies of the Sherritt Gordon mine together formed an unusually long sulphide deposit having a combined total length of almost 16,000 feet, of which 3,600 feet, between the two orebodies, carried no ore. Both were enclosed in gneisses that are highly metamorphosed sedimentary and volcanic derivatives and that formed the southwest limb of an overturned syncline. The rock forming the footwall of the deposit was gneissoid quartzite; the hanging-wall rock was garnetiferous hornblende gneiss. Pegmatite commonly occurred along both footwall and hanging wall peripheries and as isolated blocks and fragments within the ore zone. These blocks and fragments were considered to be residuals of unreplaced host rock.

The ore was relatively coarse grained and ranged from the massive to the disseminated type. The metallic sulphides in the deposit in order of their abundance were pyrite and pyrrhotite (2-1 ratio), chalcopyrite, sphalerite (marmatite), and minor chalmersite; subordinate amounts of gold and silver were recovered. The insoluble gangue content of the ore-bearing material averaged about 35 per cent.

The Bob Lake deposit also occurs within a pegmatite sill that lies along the east limb of an overturned anticline superimposed on the main syncline (Figure 27).

Farley (1948) was of the opinion that deformational thrusting accompanied by invasion of granite along an upward and south to north direction produced drag-folding, anticlinal folding, and faulting within the main syncline. The pegmatite injection was believed to have occurred during this period of deformational movement; the resultant stresses initiated shear fractures along the contacts of rocks of widely different competencies, i.e., a brittle quartzite and a hornblende gneiss. The parallelism between the major pegmatite sills and the axial planes of the folds suggests this period of disturbance. Further structural deformation followed the intrusion of the pegmatite, with accompanying differential movement taking place in the direction of the plunge and parallel to the axial planes of the folds. Fracturing within the more competent pegmatite sill created openings for ingress of ore-forming solutions.

From 20 to 25 per cent of the ore in the mine occurred in offshoot orebodies. At intervals along the main ore zone, fractures were developed in the hanging wall at acute angles to the main zone of fracturing. Pegmatite from the main sill channel

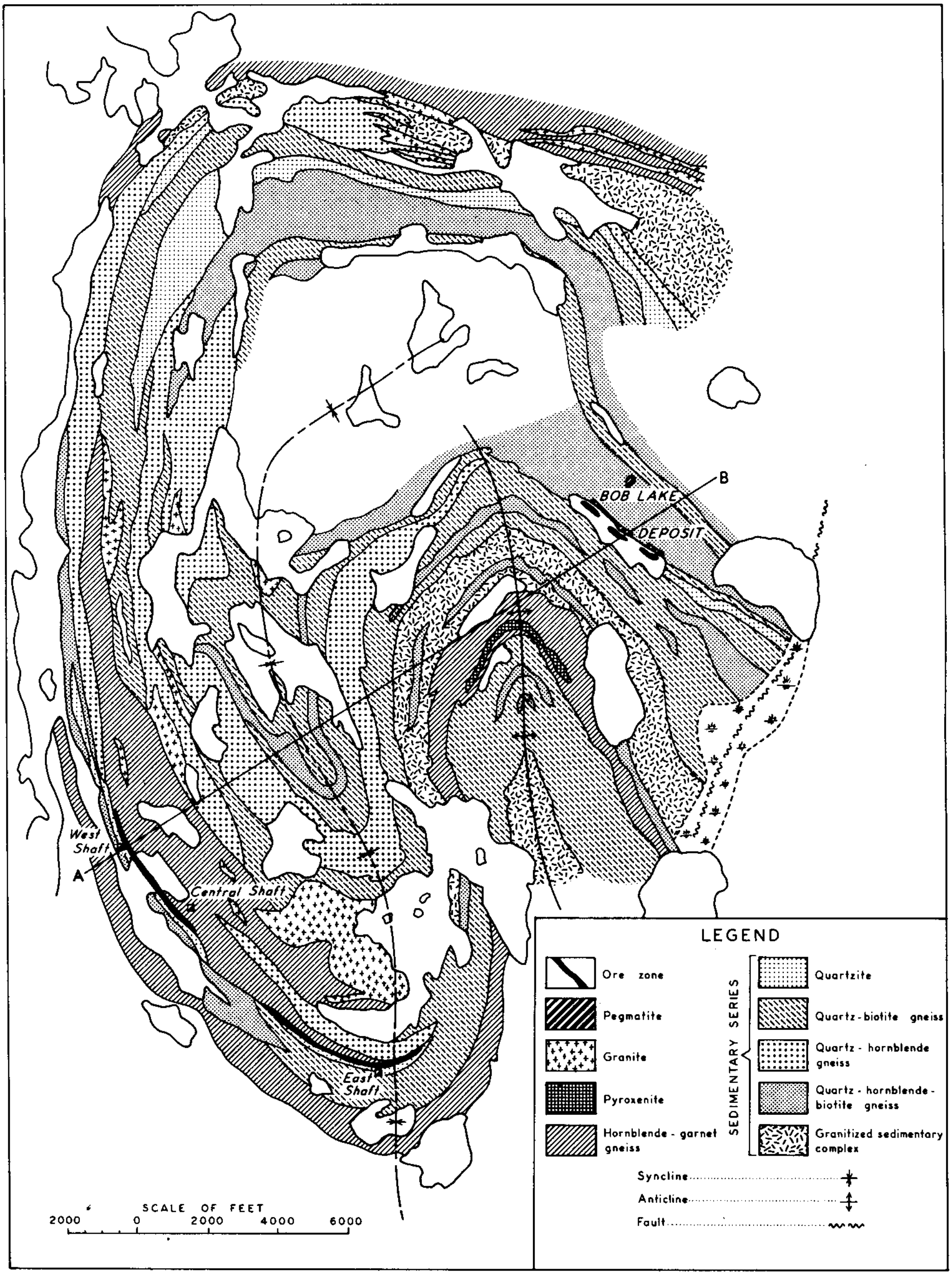

FIGURE 27 *Geology of Sherritt Gordon Mine Area, Sherridon*

was injected into these fractures to form dyke-like masses normal to the parent sill. The major offshoot fracture zones developed along east-plunging drag-folds. The dyke-like masses of pegmatite were subjected to deformational movement, previously described; the same processes of fracturing and ore replacement have taken place within the offshoot structures as in the main zone.

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THOMPSON — MOAK LAKE AREA

The Thompson-Moak Lake belt rates as one of the world's foremost nickel-producing areas, ranking second only to Sudbury in Ontario. In 1956, following ten years of intensive exploration during which several large low-grade and marginal nickel deposits were discovered, The International Nickel Company of Canada Limited announced the discovery of a large high-grade deposit at Thompson. Underground development and construction of surface facilities commenced early in 1957 and initial production was achieved in 1960.

The entire project, including mining plant, concentrator, refinery, townsite, railway and hydro-electric plant has cost an estimated $185,000,000. Nickel output in 1962 was approximately 100 million pounds. The operation is unique in that it is the only fully integrated nickel-producing operation in the world where all stages of production from mining of raw ore to refining of nickel are carried out at a single plant site.

GENERAL GEOLOGY

The nickel deposits occur on the north side of a wide zone of gneissic Precambrian rocks lying along the route of the Hudson Bay railway and marking the boundary between the Churchill and Superior geologic provinces (see chapter 2). The nickel belt proper is characterized by a series of gravity "lows" adjacent to a high-gravity strip, greywacke-type lithology, intense deformation, and a series of serpentinite intrusions. These features extend along the entire belt and are characteristic of "Alpine-type" mountain structure. It is probable, therefore, that this zone of Precambrian rocks represents the roots of an ancient mountain system. Differences in age, lithology, and structure on either side of this belt, i.e., within the Churchill and Superior provinces, have been discussed in chapter 2.

Interpretation of the detailed geological features of the area is hampered by paucity of outcrop and high degree of deformation and metamorphism. The geology of the area is known mainly as the result of only reconnaissance mapping. An area immediately around Thompson has been mapped in somewhat greater detail but even there the results must be considered as only preliminary.

The oldest of the rocks in the area appears to be a complex massive to gneissic body of hypersthene granite in which the feldspar is honey- or amber-coloured and which contains hypersthene partly or entirely altered to or rimmed by chlorite, biotite, and hornblende. A single radioactive age determination gave an age of 2,400 million years for the hypersthene granite, thus placing it as a marginal phase of the Superior province. Although contacts are not well exposed the younger sediments and gneisses presumably of the Churchill province, appear to be faulted against the hypersthene granite.

Recognizable volcanic rocks form only a minor part of the formations along the Thompson belt. They consist of fine to medium-grained metamorphosed andesite and/or basalt rarely showing signs of flow structure. It is possible that some of the exposures regarded as volcanic are actually fine-grained mafic intrusions.

Apart from the volcanic rocks the least altered rocks of the area are a series of sediments of the greywacke suite: greywacke, micaceous quartzite, argillite, and subordinate conglomerate and calcareous sediments. Some of these are reasonably fresh, others are moderately metamorphosed; some bands of non-granitized gneiss (apparently derived from sediments and containing quartz, feldspar, amphibole, biotite, and garnet), and some bands of pyroxene granulite are included in this unit.

For the most part the recognizable sediments are well bedded and in part highly crumpled and drag-folded. These rocks were classified as Assean Lake series by Dawson (1952) and were regarded as younger than the gneisses and schists of the Pre-Assean series. This opinion was not shared by Gill (1951) and recent work by the Mines Branch indicates that the gneisses and schists may have been derived from the sediments.

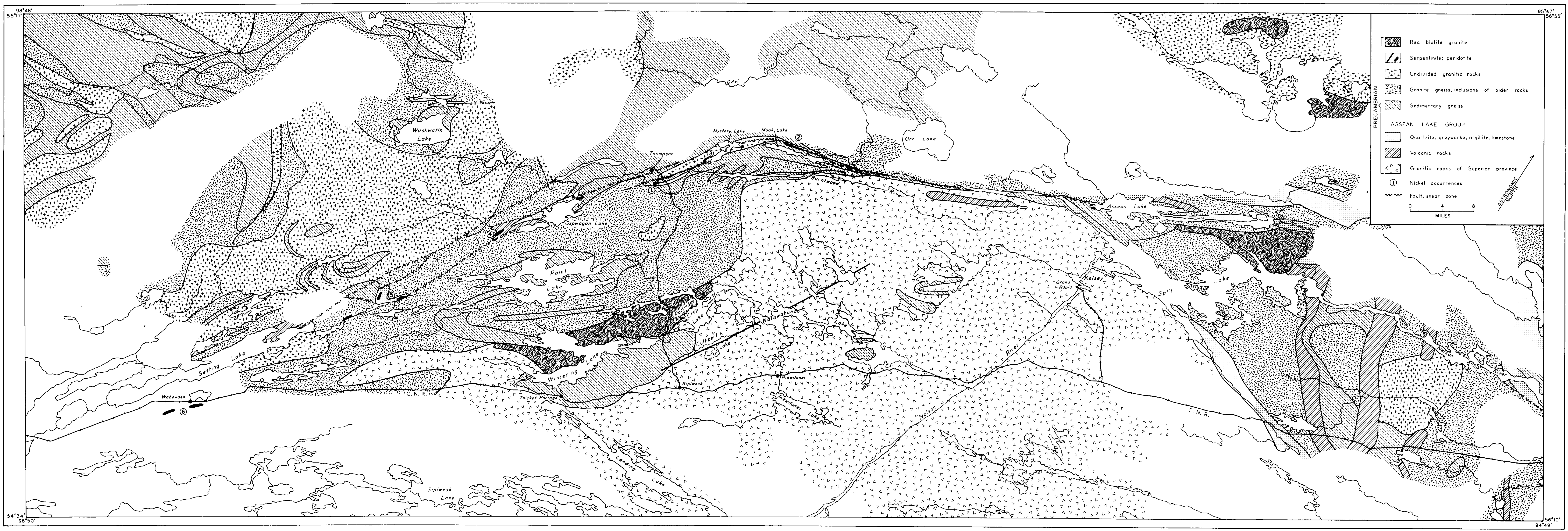

FIGURE 28

Geology of the Thompson Belt

Large areas are underlain by partly granitized sedimentary gneiss, and granite gneiss containing inclusions of sedimentary gneiss. The sedimentary gneisses are well banded and composed dominantly of quartz and feldspar with varying amounts of biotite, hornblende and pyroxene. Some of the gneisses have a high garnet content, others contain abundant magnetite or cordierite. All of the gneisses of this unit have been injected and impregnated with varying amounts of granitic material. Some bands of non-granitized sediments similar to those of the Assean Lake group occur within the gneisses and although the relationships are not definite the sediments appear to represent only moderately metamorphosed and ungranitized remnants in the gneiss.

The granite gneiss unit consists of a complex of highly gneissic granitic rocks containing numerous bands, blocks, ribbons, and irregular masses of granitized sediments. In general the granite gneiss is not as well banded as the sedimentary gneiss. The inclusions of granitized sedimentary gneiss are characteristically highly contorted.

Ultramafic and mafic rocks intrude the hypersthene granite, sediments, and gneisses but are in part, at least, intruded by younger granitic rocks. The most prominent of these intrusions are the serpentinite bodies with which the nickel deposits are associated. They occur as numerous more or less concordant intrusions, several hundred to several thousand feet long and generally a few hundred feet wide, lying within the sedimentary rocks and gneisses. They are restricted to a long narrow zone extending from Assean Lake to southwest of Setting Lake. The serpentinite bodies are characteristically lenticular, of uniform composition throughout (composed dominantly of serpentine minerals largely pseudomorphic after olivine), have a high Fe/Mg ratio and low CaO and Al_2O_3 contents. In these respects and in their mode of occurrence they are typically Alpine-type serpentinite intrusions.

In contrast to the Alpine-type serpentinites are the differentiated dyke-like intrusions of peridotite which invade the hypersthene granite. The most prominent of these, shown as a single dyke passing through Natawahunan Lake, actually consists of a closely spaced series of en echelon dykes striking northeast. These dykes differ from the serpentinites in that they contain both olivine and pyroxene, are less serpentinized, and are differentiated. The Fe/Mg ratio of the most ultramafic specimen is 3.09 as compared with 7.68 for the Alpine-type serpentinites of the area. The CaO and Al_2O_3 content of the peridotite is higher and the primary nickel content is lower than in the serpentinites.

Associated with the peridotite are numerous gabbro dykes occupying fractures parallel to those in which the peridotite occurs. Such dykes are particularly prominent around Landing Lake and Pikwitonei Lake.

Granitic rocks form the bulk of the bedrock throughout the area. These consist of massive to gneissic grey to pink granitic rocks that are undifferentiated on the map and a massive red porphyritic granite.

Structure

Because of the lack of abundant outcrops, the absence of continuous marker beds and primary structures suitable for determining tops of beds, and uniformly steep dips throughout the area, the nature of the folding is obscure. The regional trend is northeast parallel to the axis of the strip of low gravity. Dips of bedding and schistosity are steeply southeast or nearly vertical. Although it is difficult to decipher structural details, apparently the entire series of sediments and gneisses has been deformed into a number of isoclinal folds. Drag-folds are common within the sediments and gneisses and in many places the rocks are highly contorted and crumpled. Plunges of drag-folds and linear features change from NE to SW in several places along the belt. It is probable that many of the drag-folds, especially the tight V-shaped drag-folds that are common in some of the sediments, are related to faulting.

A major zone of extreme deformation and faulting appears to extend from Setting Lake to Assean Lake, passing through Ospwagan Lake, Mystery Lake, Moak Lake, and along the Odei River. Along this zone the rocks are highly schistose across widths of several hundred or thousand feet. This "break" probably represents a series of parallel, sub-parallel, and branching faults. It is generally difficult to trace a particular fault for any distance, because outcrops are insufficient and because of the generally schistose nature of the rocks across considerable widths. However, the proximity of a fault or shear zone can be deduced by the increasing intensity of schistosity and slickensiding in the sediments and gneisses.

The coincidence of the zone of maximum deformation (highly schistose rocks, drag-folding, crumpling, slickensiding, and faulting), metamorphosed but ungranitized sediments, the strip of low gravity, the occurrence of elongate conformable serpentinite intrusions, and the presence of nickel deposits, is well defined. All of these features are confined within a zone about 5 miles wide and more than 200 miles long; the nickel deposits are known to occur along a length of at least 80 miles within this belt.

Within the large area, chiefly underlain by granitic rocks, between Split Lake, Landing Lake, and Wintering Lake, numerous northeast-trending fracture zones cut across the gneissic structure of the rocks. Many of these fractures are occupied by mafic and ultramafic dykes the most outstanding of which is the swarm of en echelon peridotite dykes passing through Natawahunan Lake. The Nelson River, along much of its course, appears to follow a northeast fracture zone. Another fracture system, also occupied by dykes, strikes more or less east. Both sets of fractures appear to be restricted to the area south of the zone of maximum deformation referred to in the previous paragraph, and to lie within granites of the Superior province.

NICKEL DEPOSITS

The more important known nickel deposits are shown on Figure 28. It is readily apparent that the occurrences lie along the long narrow structural belt discussed above.

The nickel deposits are of two types: low-grade deposits that occur within serpentinite bodies (Mystery Lake, Moak Lake), and at least one higher-grade deposit that occurs mainly in sedimentary rocks and gneisses. The high-grade Thompson deposit is associated with a small serpentinite intrusion and part of the ore occurs in this rock; however, the majority of the sulphides occur in the adjacent sediments and schists.

Thompson Orebody (1)[1]

The Thompson deposit lies within a band of biotite schist bounded on the south by well-bedded quartzite and arkose and on the north side by a band of sedimentary "iron-formation" (pyrrhotite-bearing garnetiferous gneiss). These sedimentary rocks form a well-defined horizon of unknown width and several miles long, striking northeast and dipping steeply southeast. The southwest end of the band forms an anticlinal drag-fold plunging steeply southwest; along this part of the sedimentary horizon bands of plagioclase-amphibolite, plagioclase-amphibole gneiss, limestone, and skarn lie between the quartzite and biotite schist. A small lens of serpentinite, measuring a hundred feet or so wide and a few hundred feet long intrudes the sedimentary rocks around the nose of the drag-fold.

The sedimentary series is in contact with more or less stratiform grey granitoid gneiss and this in turn is in contact with an irregularly hybrid pale pink granodiorite gneiss.

The biotite schist in which the sulphides occur attains widths of 200 or 300 feet. Variable amounts of pegmatitic material in the form of small stringers, lenses, and irregular bodies invade the biotite schist. In places the schist is intimately injected and impregnated by quartzo-feldspathic material, forming a streaky schist. Small pink garnets and thin wisps of fibrous sillimanite are commonly developed in the biotite schist.

The orebody strikes N30°E and dips 65° to 75° southeast, conformable with the enclosing sediments. The deposit occurs as a long, more or less continuous but irregular sheet within the biotite schist. Much of the massive sulphide forms a sulphide breccia containg fragments of wall-rock schist, biotite flakes, in places pegmatitic material, and quartz.

The deposit pinches and swells from place to place in an irregular manner, varying from about 85 feet to only a few feet wide. In places the sulphide band splits into 2 or more branches surrounding large wedges of unmineralized or slightly mineralized country rock.

The ore consists largely of coarse-grained pyrrhotite and pentlandite containing fragments of rock and small flakes of biotite. Chalcopyrite is not abundant in the sulphides and when present usually occupies small fractures in the inclusions.

Although most of the ore lies within the biotite schist band, some massive and disseminated sulphides occur within the serpentinite body at the southwest end of the deposit. The massive ore occupies fractures within serpentinite.

The relationship between the sulphides and pegmatite indicate that the sulphides replace the pegmatite which in turn is intrusive into both the biotite schist and serpentinite; this places the time of formation or, at least, concentration, of the sulphides after the crystallization of the serpentinite.

The International Nickel Company has reported reserves of 25,000,000 tons but the total tonnage when completely estimated will be many times this figure. According to figures released by the company the average grade of the ore is almost

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[1] Numbers refer to localities on Figure 28.

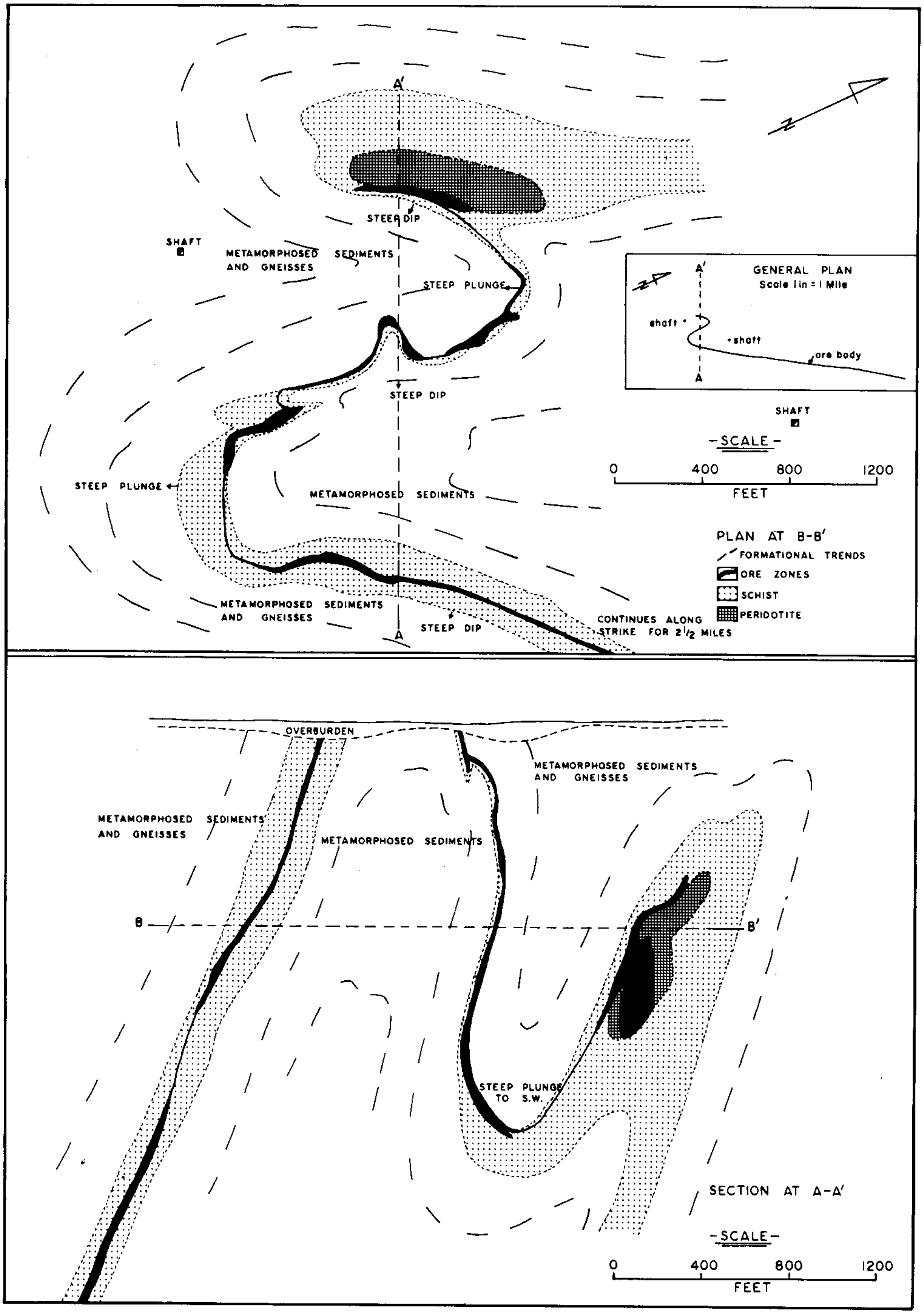

FIGURE 29 *Plan and Section, Thompson Orebody*

3 per cent nickel. Although only very small amounts of copper are present in the ore, the large tonnages being treated will permit recovery of this metal.

Moak Lake Deposit (2)

At Moak Lake disseminated pyrrhotite and pentlandite occur in a serpentinite sill that lies in quartzose sediments adjacent to well-banded granitoid gneiss. The sediments consist of quartzite, impure quartzite, and limestone. The serpentinite body pinches and swells, has a maximum thickness of about 500 feet and is roughly a mile long.

Sulphides, mainly pyrrhotite and pentlandite, are disseminated throughout the serpentinite as small grains and networks of fine irregular thread-like stringers and blebs. The network and blebs display crude alignment parallel to weak schistosity in the serpentinite.

Some massive sulphides occupy zones of fracturing in the serpentinite but these form only a minor portion of the total sulphide in the deposit. The massive ore occurs in bands, a few inches to a foot or so wide, that cannot be traced for any distance. In part, the massive sulphides consist of "breccia ore" containing fragments of silicified serpentinite and quartz which clearly filled the fractures prior to introduction of the massive sulphides.

Only parts of the serpentinite are mineralized, others are barren. There appears to be no regular distribution to the mineralized areas of serpentinite.

The Moak Lake deposit contains several tens of millions of tons of marginal grade ore. An exploration shaft has been sunk on the deposit and considerable underground work done. However, International Nickel, following discovery of the higher-grade Thompson deposit, suspended operations at Moak Lake in 1958.

Other Nickel Deposits

Extensive drilling has been done at Mystery Lake (3) where disseminated sulphides occur in serpentinite underlying the lake. This occurrence is one of the few along the belt that is known to be exposed and it first attracted the attention of the late Walter Johnson who was instrumental in interesting Inco in this area. The Mystery Lake deposit is low grade.

In 1960 Inco commenced shaft sinking on a deposit southwest of Ospwagan Lake (4). Few details are available but apparently the deposit is of the Moak type.

At Hambone Lake (5), about 6 miles northeast of the northeast end of Setting Lake, sulphides occur in sediments intruded by small serpentinite bodies. The ore structure is in the form of a large drag-fold. Considerable drilling was done on the deposit and a few million tons grading less than 1 per cent nickel were outlined by Maralgo Mines Limited who later sold the property to Inco.

Consolidated Marbenour Mines Limited and National Malartic Mines Limited have done considerable drilling near Wabowden (6) and succeeded in outlining several small deposits totalling more than 1 million tons averaging less than 1 per cent nickel. The ore occurs in serpentinite intruding "gneiss" and intruded by granite.

In addition to the work conducted along the exposed portion of the belt, the northeast and northwest extensions of the zone where they are overlain by relatively thin Palaeozoic limestones have been explored by airborne geophysical surveys, ground geophysical surveys, and diamond drilling. It is expected that exploration along the entire belt will continue for some time.

PLATE XI *The Thompson nickel mine. This operation is noted not only for its size but also for the compact plant site.*

Origin of the Nickel Ores

The association of nickel deposits with mafic and ultramafic rocks is universal and it is not difficult to explain the low-grade disseminated deposits in serpentinite. The solubility of sulphur in ultramafic magmas is high and in such magmas, if they are undersaturated with respect to sulphur, nickel crystallizes as the silicate or, if as sulphide, so late in the crystallization sequence that the sulphide phase cannot accumulate and, therefore, remains disseminated throughout the rock. This is characteristic of nickel occurrences in many serpentinite intrusions which do not give rise to a more silicious fraction in which sulphur would be less soluble and in which sulphide phases would, consequently, accumulate to form massive deposits.

It is apparent, then, that concentration, as a result of differentiation, to form the massive ores may not explain the massive Thompson deposit. Not only do physico-chemical considerations, but also the timing emplacement of the massive sulphides and the rock types in which they occur, argue against this. The massive sulphides cut pegmatite which intrudes the serpentinite, and the greater part of the orebody has been injected into biotite schist.

It may be tentatively suggested that the high-grade massive sulphides resulted from extraction and concentration of sulphides originally disseminated throughout the serpentinite. Studies of the deposits have not proceeded far enough to allow positive statements regarding possible mechanisms by which the sulphides were concentrated. Diffusion during metamorphism, granitization, and sulphur metasonatism are mechanisms which conceivably could account for concentration of disseminated sulphides into massive deposits. However, quite apart from this aspect of the origin of the deposits the regional features which were responsible for or, at least related to, the localization of the nickel occurrences are well defined. These consist of the *coincidence* of (1) the low-gravity strip, (2) narrow zone of intense deformation, (3) bands of relatively ungranitized sediments within the zone of most intense deformation, and (4) the series of Alpine-type serpentinites. These features are all restricted to a relatively narrow but remarkably long belt which constitutes the zone in which the nickel deposits occur.

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THE GRANVILLE LAKE — UHLMAN LAKE AREA

(THE LYNN LAKE DISTRICT)

The Granville-Uhlman lakes area is bounded by latitudes 56° 00′ and 57° 00′ and longitudes 98° 00′ and 102° 00′; it includes the Lynn Lake nickel-copper district. Systematic mapping of the Lynn Lake district and its extension on a scale of 1 mile to 1 inch was begun by geologists of the Manitoba Mines Branch in 1946 and continued until 1959. The results of this work have been compiled, interpreted, and presented in a comprehensive publication by Milligan (1960).

The entire area is characterized by a broad rolling topography of low relief characteristic of the Canadian Shield in northern Manitoba. The most striking feature is the presence of innumerable lakes scattered throughout the whole area and forming as much as 30 per cent of the total surface. The lakes are linked by streams many of which, although interrupted by rapids and falls, are navigable.

The largest waterway is the Churchill River and its expanded portion known as Granville Lake, which lies at an elevation of 850 feet above sea level. Away from the waterways the country is rugged with rounded ridges and hills and interspersed narrow, steep-walled valleys, low muskeg-filled depressions, and small lakes bounded by either muskeg or rock and connected by small, swampy streams. There is a remarkable coincidence between the character of the drainage and the rock structure. Where the country is underlain by massive rocks such as granite, the lakes tend to be irregular in outline and to contain many islands. Where the rocks are foliated or bedded the lakes are elongated. Sickle Lake is an outstanding example of a lake following the bedding around the nose of a synclinal structure. Pemichigamau and Kinwaw lakes follow long narrow troughs in meta-sedimentary rocks.

In parts of the area much of the pre-glacial bedrock surface exposed by ice action was later buried by ground moraine, eskers, and outwash sands deposited by the retreating ice. In these parts, a new drainage pattern characterized by swamps and sluggish streams has been established on top of the drift. This new drainage is slightly controlled in only a few places by prominent features of the underlying bedrock. A widespread blanket of clay covers much of the southeastern part of the area where Lake Agassiz once extended. The most extensive deposits are east of Harding Lake; elsewhere the clay deposits are not continuous, but thick clay banks have been noted on the Churchill River at South Bay; about 60 feet of varved clay were observed on upper South Indian Lake.

HISTORY OF EXPLORATION

There is little record of extensive exploration work in the district prior to 1930. The Caribou showing on Barrington Lake, was staked around 1930, but no further staking is reported from the area until 1934. The two best-known prospects of this period are one on Reindeer Lake and a gold showing at the south end of Cartwright Lake. A small group of prospectors from Sherridon worked in the Lynn Lake district from 1933 on, principally due north of the west part of Granville Lake. The original discovery of gold on the property of Lasthope Lake Gold Mines Limited was made in 1937 and that district experienced considerable activity between 1938 and 1940, with Central Manitoba Mines Limited and Sherritt Gordon Mines Limited the active companies. By June, 1940 a block of 417 claims covering the ground around Cockeram Lake was consolidated under Lasthope Lake Gold Mines Limited, a subsidiary of Sherritt Gordon Mines Limited.

The source of considerable sulphide float was not known until 1941, when Austin McVeigh finally located sulphides in the outcrop of what is now the "A" mine at Lynn Lake. The first sample contained less than 1 per cent copper, better than 1.5 per cent nickel and no precious metals. Magnetometer work was carried out in the area in 1943, and several anomalies were outlined. No further work was done until 1945 when staking on a large scale started in June, and by the fall Sherritt Gordon had staked 353 claims of the Elb groups. All of the sulphide deposits which came within two or three hundred feet of the surface were located with magnetic and electro-magnetic surveys and the deposits were then outlined by closely spaced diamond drill holes. By 1950, Sherritt Gordon had outlined, in eleven orebodies, the fourteen million tons of ore estimated to be the minimum required to carry the cost of a new mine, concentrator, and railway. Construction began in 1951 and by the time the 144-mile railway connection from Sherridon was completed late in 1953 the mill was in operation and concentrate was awaiting shipment. The concentrator and mining plant, along with practically the complete town of Sherridon, had been moved in by tractor train during the preceding winters. Concentrates are shipped to Fort Saskatchewan where the refinery, employing the ammonia leaching process, is located. In 1961 Sherritt Gordon Mines Limited produced 22,005,575 lbs. of nickel, 11,251,881 lbs. of copper and 191,043 lbs. of cobalt from 1,219,157 tons of ore.

Following the staking rush in the winter of 1945-46, magnetometer surveys were made on a large number of properties and many "anomalies" were tested by drilling. The results were usually disappointing and exploration activity practically ceased, except around Lynn Lake, between 1949 and 1954. Exceptions were the Nickel Lake property of God's Lake Gold Mines Limited, and the property at Tow Lake held by Anglo-Barrington Mines Limited.

Reports of mineralization in the area south of Southern Indian Lake brought prospectors there in 1958. A considerable amount of airborne and ground geophysical work, and diamond drilling has been performed since that time.

During 1961 Sherritt Gordon obtained encouraging results while investigating a recently discovered zinc-copper deposit east of Laurie Lake. This has revived interest in the western part of the area.

GENERAL GEOLOGY

The occurrence of greenstone belts and gneisses was recognized in the area by early explorers such as McInnes (1913) and Alcock (1921). Henderson's geological mapping in the Granville Lake area in 1932 established the presence of an unconformity between a group of mafic volcanic rocks and clastic sediments, which included a basal conglomerate. Norman (1934) named these latter rocks the Sickle series from their occurrence at Sickle Lake. Bateman (1945) named the volcanic rocks the Wasekwan series; a considerable thickness of interbedded sedimentary rock was included in the Wasekwan series. Bateman also recognized some sheared granitic rocks and mafic intrusions as pre-Sickle in age.

Milligan (1960) recognizes five subdivisions in the consolidated rocks between Laurie Lake and Barrington Lake. The Wasekwan series of volcanic and sedimentary rocks are the oldest. The pre-Sickle intrusive group which varies from gabbro, norite and peridotite to granite, invades the folded and schistose Wasekwan. The Sickle series of sedimentary rocks lies unconformably upon the pre-Sickle intrusions and other older rocks. The post-Sickle intrusive rocks invade the folded Sickle series. The Kisseynew-type gneisses were, in part, derived by high-grade metamorphism of the rocks of the Sickle series and may, in part, also contain some altered Wasekwan rocks.

Much less is known about the geology of the eastern half of the area where, owing to the lack of detailed mapping and the scarcity of outcrops, little evidence has been found to establish the relationship between Sickle-type and Wasekwan-type rocks[1]. North of Opachuanau Lake, the sedimentary rocks resemble the Wasekwan sediments and are interbanded with the lavas. At Karsakuwigamak

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[1] Field work by the Mines Branch in 1959 and 1961 indicate that some of the sedimentary rocks around Opachuanau Lake and Pemichigamau Lake are probably Sickle.

Lake, the scanty structural evidence available indicates that the sediments dip under and may be older than the volcanic rocks. On the other hand, good exposures of Sickle-type sediments occur at Rat Lake. These and other difficulties in correlation make it necessary to introduce a legend in two columns, one for each of the two halves of the map-area (Figure 30). It is also apparent that the "mixed gneisses" of the eastern half of the area do not correspond directly to the Kisseynew-type gneisses of the western half, but that the "gneissic granitic to dioritic" rocks of the "mixed gneiss" unit may partly correspond to the granite-gneiss of the youngest rock unit around Granville Lake.

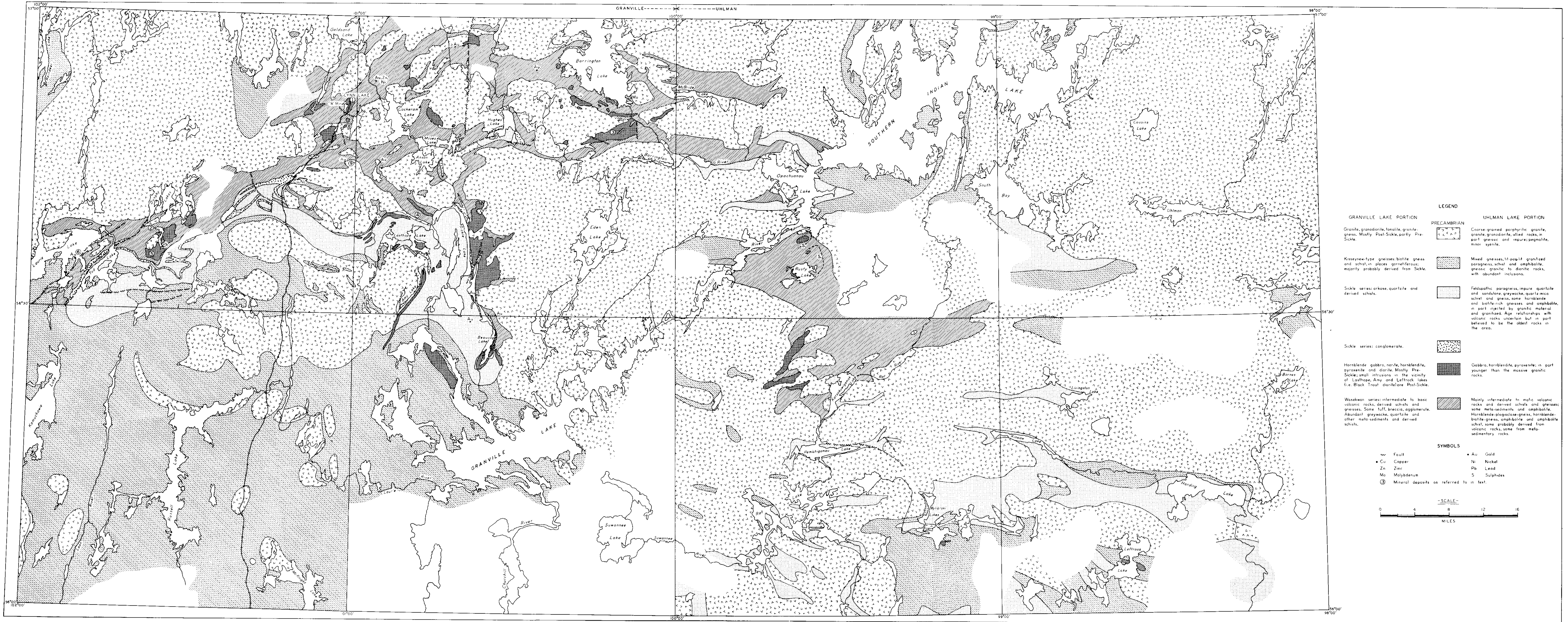
The structure of the Wasekwan rocks is obscure. Sufficient is known, in restricted areas, to show that the structure is complex and that folding has been intense, but a district-wide structural pattern has not been recognized. The Wasekwan rocks lack good exposures and reliable marker units which can be recognized with confidence. The Sickle series is considered to have been deposited in a basin, probably much larger than the present 35-mile by 50-mile area in which exposures are found in the Lynn Lake district. This basin in which arkose, sandstone, greywacke, and possibly shales and some limy beds were deposited, was deformed by a major compressive force, probably acting over a restricted width and in a northeasterly direction through Lasthope and Sickle lakes. If the Kisseynew-type gneisses are included as the metamorphosed equivalent of the Sickle, the present remnants of the Sickle rocks form two large lobes. One extends southward from Sickle Lake to Granville Lake, the other extends westward beyond McGavock Lake and to the south of Laurie Lake. The space between the two lobes is occupied by granitic rocks, in large part at least, emplaced subsequent to the folding.

The mafic intrusive rocks of the area merit detailed description. Included in this unit are occurrences at Lynn Lake in which the orebodies have been found. The Lynn Lake gabbro is widely distributed as bodies of appreciable size throughout the district. The largest bodies of gabbro occur near Lynn Lake, south of Barrington Lake, east of Sickle Lake, and south of Dunphy Lakes. In general, this gabbro has been found to be younger than the Wasekwan volcanic and sedimentary rocks but older than all the other units of the area. The gabbro is usually described as a fresh-looking, massive medium-grained dark green rock, composed of plagioclase and amphibole. The original rocks have been strongly uralitized; small remnants of pyroxene have been observed in a few specimens. The Lynn Lake bodies are the only ones, so far, to produce ore but massive barren sulphides have been found in the large body 4 miles southwest of Lynn Lake.

Post-Sickle intrusions of mafic rock are not common. The Black Trout diorite is considered to be post-Sickle and occurs in several small bodies south and west of Sickle Lake and near Beaucage, Lasthope and Amy lakes. The characteristic feature of the diorite is its altered appearance. It consists mainly of black biotite, pseudomorphic after hornblende, and grey plagioclase. The rock contains sufficient disseminated magnetite to cause strong magnetite anomalies.

Mafic intrusive rocks are neither widespread nor abundant in the eastern half of the area. The gabbro at Leftrock Lake appears to be intruded by gneissic granite, but some (not shown on Figure 30) may be younger than the granites.

The rocks of the Granville Lake-Uhlman Lake area are all of Precambrian age and lie in the Churchill Province of the Canadian Shield. In 1960, three absolute



LEGEND

PRECAMBRIAN

GRANVILLE LAKE PORTION		UHLMAN LAKE PORTION
Granite, granodiorite, tonalite, granite-gneiss. Mostly Post-Sickle, partly Pre-Sickle.		Coarse-grained porphyritic granite, granite, granodiorite, allied rocks, in part gneissic and impure; pegmatite, minor syenite.
Kisseynew-type gneisses: biotite gneiss and schist, in places garnetiferous; majority probably derived from Sickle.	▨	Mixed gneisses, lit-par-lit granitized paragneiss, schist and amphibolite, gneissic granitic to dioritic rocks, with abundant inclusions.
Sickle series: arkose, quartzite and derived schists.		Feldspathic paragneiss, impure quartzite and sandstone, greywacke, quartz-mica schist and gneiss, some hornblende and biotite-rich gneisses and amphibolite, in part injected by granitic material and granitized. Age relationships with volcanic rocks uncertain but in part believed to be the oldest rocks in the area.
Sickle series: conglomerate.		
Hornblende gabbro, norite, hornblendite, pyroxenite and diorite. Mostly Pre-Sickle; small intrusions in the vicinity of Lasthope, Amy and Leftrock lakes (i.e. Black Trout diorite) are Post-Sickle.	▦	Gabbro, hornblendite, pyroxenite; in part younger than the massive granitic rocks.
Wasekwan series: intermediate to basic volcanic rocks, derived schists and gneisses. Some tuff, breccia, agglomerate. Abundant greywacke, quartzite and other meta-sediments and derived schists.	▨	Mainly intermediate to mafic volcanic rocks and derived schists and gneisses; some meta-sediments and amphibolite. Hornblende-plagioclase-gneiss, hornblende-biotite-gneiss, amphibolite and amphibolite schist, some probably derived from volcanic rocks, some from meta-sedimentary rocks.

SYMBOLS

~	Fault	• Au	Gold
• Cu	Copper	Ni	Nickel
Zn	Zinc	Pb	Lead
Mo	Molybdenum	S	Sulphides
③	Mineral deposits as referred to in text.		

-SCALE-

0 4 8 12 16

MILES

FIGURE 30

Geology of the Granville Lake — Uhlman Lake Area age determinations by the A^{40}/K^{40} method, were made on rocks from the Lynn Lake district and the ages are 1.74 x 10^9 years for a sedimentary gneiss of the Wasekwan series and 1.64 x 10^9 and 1.70 x 10^9 years for Pre-Sickle "granites," members of a complex known as *massive and gneissic grey hornblende-biotite tonalite* which is intrusive into the Wasekwan rocks (Moore et al., 1960).

Correlation of the volcanic and sedimentary rocks of the map-area with other areas has not been attempted. Harrison (1951), however, suggests that on a broad regional basis, the Sickle series should be correlated with the Missi strata of Flin Flon and the Wasekwan with the Amisk rocks of Flin Flon and elsewhere.

MINERAL DEPOSITS

The Lynn Lake district was prospected extensively between 1945 and 1949, when exploration reached almost every greenstone belt of the area. It is known, however, that much of the work was of a very superficial nature with intense exploration limited to very few properties.

References to numerous sulphide occurrences of the district and many showings of gold-bearing quartz veins can be found in Mines Branch Publication 57-1 (G. C. Milligan).

A considerable amount of information has been published about the orebodies of the Lynn Lake district. The typical assemblage of sulphides of the "A" and "El" orebodies is essentially pyrrhotite-pentlandite-chalcopyrite. The penlandite occurs characteristically in a free state. Copper, zinc, and gold have been found in a number of bodies outside the gabbro plugs there, but within one or two miles of them. At least one other body has been found which also contains galena. It occurs about three miles from Lynn Lake. There is a suggestion therefore that there may be some form of systematic distribution of metals in the area.

A small lead-bearing vein has also been found at Snake Lake south of Dunphy Lakes, but lead seems to be rather uncommon in the district.

The copper-zinc deposit discovered in 1960 east of Laurie Lake (Fox Lake deposit) consists of a lenticular mass of pyrite containing chalcopyrite and sphalerite.

Gold-bearing quartz veins have been found at Lasthope Lake, McVeigh Lake, Cartwright Lake, and near Beaucage Lake. In the latter case the gold is associated with pyrite in quartz veins cutting Black Trout Diorite and sedimentary rocks of the Sickle series. At Cartwright Lake the gold is in a severely fractured quartz porphyry dyke, whereas at Lasthope and McVeigh lakes the veins are in hornblende-biotite schists, granodiorite, and quartz-rich sedimentary rocks.

East of Lynn Lake and southeast of the Churchill River, in the vicinity of Rusty Lake, the Hudson Bay Exploration & Development Co. Ltd. and other companies have conducted airborne and ground electro-magnetic surveys and diamond drilling since 1958. Sulphides, mainly pyrrhotite, in gneisses similar to those around Sherridon, are widespread in the area.

Further to the north, near MacBen Lake on the boundary of the map-area, the Canadian Nickel Company Limited explored a body of mafic and ultramafic rocks in 1947. Following a drilling program the claims were allowed to lapse. Widely scattered amounts of nickeliferous pyrrhotite were reported.

In considering the area as a whole it appears that the enconomic possibilities are not confined to nickel-copper-cobalt ore. The search still continues for zinc-copper and copper deposits outside the mafic intrusive rocks. Occurrences of chalcopyrite are very common in almost all the greenstone belts of the area, though up to the present only one deposit, that at Fox Lake, is of economic importance. Most of the area also merits investigation for gold deposits.

Sherritt Gordon Mines Limited (1)[1]

The nickel-copper orebodies occur entirely within the "Lynn Lake gabbro" which consists of a closely related group of mafic rocks intruding Wasekwan volcanic and sedimentary rocks as irregular stock- or plug-like bodies. The components of the "Lynn Lake gabbro" are gabbro, diorite, amphibolite, quartz hornblende diorite, and some norite and peridotite.

The "A" orebody is the main deposit of a group of seven, designated from "A" to "G," which in most respects are all similar. This group of orebodies forms the "A" mine.

The "A" orebody is irregular in outline, but has approximately equal length and breadth. In vertical section, the deposit consists of several blocks of ore between thrust faults which dip steeply westward. The grade of the ore appears to be directly proportional to the intensity of brecciation, with the highest grade material originating at or near one of the faults, and extending toward the next fault. The ore grades laterally outward to an arbitrary but recognizable limit in rock which contains disseminated sulphides. The host rock is mostly amphibolite with some diorite. The orebody is a disseminated sulphide deposit, which in the relative order of abundance consist of pyrrhotite, pentlandite, chalcopyrite, and pyrite, with cobalt, zinc, and gold in minor amounts. When production began in 1953 it contained 4,975,000 tons of ore averaging 1.22 per cent nickel and 0.64 per cent copper.

The "El" orebody is distinctive because it occurs within the core of a very small plug, about 350 feet in diameter. As in the "A" mine, the host rock is mostly amphibolite, with some diorite, peridotite, and quartz-hornblende diorite.

The ore is of two types: (a) Massive sulphides with a variable number of unmineralized rock remnants. (b) Mineralized amphibolite and diorite adjacent to, but separate from, the massive body.

The grade of the massive sulphide of the "El" mine is the highest in any of the orebodies. When production began the massive ore was estimated to contain 5.5 per cent nickel, 1.5 per cent copper, and 0.20 per cent cobalt. The disseminated ore of the mine was estimated at 0.75 per cent nickel, and 0.40 per cent copper, a little less than the average of all the orebodies. The combined reserves at the "El" orebody were 2,445,000 tons averaging 2.50 per cent nickel and 0.93 per cent copper.

Characteristic of the ore of this mine are the residuals of unmineralized rock which form inclusions in the massive sulphides. They are usually well-rounded, and are from ½ inch to several feet across. Exceptionally high cobalt content is reported from the haloes of pyrite and chalcopyrite which, in some places, surround the inclusions. Where the "remnants" are especially numerous the sulphides are, in effect, veinlets between the remnants filling the fractures of the brecciated rock.

The prime structural control of the ore, as at the "A" mine, is apparently a shear zone which strikes northwest and dips north at 50 degrees. This can be

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[1] Numbers refer to localities on Figure 30.

followed through the mine to the bottom of the present workings, but seems to have negligible displacement. The massive ore is adjacent to this fault, where it cuts the core of the plug, and occurs in both the hanging- and foot-wall. The lower-grade disseminated ore is also associated with the same fault, but forms a separate body.

Origin of the Nickel-Copper Ore

Conflicting opinions on the mode of origin of the ore at Lynn Lake have been expressed by several writers (Allan, 1948; Hunter, 1950; Ruttan, 1955; Milligan, 1960; Emslie and Moore, 1961). The arguments may be divided into two main hypothesis: (1) The ore was emplaced after the consolidation of the intrusion from hydrothermal solutions originating either from a mafic of felsic magma. (2) The ore segregated, as a sulphide liquid, from a mafic magma at some stage during the crystallization of the Lynn Lake gabbro.

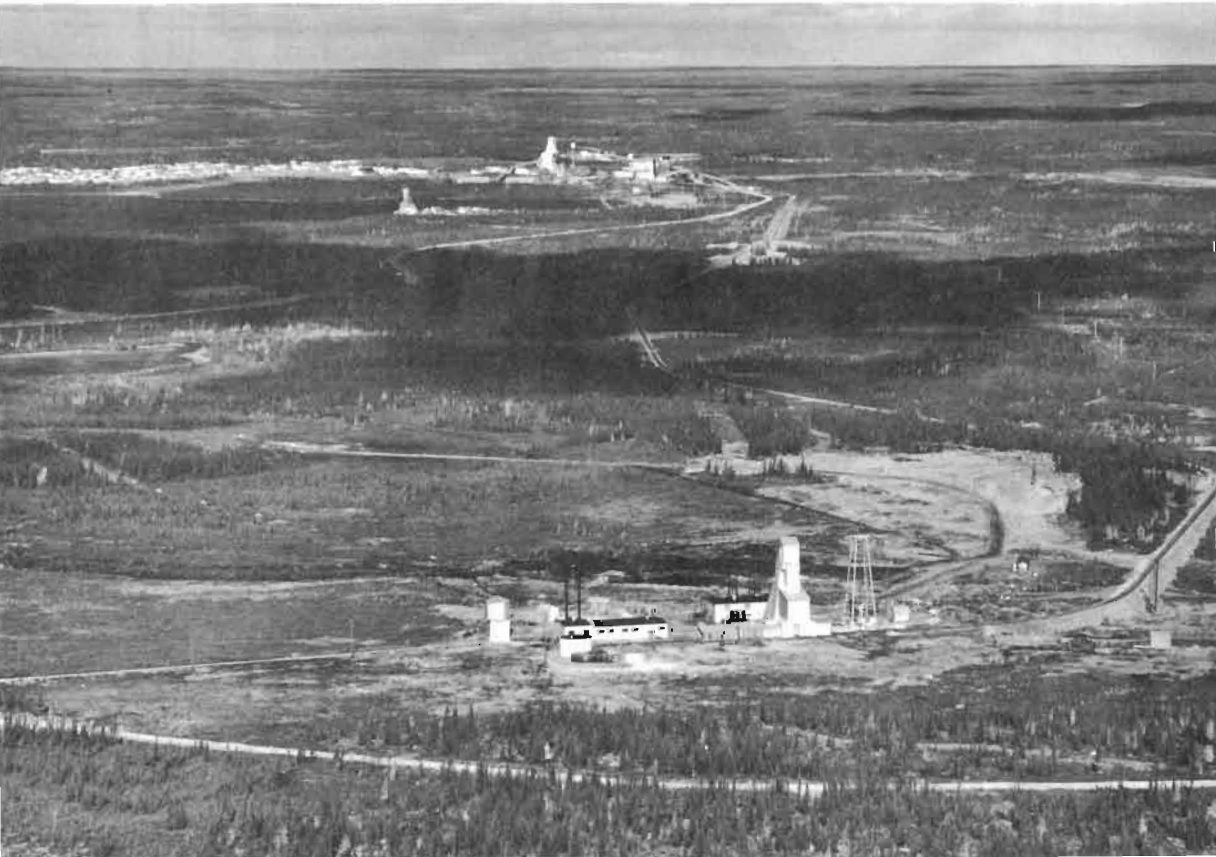
Allan (1948) concluded that the ores were high temperature hydrothermal deposits. His work was restricted to a petrographic examination of the intrusive rocks and a study of polished sections of ore from drill core.

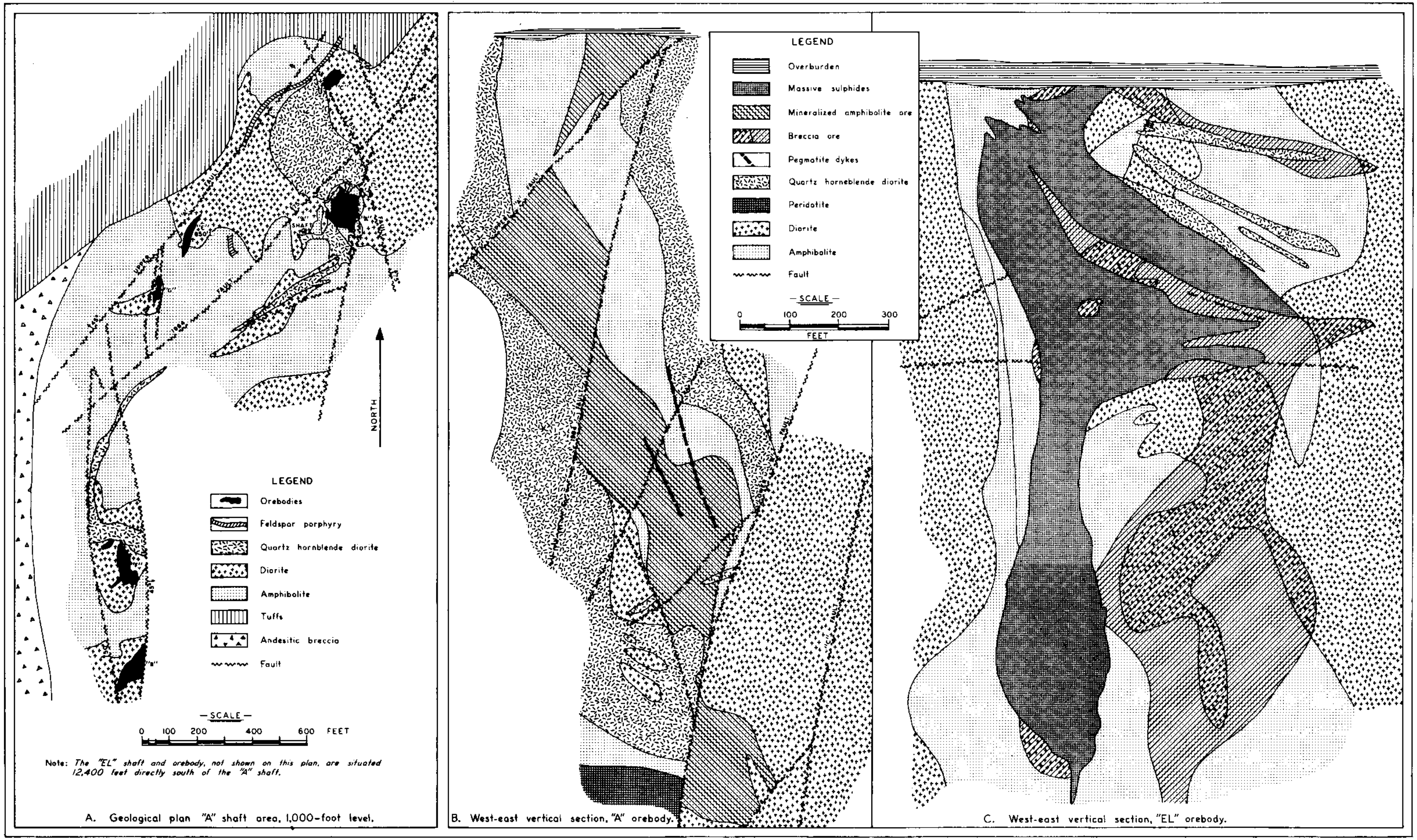
Hunter (1950) recognized that the Lynn Lake gabbro had been differentiated and concluded that the ore had segregated from the mafic magma and collected in the more mafic, western part of the intrusion.

Ruttan (1955) believed that the ore deposits were formed by replacement from solutions, the actual source of metals being either the granite or the mafic intrusive rocks. He favoured the granite as a source, and assumed that the nickel, copper cobalt, zinc and gold minerals of the Lynn Lake area have originated from the same

Nickel mines at Lynn Lake. In the foreground is the "El" mine. In the background are the "A" mine and townsite.

PLATE XII





Note: *The "EL" shaft and orebody, not shown on this plan, are situated 12,400 feet directly south of the "A" shaft.*

A. Geological plan "A" shaft area, 1,000-foot level.

B. West-east vertical section, "A" orebody.

C. West-east vertical section, "EL" orebody.

FIGURE 31

Plan and Sections, Lynn Lake Orebodies source. Copper, zinc and gold, with traces of nickel would be deposited in the sediments and volcanic rocks under acid conditions, and nickel, copper, and cobalt (with traces of zinc and gold) within the mafic plugs under the neutral to alkaline conditions.

Milligan (1960) concluded from the available information that magmatic segregation is an untenable hypothesis because the sulphides are present in quartz fillings of late faults and were, therefore, mobile after the consolidation of the gabbro mass and because rocks such as minor granitic bodies and younger black dykes which cut the gabbro are also mineralized. He concluded that the period of mineralization must long post-date the gabbro. Should the late diorite and quartz-hornblende dykes be post-Sickle in age, as it is at least possible, then gabbro and sulphides are separated by a complete orogeny.

Following this trend of thought, Milligan apparently did not take into account the possibility of partial remobilization or reworking of early-formed sulphides.

Emslie and Moore (1961, p. 71) state that evidence supporting a hydrothermal origin of the ore deposits is notably absent and that conversely there is a preponderance of evidence pointing to the development of the nickel-copper deposits by crystallization from an immiscible sulphide liquid within the gabbro. They summarize the main points supporting this theory of origin as:

"(1) The orebodies are entirely confined within a differentiated mafic intrusive mass.
(2) All known orebodies occur in the lower part of the gabbroic complex.
(3) The sulphide minerals crystallized under high-temperature anhydrous conditions.
(4) Physical-chemical considerations of the composition and the liquid line of descent of the magma, partial oxygen pressure, and cooling history all favor development of an immiscible sulphide liquid.
(5) The ore mineral assemblage is identical with those occurring in other nickel-copper sulphide deposits that have been interpreted as magmatic segregates.
(6) The composition of the sulphide ores suggest crystallization initially as a pyrrhotite solid solution which subsequently exsolved pentlandite and chalcopyrite. A later chalcopyrite may have formed from copper-rich residual sulphide liquids."

Their arguments are supported by a study of trace element trends in the gabbroic rocks and by comparison with similar studies of other differentiated mafic intrusions.

Fox Lake Deposit (2)

In 1961 Sherritt Gordon Mines Limited announced the discovery of an important copper-zinc deposit some 28 miles southwest of Lynn Lake. The discovery was credited to airborne geophysical prospecting. A total of 26,292 feet of diamond drilling in 41 holes was completed in outlining the deposit to a depth of 1,000 feet. The deposit is located in greenstones and interbanded sedimentary rocks approximately 1 mile west of the Snake Lake gabbro. It consists of a lenticular mass of pyrite with minor amounts of chalcopyrite and sphalerite, about 1,500 feet in length with an average width of about 80 feet, dipping 70° to the north. It maintains its size and grade to the depth drilled. In the part of the deposit drilled there appears to be a concentration of zinc values on the west end and a concentration of copper values on the foot-wall side to the west of the zinc concentration. The tonnage and average grades indicated in the part of the deposit drilled are as follows:

	Tons	% Copper	% Zinc
Whole deposit to depth drilled	12,000,000	1.01	2.39
Copper zone to depth drilled	2,700,000	2.71	1.77
Zinc zone to depth drilled	1,900,000	0.45	4.30

Milling tests carried out on all three of the above types indicate that high recoveries and separation of the copper and zinc can be made, with copper concentration running better than 25 per cent copper and zinc concentrates running 50 per cent zinc. The copper concentrates carry from 0.12 to 0.14 ounces of gold and 3.0 to 3.5 ounces of silver per ton.

Other copper-zinc occurrences are present in the general vicinity of the Fox Lake deposit and these merit further investigation.

Tow Lake Nickel Group (3)

Genrico Nickel Mines Limited, a subsidiary of Anglo-Barrington Mines Limited hold a group of 31 unsurveyed claims between Tow Lake and Barrington River. The claims cover a partially differentiated gabbro intrusion. Numerous geophysical surveys performed on this intrusion between 1947 and 1958 included magnetic, self-potential, electro-magnetic, and gravity surveys. A limited number of conductors and a large number of magnetic maxima have been outlined and drilling programs to test these, were conducted between 1953 and 1957. The most important were thirteen holes, with a total length of 7,479 feet, drilled between July and November, 1955; most core contained sizeable lengths of sparsely disseminated pyrite and pyrrhotite in gabbro displaying various degrees of alteration. In only one hole, 12 inches of massive sulphides were found. Assays of core from this same hole also showed 3.38 per cent copper for seven feet at 275 feet; 0.27 per cent copper and 0.25 per cent nickel for 16 inches at 343 feet. Bands rich in magnetite were intersected in many holes and explain most of the magnetic maxima.

Hunter discussed the petrology of the gabbro at considerable length. He recognized three zones in the gabbro, and concluded that they resulted from slight differentiation while the gabbro was horizontal, and that the mass had later been rotated to its present vertical attitude. He further concluded that it had lacked an appreciable sulphur content at any stage and that this together with its low magnesium content, made it an unlikely host rock for a nickel sulphide orebody.

However, structural indications led Genrico Nickel Mines Limited to take a more optimistic view. The company reported that occurrences of sulphides were located at the intersection of a number of shears and fracture zones. This prompted re-examination of the surface geology in 1958 and some additional drilling.

Smoke Group (4)

Lasthope Lake Gold Mines Limited, a subsidiary of Sherritt Gordon Mines Limited explored a gold occurrence discovered in 1934 northwest of Sickle Lake.

Some shallow test pits were opened in the early development work and in 1939 Sherritt Gordon drilled 59 holes with a total length of 10,260 feet. To a depth of

150 feet, this drilling indicated about 140,000 tons containing 0.23 ounces of gold per ton. The vein, known as the Madole vein, outcrops for 735 feet and was followed by drilling for an additional 1,000 feet. It strikes northwest, and fills a fracture in thinly bedded impure quartzite. It contains sparse pyrite, chalcopyrite, galena, and sphalerite, but no visible gold.

K.Z. and Gal Groups (5)

These groups were located at the south end of Snake Lake (south of Dunphy Lakes) and were underlain by greywacke and other sediments and part of a gabbro body. Galena was discovered on the south bank of the creek which drains Snake Lake. Trenching at the contact between quartz-biotite-feldspar gneiss and schistose gabbro shows pyrrhotite, pyrite, massive galena, and disseminated chalcopyrite. The width of the mineralized zone varies from 1 inch to 12 inches. Some vein quartz is present. A sample made up of fragments from the pits contained 3.06 per cent lead, 0.73 per cent copper, and 0.12 ounces of gold and 10.0 ounces of silver per ton. A grab sample of the vein quartz contained 0.61 ounces gold and 31.1 ounces of silver per ton.

Caimito Group (6)

This group covers the largest island on the south shore of Laurie Lake and was staked in 1939. The prospect consists of dark gold-bearing quartz veins in a silicified amphibolite on the east shore of the island. A chip sample from a pit contained 0.03 ounces of gold per ton across 4 feet 7 inches.

In 1953 most of the area of the group was flooded when the Eager Lake dam was erected. Prior to the flooding, Sherritt Gordon drilled several holes on behalf of Caimito Gold Mines Limited. They were drilled under the quartz showings and also to the northwest. One of the holes contained a 3.3-foot section which averaged 1.5 per cent copper.

In the course of routine testing of the cores, a spectrographic analysis indicated 0.02 per cent gallium.

Giant Group (7)

A gold prospect in the southeast bay of Cartwright Lake was discovered in 1934 in a sheared "porphyry" dyke. Most of the trenching was done on the Giant claims and in 1952 the prospect was diamond drilled. According to G. S. C., Paper 45-14, the prospect was sampled by Professor A. M. Bateman in 1935. He obtained gold assays of $10.60 across 20 feet (gold at $20.67 per ounce?). Sampling by the owners at about that time, is reported to have shown $11.90 across a width of 30 feet. The intrusion of porphyry may be post-Sickle in age. Further details are lacking.

D.H. and F.L. Groups (8)

The D.H. group of 90 claims and fractions and the F.L. group of 54 claims were staked on behalf of God's Lake Gold Mines Limited in 1946. The F.L. group adjoins the Elb group of Sherritt Gordon Mines Limited to the west.

A magnetometer survey of the two groups was carried out in 1947. On the F.L. group the majority of the anomalous areas are on the west side of Wheatcroft Lake, less than 2 miles from the "A" and "El" mines at Lynn Lake.

A major drilling program was carried out on the F.L. 15 claim, with thirty-one vertical holes totalling 8,129 feet drilled prior to 1952. Sulphides of ore-grade were found in all but two holes. Detailed drill logs are not available, but the summaries show the sulphides to be present in a variety of rock types. These include "basic intrusive," "basic flows and sediments," "fragmentals," and "sediments." This drilling program indicated a mass of mineralized rocks amounting to at least 500,000 tons with an average grade of 0.9 per cent copper and 2.2 per cent zinc. The mineralized zone slopes southwest at about 52 degrees and its thickness may also increase in that direction.

In 1953 and 1954 an electro-magnetic survey was carried out on the property and sixteen more holes were recommended to test the anomalies. Hole 22 on the F.L. 15 claim disclosed 34 feet averaging 1.61 per cent copper and 1.57 per cent zinc. The highest grade was in hole 20 where 14.5 feet averaged 3.31 per cent copper and 0.76 per cent zinc.

Other anomalies on the property were also tested by diamond drilling and in some of them sulphides of ore-grade were encountered.

Faust, Dave, C. L., Ace Groups (9)

These groups were staked in 1939 and 1940 on behalf of Sherritt Gordon Mines Limited and Central Manitoba Mines Limited to explore the area for gold after quartz veins were discovered near McVeigh Lake and Lasthope Lake.

Gold-bearing float along McVeigh Lake was traced to the *Johnson Shear.* Trenching exposed this shear at intervals along practically the entire north side of Foster Lake and gold was found at a number of places along a length of 4,500 feet. Further to the west, on the northeast shore of Franklin Lake gold was found in a structure which is believed to be the extension of the *Johnson Shear.* There, the shear is 40 feet wide and contains quartz stringers with sparse sulphides, and associated chlorite and carbonate. Half-inch quartz-carbonate veinlets, which cross the main shear, carry coarse gold and a little galena and pyrite. Forty-five holes were drilled to test this zone in 1940 and more were drilled in 1941.

Gold also occurs east of Wasekwan Lake on the C.I. claims where a network of quartz stringers fills the fractures of an albitite dyke. Surface sampling indicated gold in commercial grade for a length of 430 feet, with an average width of 20 feet. However, diamond drilling indicated only low values in the underlying fresh rock.

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Map 343A — Granville Lake Sheet (West Half).
Map 344A — Granville Lake Sheet (East Half).

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REINDEER — BIG SAND — NORTHERN INDIAN LAKES AREA

This almost uninhabited area comprises 15,468 square miles bounded by latitudes 57° 00′ and 58° 00′ and longitudes 96° 00′ and 102° 00′. The only settlement is Brochet, situated on the north shore of Reindeer Lake. The northwestern part of the area is drained by the South Seal River, and the central part by the Churchill River. Cochrane and Paskwachi rivers drain the west part of the area into Reindeer Lake. The area is accessible by canoes from Pukatawagan on the Lynn Lake line of the Canadian National Railways. It can be reached conveniently by aircraft from Lynn Lake, Ilford, Thompson and Churchill. Winter roads reach the southern part of the area from Lynn Lake and Ilford. Drift cover is extensive especially in the eastern half where more than 90 per cent of the surface is covered by overburden. Glacial striae and uniformly parallel drift ridges indicate that the ice advance was from the north and northeast except near the eastern border where it was from the east. Many large eskers occur in the northwest part of the area; kames and other glacial and fluvio-glacial deposits are scattered throughout. Alcock visited the area in 1920 and examined high ridges of gravel and sand in the vicinity of Chipewyan Lake. He described this topographic feature as the terminal moraine of the Seal-Churchill divide. As the result of glacial molding the relief is low, rarely exceeding 200 feet, but some bedrock hills in the northwest corner of the area rise to about 400 feet.

GEOLOGY

The area is largely underlain by gneissic and massive granitic rocks and belts of meta-volcanic and meta-sedimentary rocks which are neither extensive nor are widely distributed.

Meta-volcanic rocks (1) occur as a narrow belt west of Southern Indian Lake and underlie a larger area south of Partridge Breast Lake. A few outcrops of meta-volcanic rocks occur on Gauer and North Knife lakes. The rocks are essentially hornblende-biotite-plagioclase-quartz gneisses and schists that contain some garnet, muscovite, sillimanite, potash-feldspar and, locally, minor tourmaline, sphene, apatite, zircon, epidote, chlorite, carbonates, magnetite, and pyrite. At Southern Indian Lake the meta-volcanic rocks are characterized by abundant sulphides and are cut by dykes of muscovite pegmatite and a sill of serpentinized dunite. A band of meta-volcanic rocks, approximately 4,000 feet wide, interfingering with meta-sedimentary rocks, extends along the north shore of Barrington Lake near the southern boundary of the map-area. Hornblende gneisses possibly of meta-volcanic origin occur at Paskwachi Bay on the southeast shore of Reindeer Lake.

Meta-sedimentary rocks (2) occur as narrow bands in four localities, on Southern Indian Lake and Denison Lake, and in scattered localities on Vanderkerckhove, Goldsand, and Wells lakes, and 8 miles west of Melvin Lake. The rocks are grey, fine-grained, distinctly banded micaceous schists and gneisses with a few bands of white, garnetiferous quartzite. A remnant band of meta-conglomerate approximately 100 feet thick occurs in hornblende syenite on Southern Indian Lake near the southern boundary of the map-area.

Large belts of mixed gneisses (3) consisting predominantly of paragneiss derived from meta-sedimentary and meta-volcanic rocks and containing between 25 and 75 per cent granite gneiss and granite (4) have been outlined in the central and western parts of the map-area. In the eastern half of the area, however, these rocks are less abundant and contain a greater admixture of introduced material; at places they could be classified as migmatite, veined gneiss, or schlieren granite. At places where inclusions of older rocks are extremely abundant, the term hybrid gneiss is applicable. The rocks are usually light grey in colour, strongly gneissic and garnetiferous. Probably the most common assemblage is hornblende-biotite-feldspar-quartz.

Map-unit (4) includes a large variety of granitic rocks which comprise granite gneiss, massive and slightly gneissoid granite, granodiorite, quartz monzonite, syenite, and diorite.

The granite gneiss which occurs extensively in the western part of the area is extremely variable in composition, colour, and grain size, and commonly contains

FIGURE 32

Geology of Reindeer — Big Sand — Northern Indian Lakes Area remnants of older rocks. The other granitic rocks are more massive and less contaminated. The granitic rocks are fine to coarse-grained and at places may be porphyritic.

Along Seal River the rock is a pink, massive, medium-to-coarse-grained biotite granite which is locally syenitic. A large batholith of massive, coarse-grained hornblende syenite occurs on the southern shore of Southern Indian Lake. Massive granodiorite outcrops in the northern bays of the lake and on many islands in its center.

In the eastern half of the map-area a medium-grained, generally massive, biotite quartz monzonite surrounds Wood Lake. North of that lake the most abundant rock is a pink medium-grained, predominantly massive, locally porphyritic biotite granite. The same type of rock also outcrops on parts of the south shore of Northern Indian Lake where it shows pronounced lineation.

Large masses of flesh-pink to grey porphyritic, quartz-rich biotite granite and granodiorite occur near Reindeer Lake. A white to flesh-pink leuco-granite (alaskite) which may be the youngest intrusive pluton in the area, outcrops on Paskwachi Bay and on Vanderkerckhove Lake.

Pegmatite and aplite masses, dykes, and sills are common almost everywhere. The rocks are rich in potash, normally pink, massive, and at places display graphic intergrowths of quartz and feldspar. On islands in the central part of Southern Indian Lake the pegmatite contains abundant large crystals of magnetite and black tourmaline.

Mafic intrusive rocks are not abundant in the area. The largest is a body of gabbro 2 miles in width known as the MacBen Lake plug. This gabbro is cut by pyroxenite dykes and has been explored for nickeliferous pyrrhotite. A small differentiated stock of gabbro, diorite, and minor anorthosite occupies the islands and part of the shore of Melvin Lake. Sheared and slightly pyritized, dark grey to greenish diorite outcrops at the north end of Barrington Lake and on Brochet Bay on Reindeer Lake. Other small bodies of mafic rock, too small to be shown at the scale at which mapping has been done have been grouped with the granitic rocks.

Little is known about the structure of the area. In the granitic and highly granitized rocks the gneissic banding generally trends eastward and southeastward and dips are invariably steep. Locally, prominent variations in trends of gneissosity, as at Denison and Partridge Breast lakes, indicate complex folding. Kretz (1958) noted that in general, in the Northern Indian Lake area, lithologic boundaries appear to pass indiscriminately across planar and linear structures in the rocks. Gadd (1948) made similar observations in connection with the Brochet map-area. Structural trends on his map show complex folding, especially in the meta-sedimentary rocks near the southern boundary of the map-area. Few faults may be outlined with certainty in the area; assumed faults are shown on the maps mainly on evidence of scarps, prominent linear features, and pronounced compositional lineation or shearing.

MINERAL OCCURRENCES

Because of the highly granitic terrain and difficulty of access only a few prospectors have sporadically visited the area. Several small to fairly large mineralized zones, usually with pyrrhotite and pyrite, occur within the area. Low values or traces of nickel and copper were obtained from some of these occurrences. All were described in detail by Quinn (1956) and are shown as S on Figure 32.

In 1947 the Canadian Nickel Company Limited explored a body of mafic and ultramafic rocks near MacBen Lake in the southwest corner of the map-area. A plug-like body of gabbro up to 2 miles in width is cut by dykes of pyroxenite up to 8 feet or more wide. Both the gabbro and the pyroxenite are cut by a few dykes of pink, massive, coarse-grained biotite granite and pegmatite as much as 200 feet wide. A few grains of chalcopyrite, nickeliferous pyrrhotite, pyrite, and magnetite are scattered throughout much of the plug. The pyroxenite host rock may contain up to 5 per cent sulphides. Assay of a selected surface sample returned 0.10 per cent nickel and 0.07 per cent copper.

This occurrence was covered by 69 claims of the K.B. and Rat groups on which The Canadian Nickel Company Limited did approximately 6,000 feet of diamond drilling. The claims were allowed to lapse in 1949. Logs and drill hole location maps are available at the Mines Branch offices. A few assays of sections of core show low nickel values.

Several gossan zones in meta-volcanic rocks occur on the shore and islands in a bay on the west side of Southern Indian Lake. Zones in schistose amphibolite, containing up to 20 per cent disseminated pyrrhotite and pyrite, and up to 20 feet wide and 700 feet long, trend in a northeasterly direction. These sulphides, however, appear to be barren; an assay showed a trace of gold, less than 0.02 per cent each of copper, nickel, and cobalt.

A few scattered grains of pyrrhotite were observed in the gabbro and confined to an outcrop of anorthosite within this body on the north shore of Hook Island on Melvin Lake. A small amount of nickel was present in the sulphides.

Drilling for nickel and copper was also performed recently in the vicinity of Goldsand Lake.

A small gossan zone has been observed on the west arm of Vandekerckhove Lake, where pyrite is disseminated in a small outcrop of quartz-sericite schist.

Pegmatites of the area contain traces of radioactive minerals, black tourmaline and, locally, substantial amounts of muscovite.

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LAC BROCHET — SEAL RIVER AREA

The Lac Brochet - Seal River area lies between latitudes 58° 00′ and 60° 00′ and longitudes 95° 00′ and 102° 00′.

The Seal, Wolverine, Caribou, South Knife, and North Knife are major rivers draining and giving access to the area. The Seal River rises east of the north end of Reindeer Lake and flows northeast for approximately 250 miles to enter Hudson Bay about 30 miles north of Churchill. Travel upstream is arduous, particularly on the Seal River which rises 840 feet between Hudson Bay and Shethanei Lake. Travelling downstream, most of the rapids can be lined or waded. In the northern part of the area a winter road has been broken from Churchill to Nueltin Lake via Caribou and Little Duck lakes. The most convenient means of access, however, is by chartered aircraft available at Churchill, Ilford, and Lynn Lake.

The area is extensively covered by Pleistocene deposits of glacial drift. Low broad hills and drumlinoid ridges of till with intervening swamps and lakes are the most prominent regional features.

Superimposed on the drift are eskers and kames composed of gravel and sand. In addition to these deposits of glacial origin, a conglomerate of interglacial age, overlain by till, occurs on the Seal River north of Great Island. In general the drift cover of the area is extensive; at many places it is up to 75 feet thick and only the main rivers have cut channels through the overburden to bedrock. There is evidence that, at places, the Seal River follows a pre-glacial channel; ten miles west of Great Island the river passes for more than a mile through a gorge, approximately 60 feet deep, in gneissic granite. It is estimated that such a channel could not have been cut in post-glacial times.

Recent sand dunes are common north of Knife Lake and their forms show that the prevailing winds are from the northeast.

The land area is free of snow cover by late May; lakes, however, are usually frozen until the end of June. In the northern half of the area frozen ground was found at a depth of from 12 to 18 inches throughout the entire field season of 1952. Patterned (polygonal) ground occurs in peat swamps in the northern part of the area.

Most of the drift hills probably have bedrock cores covered by a layer of drift molded on them; bedrock is much more abundantly exposed in the vicinity of sand, gravel, and boulder ridges, particularly the ridges with a high percentage of clean washed sand; at places frost-heaved blocks of rocks brought to the surface give evidence of the nature of bedrock; outcrops on shores of lakes may be exposed by the action of lake ice which shoved the drift cover into five- to twenty-foot ridges bordering the widest parts of the lakes; bedrock commonly is exposed consistently along the courses of main rivers and in a few places along the more important tributaries.

In 1769 and again in 1770, Samuel Hearne, the first white man to travel on the Seal River, spent the winter on Shethanei Lake. J. B. Tyrrell was the first to record geological information on rocks along the west coast of Hudson Bay in 1893. The first geological survey of the area was a reconnaissance of the Seal River by A. W. Johnston in 1935. A geological reconnaissance survey along the Wolverine and Caribou Rivers was performed by Russell in 1952. In 1955 G. C. Milligan visited the Great Island and Shethanei Lake area and in 1957 F. C. Taylor mapped the Shethanei Lake area. In 1960 K. L. Currie mapped the Whiskey Jack Lake area to the west, leaving an unmapped section between longitudes 99° 00′ and 100° 00′. A group of claims was staked on Great Island in 1925. Since 1952 a few prospectors have been active in the area. More than 2/3 of this extensive area is already covered by 102 aeromagnetic maps at a scale of 1 inch to mile, published by the Geological Survey of Canada. Aerial survey of the rest of the area is completed.

GENERAL GEOLOGY

The area lies entirely within the Churchill province of the Canadian Shield. It is underlain chiefly by massive granites and gneisses and discontinuous belts of sedimentary rocks with lesser amounts of volcanic rocks.

In the *Shethanei-Great Island area*, rocks of two distinct ages are present: the older consist of quartz-rich sediments, some volcanic rocks, granite, and gneisses derived chiefly from sedimentary rocks; the younger, the Great Island group, consist solely of sedimentary rocks, chiefly quartz-rich, but also including shale and carbonate. Rocks of both ages were involved in orogenic deformation.

Grey to dark grey impure quartzite is the predominant sediment of the older series with lesser amounts of greywacke, sandstone, conglomerate, siltstone, argillite, and arkose. Volcanic rocks are rare; basalt and andesite ranging from massive flows to coarse flow breccia are the commonest types. Rhyolite, rhyolite breccia, and pillowed basalt are very minor. Many of the sedimentary rocks are metamorphosed to paragneisses: biotite-quartz gneiss, staurolite schist, garnet-biotite-quartz gneiss, mica schist, cordierite-gneiss, and biotite-calcite rock.

The granitic rocks are divided into two types, gneissic and massive. Both types are pink to grey, rarely white, medium to coarse-grained, rarely graphic, locally porphyritic, and commonly contain biotite or hornblende. Narrow pegmatite dykes are common in both types. West of Great Island dykes, sills, and stocks of quartz porphyry occur. Two stocks of quartz gabbro occur in the area.

The name, Great Island group, was given by Taylor (1958) to a well-exposed group of rocks in the vicinity of Great Island. Lithologically this group is characterized by shale, slate, quartzite, arkose, dolomite, minor greywacke and conglomerate. Contacts between the Great Island group and the other rocks are not exposed but structural, lithological, and geophysical evidence show that this group unconformably overlies the older sedimentary volcanic, and granitic rocks.

The area underlain by rocks of the Great Island group is characterized by low magnetic intensity (G.S.C. Maps 630G and 631G) except in the southwest corner of the group where they are probably thin (dips 15 to 35 degrees) and permit the magnetic influence of the underlying rocks to show on the aeromagnetic maps.

At the western and eastern borders of the Great Island group, isomagnetic lines parallel the assumed position of the unconformity and locally changes in intensity are abrupt.

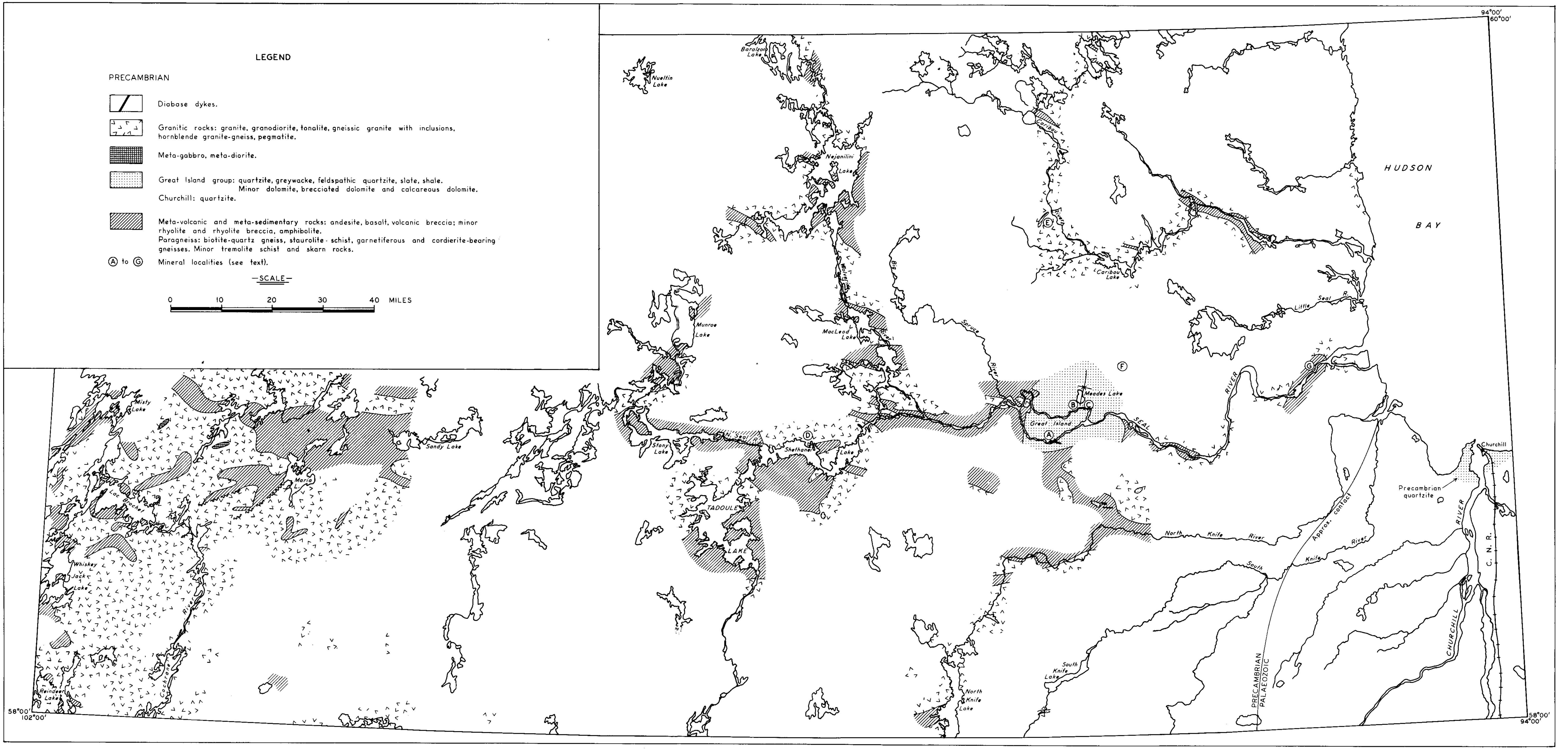

FIGURE 33

Geology of the Lac Brochet — Seal River Area

The youngest rocks are diabase dykes and an amphibolite, all occurring in the Great Island group. Other amphibolites of the area may be older than the Great Island group.

The structure of the older rocks of the area is complex and practically unknown. The main trend of the rocks is eastward. Bedding plane structures suggest complex and tight folding in many parts of the area.

The west part of Shethanei Lake probably occupies a syncline, but this interpretation is based on scant geological data. The Great Island group has been extensively folded and three steeply plunging synclines are distinguishable. The most prominent surrounds Meades Lake to the south and plunges northward at approximately 80 degrees. Eight miles farther north it terminates in a less steeply southward-plunging syncline, thus forming a basin. Near the southeast limit of the Great Island group another syncline plunges southwest.

Fault are not prominent in the area. The only one mapped occurs in the southeast corner of the Great Island group of rocks.

In the *Wolverine and Caribou rivers area* the rocks are micaceous quartzite, mica schist and garnet-mica schist, a few thin bands in a granitic complex consisting of grey gneisses, older massive and gneissic grey granite, and younger pink granite.

Contacts between the grey gneiss, the grey granite, and sedimentary rocks are gradational.

The grey granite is a medium- to coarse-grained biotite granite. It contains numerous pegmatitic and aplitic phases. The grey gneiss is a hybrid rock which marks the transition from granite gneiss to sedimentary rocks. It contains numerous xenoliths of sedimentary origin. A younger porphyritic pink granite, with phenocrysts of orthoclase 1 to 1½ inches in length, occurs northeast of Caribou Lake. Of interest are pegmatitic phases which contain 5 to 10 per cent magnetite.

Rocks composed almost entirely of silica and containing a few grains of muscovite occur in the central part of Nejanilini Lake area. These rocks represent almost complete silicification of pre-existing sediments and grey gneiss.

The regional trend of gneissosity and bedding planes is eastward. The axial plane of a syncline is present near the north side of the sedimentary rocks at MacLeod Lake. There is a suggestion of a large drag-fold structure at Nejanilini Lake, indicating that the rocks were once part of the south limb of a regional syncline. No major faults or shear zones were found. Lineaments seen on aerial photographs were found to be a reflection of bedding planes, joint sets, and planar structures in the sedimentary, metamorphic and igneous rocks.

Little is known about the rocks at Tadoule, Stony and Munroe lakes (area west of longitude 98° 00′). Several belts of sediments trend eastward and consists chiefly of quartzite, greywacke, conglomerate, mica schist, and gneisses. Volcanic rocks are rare.

The "greenstone" belt near the outlet of Seal River consists predominantly of intermediate to mafic volcanic rocks. Pillowed lavas were observed north and south of the river. The rocks trend northeast and are sheared in many places.

In the Whiskey Jack Lake area, 60 per cent of the terrain is underlain by massive to faintly gneissic pink and grey granitic rocks (4); approximately 20 per cent by a complex of granitized rocks and gneisses rich in inclusions of older rocks

(2). The remaining 20 per cent consists of discontinuous, small belts of schists and gneisses derived from a predominantly sedimentary series with minor volcanic rocks (1). Bodies of meta-gabbro (3) are rare; the two intrusions shown on the map contain uralitized augite and seem to be sill-like elongate masses.

Currie (1960) divided the rocks derived from the original sedimentary series into four units: (1) biotite-plagioclase schist, typically containing plagioclase augen, minor biotite gneiss; (2) garnet-cordierite gneiss, plagioclase-cordierite gneiss, minor tremolite schist and skarn rocks; (3) biotite-quartz-feldspar gneisses, hornblende-quartz-feldspar gneisses, hybrid gneiss and migmatite, minor calcareous quartzite; and (4) quartzite, feldspathic quartzite, glassy quartzite. The quartz-poor rocks pass gradationally into quartz-rich gneisses. The widest belt lies between Maria and Sandy lakes, but the thickness there is greatly exaggerated by isoclinal folding. Pure, coarse, white quartzite occurs only in two localities south and south-east of Maria Lake and does not seem to be associated with the other meta-sedimentary rocks.

Structurally, the area is complex. Two directions of folding are indicated along North Seal River, where east-trending folds in the meta-sediments cut off northeast-trending folds in the granite. There are also two pronounced directions of faulting, N 80° W and N 45° E.

MINERAL OCCURRENCES

On the southwest corner of Great Island, at *locality A*, quartz veins are common in interbedded grey arenaceous shale and dark grey quartzite. Some vertical veins trend north and others are conformable with the bedding. Pyrite, and lesser amounts of arsenopyrite and marcasite are present. Values in antimony, copper, zinc, gold, and nickel are reported from the area.

At *locality B*, on the north side of Great Island, a banded amphibolite occurs in a red shale. In 1951 a pit was sunk in the amphibolite where it is cut by a quartz vein. Gold was reported from this locality. An amphibolite, containing low concentrations of disseminated magnetite, is exposed a mile west-northwest of locality B.

About 100 feet south of locality B a red shale grades into a bluish-black ironstone from which one sample assayed 47 per cent iron. Values of 3, 4 and 11 per cent zinc from some samples of the bluish-black material have been reported.

Near the southwest shore of Meades Lake fractured and possibly sheared quartz veins in a biotite greywacke contain a little pyrite and ankerite.

At *locality C*, several pits were dug in a white clay possibly of glaciolacustrine origin. Samples sent to the Mines Branch Analytical Laboratory had a high silica content; over 80 per cent of the material was minus 325 mesh.

At *locality D*, on the north side of Shethanei Lake, radio-active rocks are reported to occur.

At *locality E*, along the Caribou River, a persistent rusty weathering bed containing pyrrhotite and some chalcopyrite occurs in a narrow band of micaceous quartzites and mica-garnet schists.

At *locality F*, Jellicoe Mines Limited drilled a magnetic anomaly of 12,300 gammas (Geological Survey of Canada Map 550G). A drill hole encountered iron-formation from 319 to 514 feet. The 195-foot section of core was reported to average 28.5 per cent soluble iron. The hole was stopped in iron-formation. Zinc and silver values were reported from other holes drilled in this general locality.

At *locality G*, sheared greenstones are reported to contain disseminated sulphides.

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CHURCHILL

At Churchill, quartzite of questionable Proterozoic age occurs near the mouth of the Churchill River.

The rock is made up of about 70 per cent fairly well-rounded quartz grains and 30 per cent interstitial sericite. There are two main sizes of quartz grains, the larger from 0.5 mm. to 0.8 mm. in diameter and the smaller from 0.07 to 0.1 mm. The sericite is secondary and appears to have an arrangement parallel to the bedding. Well rounded pebbles of white quartzite, up to 3 inches in diameter, are scattered irregularly through the formation.

The rocks have southeast dips west of the river and persistent southwest dip of 70 to 80 degrees east of the river. If the structure is not overturned it seems that the lagoon and harbour represent a southward plunging syncline.

The Churchill quartzite is overlain by Ordovician sediments. Tyrrell reported a fissure in the quartzite filled with limestone mainly composed of corals which seemed to be in the same position in which they originally grew on the surface of the quartzite. The relationship between the quartzite and other Precambrian rocks of Manitoba is unknown.

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CHAPTER V

PALAEOZOIC, MESOZOIC, AND CENOZOIC GEOLOGY OF MANITOBA

INTRODUCTION

A thick sequence of sedimentary rocks overlies the Precambrian basement in southwestern Manitoba and in the Hudson Bay Lowland. The Post-Cambrian rocks have been divided on the basis of geologic age and differing lithology into the various formations listed in Table 11 and shown on figure 34.

In southwestern Manitoba the sedimentary rocks were deposited along the northeast border of the Williston Basin whose center lies in western North Dakota. Periods of subsidence accompanied by marine transgressions alternated with periods of emergence and erosion. The Palaeozoic deposits are predominantly limestones and dolomites formed largely by organic processes in widespread seas. The Mesozoic and Cenozoic rocks are predominantly shales and sands derived from a rising mountain belt far to the west and deposited in shallow seas and as alluvial plains. After a final depositional period in early Cenozoic time, the area was subjected to continuous erosion, including Pleistocene glaciation, which carved the present land surface.

In the Hudson Bay Lowland, limestone, dolomite, and sandstone of early Palaeozoic age overlie the Precambrian rocks; apart from Pleistocene glacial deposits and Recent alluvial and swamp deposits, rocks younger than Palaeozoic are not present in this area. It is possible that the depositional areas of southwestern and northeastern Manitoba were connected during submergent periods in early Palaeozoic time; any deposits that may have been present in the intervening area have since been eroded.

SOUTHWESTERN MANITOBA

PALAEOZOIC ERA

The Precambrian surface in southern Manitoba is covered by sandstone and shale of the Ordovician Winnipeg formation in all areas except the extreme southwestern corner of the province where a thin bed of glauconitic sandstone is present. The glauconitic sandstone is part of the Deadwood formation of Cambro-Ordovician age. The main section of Palaeozoic strata above the basal sands is composed of dolomite and limestone, with thin shale and evaporite beds, of Ordovician, Silurian, Devonian, and Mississippian ages. The deposition of these rocks was associated with the development of the Williston sedimentary basin which extended into southwestern Manitoba.

Ordovician

The rocks of Ordovician age have been divided in ascending order into the Winnipeg, Red River, Stony Mountain, and Stonewall formations. They form the bedrock surface through a broad arc of flat lake and marsh land along the western edge of the Precambrian Shield.

TABLE 11
GEOLOGIC FORMATIONS OF MANITOBA

Era	Period*	Formation	Member	Max. Thickness	Basic Lithology
CENOZOIC	Recent				Soil, alluvial deposits, sand dunes, bogs.
	Pleistocene			450	Glacial deposits
	0 to 60 Eocene to Pliocene	Not present in Manitoba			
	Palaeocene	Turtle Mountain		400	Shale, sandstone, lignite
		Boissevain		100	Sand and sandstone, greenish grey
MESOZOIC	Cretaceous 60 to 130	Riding Mountain	Odanah	1100	Hard grey siliceous shale
			Millwood		Greenish bentonitic shale
		Vermilion River	Pembina	80	Non-calc. shale, bentonite beds
			Boyne	150	Calcareous speckled shale
			Morden	200	Carbonaceous shale; septarian concretions
		Favel		125	Calc. speckled shale, limestone bands
		Ashville | Ashville Sand		375	Non-calc. silty shale; 0-90′ sand
		Swan River		300	Sand, sandstone, shale, clay
	Jurassic 130 to 155	Waskada		175	Varicoloured shale
		Melita		475	Varicoloured shale, calc. shale, limestone
		Reston		150	Argillaceous limestone and shale
		Amaranth	Upper: evaporite	175	Anhydrite, gypsum; shale, dolomite
			Lower: red beds	160	Dolomitic shale to siltstone, anhydritic
	Triassic	Not present in Manitoba			
PALAEOZOIC	Permian Pennsylvanian 155 to 240				
	Mississippian 240 to 265	Charles		115	Dolomite and anhydrite
		Mission Canyon		300	Limestone, dolomite, anhydrite; oil production
		Lodgepole	Whitewater Lake Virden Scallion Routledge	580	Limestone, argillaceous and cherty; shale; oil production
		Bakken		55	Black shale and siltstone
	Devonian 265 to 320	GROUP			
		Qu'Appelle	Lyleton	115	Red dolomitic shale
		Saskatchewan	Nisku	130	Fossiliferous limestone and dolomite
			Duperow	560	Shaly limestone, dolomite, anhydrite; cyclical
		Manitoba	Souris River 1st Red	300	Limestone, evaporite, shale; cyclical
			Dawson Bay 2nd Red	220	Limestone, anhydrite, basal red shale
		Elk Point	Prairie Evaporite	430	Halite, with potash, anhydrite, dolomite
			Winnipegosis	335	Dolomite, reef and inter-reef
			Elm Point	50	High calcium limestone
			Ashern	50	Dolomite and Shale, brick red
	Silurian 320 to 360	Interlake		400	Dolomite
	Ordovician 360 to 440	Stonewall		60	Dolomite
		Stony Mountain	Gunton	180	Dolomite, upper part shaly
			Penitentiary		Argillaceous dolomite
			Stony Mtn. Shale		Fossiliferous calc. shale; red, grey, green
		Red River	Upper dolomite	550	Dolomite, minor limestone
			Selkirk		Dolomitic limestone, mottled
			Cat Head		Dolomite, cherty
			Dog Head		Dolomitic limestone, mottled
		Winnipeg		225	Quartzose sand, sandstone; shale
	Cambrian 440 to 520	Deadwood		35	Glauconitic sandstone
		Major unconformity			

*Numerals refer to age in millions of years.

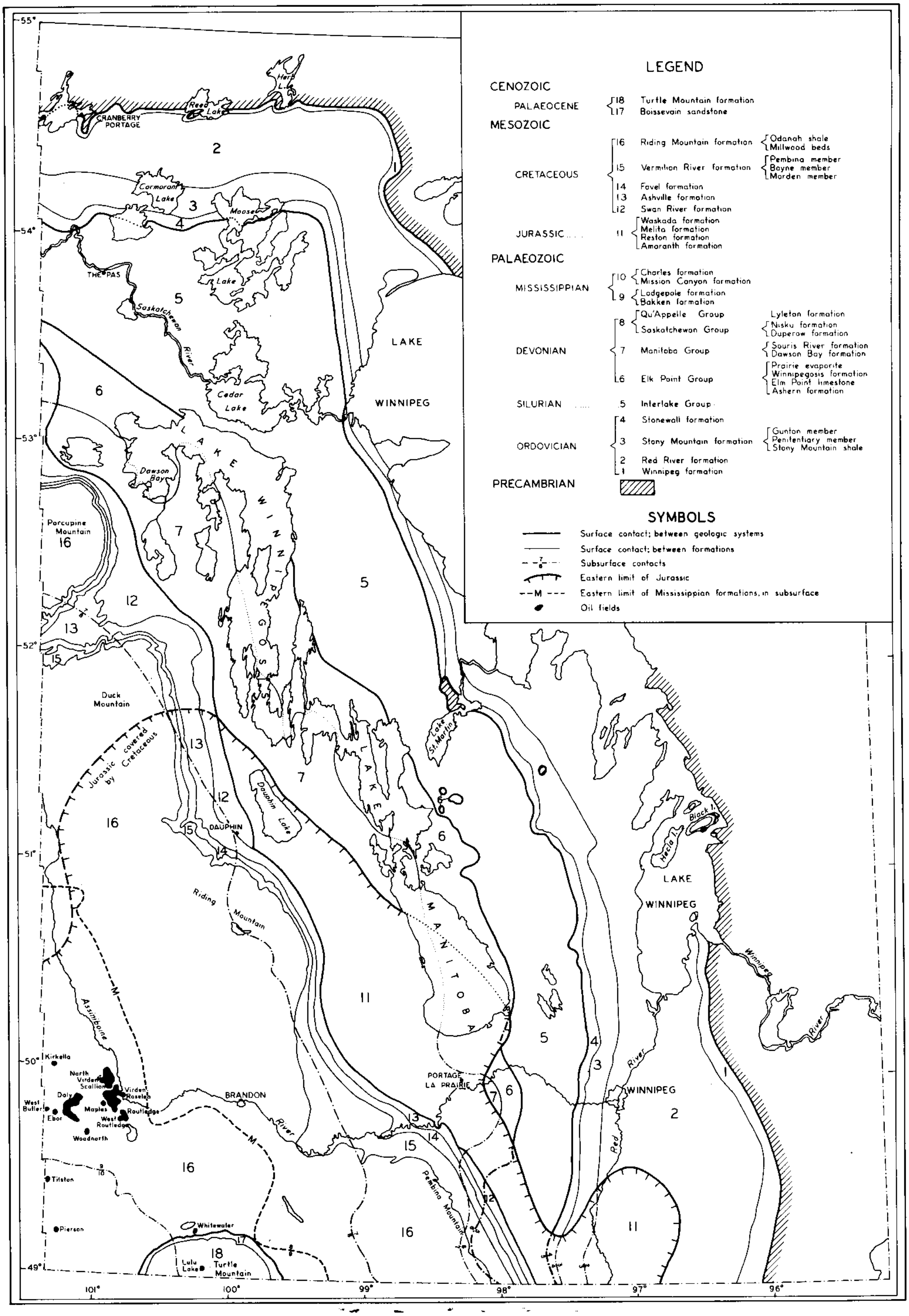


FIGURE 34 *Post-Cambrian Geology of Manitoba*

Winnipeg Formation

The Winnipeg formation is exposed on several islands in, and along the middle part of the west shore of, Lake Winnipeg. It consists of a 45-foot basal sandstone unit composed of poorly consolidated well-rounded and frosted quartzose sand, and an upper 35-foot unit of interbedded shale and sandstone. Between the two units is a thin zone containing pyrite nodules. Silica sand has been recovered from the outcrop on Black Island in Lake Winnipeg.

Several sandstone outcrops, none over 20 feet thick, occur along the Precambrian-Palaeozoic contact northwest of the north end of Lake Winnipeg. Because the seas in which the Winnipeg sediments were deposited advanced from the south and southwest, the sediments in the northern area are thinner and younger, and the shale content is markedly lower than in the southern part.

In the subsurface, the thickness of the formation increases from 80 feet at Lake Winnipeg to 225 feet in the southwest corner of the province where it occurs at a depth of over 7,000 feet. The two outcrop units cannot be differentiated in the subsurface because of widespread facies variations. For example, in the Carman area and to the east, the formation is 200 feet thick, of which the lower 100 feet is predominantly shale, and the upper 100 feet predominantly sand; this sequence is the reverse of that in the outcrop areas. The Carman sand body is of importance as a potential aquifer in the area east of Winnipeg.

Red River Formation

Outcrops of the predominantly carbonate Red River formation are scattered in the northern part of the Red River valley, but none show more than 50 feet of section and most, less than 20 feet. More extensive outcrops occur along and west of Lake Winnipeg, and along the Palaeozoic-Precambrian contact northwest of the north end of Lake Winnipeg where dolomites form an escarpment up to 100 feet high; outliers occur within the adjacent Shield area.

In southern Manitoba, where the formation is 480 feet thick, it has been divided into the Dog Head, Cat Head, Selkirk, and upper dolomite members, but relationships between the units and their correlation with the subsurface section are not known definitely.

The subsurface section increases in thickness to 550 feet along the south border of the province. The lower 100 to 150 feet is a mottled dolomitic limestone containing large cephalopod and gastropod fossils; the basal part contains silt and clay impurities. The overlying 200 to 250 feet are bioclastic limestones in which dolomitization proceeded to a more advanced stage, imparting a characteristic mottling. This section includes the Selkirk member from which the well-known Tyndall building stone is quarried. Some of the rocks in this section contain chert nodules, as well as large fossils. The degree of dolomitization of both these zones increases to the north.

The uppermost 100 to 150 feet is a fine-textured dolomite, some of which was formed possibly by primary chemical precipitation. Evaporitic conditions existed during part of upper Red River time and thin anhydrite beds occur in the subsurface of the Virden-Birtle area. Locally, a thin bed of limestone occurs at the top of the formation.

The sharp change from the clastic sediments of the Winnipeg formation to the Red River carbonates indicates steady subsidence of the sedimentary basin which continued until the onset of the evaporitic conditions in upper Red River time. An upwarping surge followed, which caused the influx of argillaceous material of the Stony Mountain formation.

Stony Mountain Formation

The Stony Mountain formation is well exposed in a quarry at Stony Mountain, and complete 140-foot sections have been intersected in nearby wells. The lower part of the formation, the Stony Mountain shale member, is 75 feet thick and consists of a greenish to purple-grey argillaceous limestone with interbedded calcareous shale. It is separated by a 15-foot bed of argillaceous dolomite, the Penitentiary member, from the uppermost 50-foot Gunton member composed essentially of dolomite. The upper part of the Gunton member is argillaceous, sandy, and reddish in colour.

The Stony Mountain formation thickens in the subsurface to 180 feet along the western boundary of the province. The shale content of the Stony Mountain shale member decreases northward from the outcrop area, and the dolomite content of the limestones increases. In western Manitoba, thin anhydrite beds indicate that evaporitic conditions existed in late Stony Mountain time.

The Penitentiary member is strikingly mottled and is used as a decorative building stone. The Gunton dolomite is used for crushed stone, and was once quarried for marble in the Interlake area.

Stonewall Formation

In its outcrop area the Stonewall formation has a thickness of 50 feet, of which the lower 25 feet is exposed in several quarries at Stonewall. The quarry section consists of yellowish brown or grey dolomite that is mottled in places; it is used mainly as a source of high-magnesia lime.

The subsurface section in southwestern Manitoba is almost uniform in thickness, ranging from 50 to 60 feet. The formation consists of mottled dolomitized limestone and dense dolomite with some thin shaly and sandy beds. In the southwest corner of the province only, a 10-foot bed of dense anhydrite occurs in the lower part of the section. The anhydrite marks the peak of another sedimentary cycle similar to those of Red River and Stony Mountain times. The top of the Stonewall formation is marked by an argillaceous zone.

The Stonewall formation, once thought to be of Silurian age, is now considered to be, at least in part, of Upper Ordovician age. Recent studies suggest that the Ordovician-Silurian boundary may lie within the formation (Brindle, 1960).

Silurian

Up to 400 feet of dolomite of Silurian age are present in Manitoba. The rocks are all included in the Interlake group; some geologists have attempted to divide them into units on the basis of periodic thin sandy or silty beds.

INTERLAKE GROUP

The top part of the Interlake group in southern Manitoba has been removed by pre-middle Devonian erosion and the thickness decreases from 400 feet in the southwestern corner of the province to zero at the erosion edge just west of Winnipeg. Outcrops are scattered through the Interlake region from Inwood to The Pas. White high magnesia lime is produced from Silurian dolomite quarried at Inwood.

The Interlake group is characterized by limited variation in lithology. The dolomite is generally extremely fine textured in the lower part and fine to medium grained and crystalline in the upper part. The rocks consist of reef deposits and associated inter-reef bioclastic material; numerous fossils occur within the group. Some of the dolomite was formed by primary deposition, and the greater part of the strata was deposited in shallow seas. Evidence of evaporitic conditions is shown by local thin anhydritic beds. Limestone occurs locally in the upper part of the formation.

The gypsum-anhydrite deposits at Gypsumville are over 100 feet thick and lie within the outcrop belt of Silurian rocks; however, no direct contacts between the gypsum and surrounding rocks have been found. The Precambrian ridge east of the gypsum deposit may have resulted in a local shallow basin in which evaporitic conditions existed, possibly in Silurian time.

Devonian

The Devonian strata comprise the thickest unit of the Palaeozoic section, and over 1,400 feet of Devonian rocks are present in the southwest corner of Manitoba. Only the lower half of the Devonian section is exposed; the upper half is covered by overlapping younger rocks. The outcrop belt extends from the southeast shore of Lake Manitoba northwest to beyond Dawson Bay on Lake Winnipegosis. The subdivisions of the Devonian system are shown in Table 11.

ELK POINT GROUP

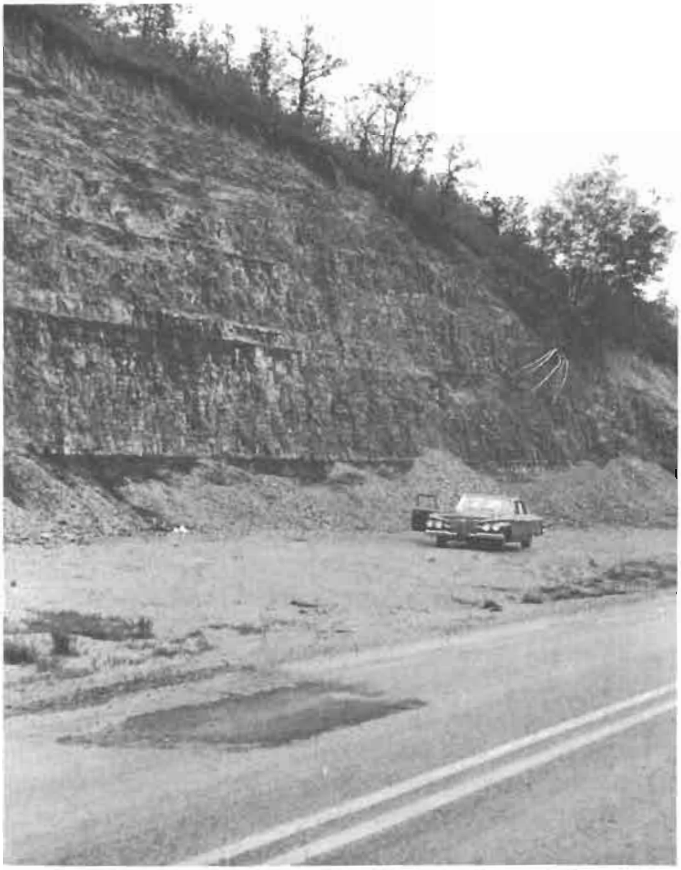
Ashern Formation

The Ashern formation was deposited in Middle Devonian seas which transgressed the eroded and weathered surface of Silurian strata. It is exposed in a narrow belt northeast of Lake Manitoba where it consists of 25 feet of brick red to greyish orange argillaceous dolomite. In some places the lower few feet consist of a breccia in which the argillaceous dolomite contains fragments of the underlying Silurian dolomite. Residual red clay is associated in many places with this lower, unconformable contact. Small pyrite nodules are scattered throughout the formation.

The Ashern formation is 10 to 50 feet thick in the subsurface, and consists of red and green dolomitic shale and red and purplish argillaceous dolomite. Breccia and red clay occur at the lower contact, and the basal beds contain quartz silt and sand.

Elm Point Limestone

Overlying the Ashern formation is the finely granular, yellowish grey Elm Point limestone. The formation is about 50 feet thick in the outcrop belt along the northeast shore of Lake Manitoba, and shows a striking yellowish brown mottling,



A. Cretaceous shales along highway No. 3 near La Riviere.

B. Ordovician Limestone, Black Bear Island, Lake Winnipeg.

the result of incipient dolomitization. Some thin beds within the formation are highly fossiliferous. The rock is quarried at Steep Rock and Spearhill as a high-calcium limestone, but has a slightly higher dolomite content to the south at Oak Point.

The Elm Point limestone is typically developed in the subsurface in the area adjacent to the outcrop belt. However, it is a local basal limestone facies, and throughout most of southwestern Manitoba it grades to a calcareous dolomite which is included in the Winnipegosis formation.

Winnipegosis Formation

The Winnipegosis formation is well exposed along the shores of Lake Manitoba and Lake Winnipegosis, and is composed of reef and inter-reef facies. The reefs consist of hard dense massive dolomite, commonly highly fossiliferous. Inter-reef deposits consist of poorly fossiliferous bedded dolomite containing some thin shaly bands. The formation varies in thickness from 70 to 100 feet in inter-reef areas up to 335 feet in reefs. The reefs formed in a normal marine environment on the shelf of the Elk Point basin.

The upper beds of the formation are anhydritic in the subsurface, and towards the center of the basin the formation varies from 40 to 150 feet in thickness, where the upper part of the Winnipegosis formation grades laterally into the Prairie evaporite.

Prairie Evaporite

The Prairie evaporite is present only in the subsurface and extends from southwest of Lake Manitoba westward into Saskatchewan. On the shelf area east of Oak Lake it consists of 10 to 35 feet of anhydrite. Basinward from Oak Lake, where the formation thickens rapidly to 430 feet along the Saskatchewan boundary, the formation consists mainly of halite; some thin beds of potassium salts occur in the upper part of the formation. The potassium salts, which are precipitated only from very concentrated brines, indicate that evaporation to dryness may have occurred within the basin during the latter part of Elk Point time.

MANITOBA GROUP

Dawson Bay Formation

This formation outcrops in the vicinity of Dawson Bay at the northwest end of Lake Winnipegosis. The basal 30 to 40 feet is a red to greenish grey shale called the "second Red Beds" which form an excellent stratigraphic marker. The remainder of the 100- to 200-foot section consists of argillaceous and fossiliferous limestones, calcareous shale, and a possible reef limestone in the basinward part. Some massive anhydrite occurs in the upper part of the formation in the basin area. The sequence of strata represents the essentially cyclical shale-limestone-evaporite nature of the formation. This cycle is similar to that of the underlying Elk Point group (Ashern, Winnipegosis, Prairie evaporite formations) and is repeated again, in places incompletely, in the overlying Devonian formations.

Souris River Formation

The upper part of the Manitoba group comprising the 200- to 300-foot thick Souris River formation, consists of several shale-limestone-evaporite cycles. The basal red and green shales are called the "First Red Beds," and are overlain by 25 feet of argillaceous limestone and 50 feet of high-calcium limestone, the Point Wilkins member. This member is well exposed at Point Wilkins on Dawson Bay, and in a quarry north of Mafeking. It is overlain by a massive thick-bedded dolomite, of which 10 feet is exposed.

The remainder of the formation, not exposed in outcrop, consists of several repeated shale-limestone-evaporite cycles, usually thin and incomplete. Thin evaporitic beds (anhydrite and anhydritic dolomite) and argillaceous zones are interbedded with the carbonates. The upper limit of the formation is a 25- to 50-foot zone of grey shale and argillaceous limestone.

SASKATCHEWAN GROUP

Duperow Formation

The Duperow and younger Devonian formations occur only in the subsurface. The Duperow formation, which attains a thickness of 560 feet in Manitoba, consists of several cyclical sequences of argillaceous limestone, fossiliferous limestone, reef dolomite, anhydritic dolomite, and anhydrite. The upper contact is marked by a 10- to 30-foot zone of red and green dolomitic shale and argillaceous limestone. The Devonian seas reached their maximum extent in Duperow time.

Nisku Formation

The upper 130 feet of the Saskatchewan group, composed of highly fossiliferous fragmental limestone and dolomite, is included in the Nisku formation. The unit is a widespread biostromal reef complex deposit that shows little variation in thickness.

QU'APPELLE GROUP

Lyleton Formation

The youngest Devonian strata in Manitoba are the red dolomitic shales of the Lyleton formation which ranges in thickness from 20 to 115 feet, thinning to the east. Some strata are anhydritic and in places the formation contains some fine quartz sand. The deposition of these sediments was influenced by an evaporitic environment to the west. They represent the last deposits of the Devonian seas prior to their withdrawal at the end of Devonian time. A limited period of erosion followed before the advance of Mississippian seas.

Mississippian

Mississippian strata occur only in the subsurface in the southwestern part of Manitoba, and reach a maximum thickness of 1,000 feet under the southwest corner of the province. They are of particular interest as they are the only known oil-bearing rocks of commercial importance in the province. The strata are divided in ascending order into the Bakken, Lodgepole, Mission Canyon, and Charles formations.

Bakken Formation

Mississippian seas advanced from the west over the slightly eroded surface of Devonian rocks and deposited up to 55 feet of black shales and siltstones of the Bakken formation, probably under swamp conditions. The formation is divided into Lower, Middle, and Upper Bakken members.

The Lower Bakken member consists of 10 to 15 feet of black bituminous shale and is present only in the Waskada area. The Middle Bakken member consists of 25 to 30 feet of very fine-grained partly pyritic calcareous sandstone that has a wider extent that the Lower Bakken member. The Upper Bakken member consists of 3 to 11 feet of calcareous shale which is black in the south and reddish in the north part of the area.

Lodgepole Formation

The Lodgepole formation consists predominantly of argillaceous limestone up to 580 feet thick. However, the lower part is exceedingly variable in lithology. In the eastern area the lower part consists of relatively clean limestone in which several members can be distinguished: the basal brown to black Routledge shale, in the Virden and Turtle Mountain areas only; the thick Scallion member of cherty limestone; and the Virden and Whitewater Lake beds of cyclically interbedded limestones and some calcareous shales. In the western area the lower part of the Lodgepole consists of a heterogeneous assemblage of calcareous shale and argillaceous limestone. The upper part of the Lodgepole formation is as much as 300 feet thick and consists of widespread limestone alternating with argillaceous limestone.

Almost all of Manitoba's oil production has been obtained from the middle part of the Lodgepole formation, including the upper part of the Scallion member, and the Virden and Whitewater Lake beds.

Mission Canyon and Charles Formations

The upper 400 feet of the Mississippian section is a complex cyclical sequence of carbonate beds and interbedded evaporite layers. The contact between the Mission Canyon and Charles formations is placed at the base of the second lowest evaporite bed; the lowermost evaporite bed is included as the MC-2 member of the Mission Canyon formation; the two formations are in part laterally equivalent.

The basal part, or MC-1 member, of the Mission Canyon formation is composed of limestone and dolomite. Toward the basin margins, the member changes laterally to the evaporitic MC-2 member composed of anhydrite and dolomite, and the two members constitute a complete evaporite cycle. The overlying MC-3 member of fossiliferous fragmental limestone, in part anhydritic or dolomitic, occurs only in the extreme southwest corner of the province; it shows a similar lateral or facies change to evaporites of the Charles formation.

The Charles formation grades from dense dolomite and anhydritic dolomite to anhydrite, and is in part argillaceous and sandy. It has a maximum thickness of 115 feet in the southwest corner of Manitoba, but has been truncated eastward by pre-Jurassic erosion. The Charles and Mission Canyon formations were deposited during the regressive stage of the Mississippian seas when restricted evaporitic conditions existed at the margin of the basin.

A small amount of oil production has been obtained from the MC-1 and MC-3 members of the Mission Canyon formation in Manitoba.

MESOZOIC ERA

The deposits of the Mesozoic era consist of a thick sequence of Jurassic and Cretaceous rocks, predominantly shales, deposited unconformably on top of Palaeozoic rocks. Following the retreat of the Mississippian seas, the Palaeozoic strata were subjected to a long period of erosion until the deposition of the Jurassic Amaranth formation. The eroded surface had a local topographic relief of 20 to 300 feet, the relief being greatest where the edge of the Mississippian strata formed an escarpment.

Jurassic

No surface exposures of the Jurassic rocks are known in Manitoba as the expected outcrop belt is covered by glacial drift. The Jurassic strata thicken to the southwest and are almost 1,000 feet thick in the southwestern corner of the province. The section has been divided in ascending order into the Amaranth, Reston, Melita, and Waskada formations.

Amaranth Formation

The lower part of the Amaranth formation consists of widespread red beds; they are thin or absent over the Mississippian escarpment, but reach a maximum thickness of 160 feet in southwestern Manitoba. The predominant rock type is a reddish brown dolomitic shale; the lower part is more sandy and silty and the upper part contains orange-pink anhydrite beds up to 1 foot thick.

Thick beds of anhydrite, with some interbeds of shale and dolomite, form the upper Amaranth unit, which attains a thickness of 175 feet along the western boundary of the province. To the east where the formation is close to the surface, most of the anhydrite has been converted to gypsum; this rock is mined near the town of Amaranth.

Reston Formation

The Reston formation consists of 15 to 150 feet of interbedded argillaceous limestone and shale, deposited under more normal marine conditions. The shale is concentrated in the lower part of the formation and the lower contact is marked by a thin breccia zone. The top of the formation is marked by a thin zone of shallow-water sandy oolitic limestone.

Melita Formation

The lower part of the Melita formation is composed of up to 200 feet of vari-coloured shales with thin sandstone interbeds. The enclosed fossils are of both marine and non-marine types, indicating that the sediments were deposited under shifting marine and terrestrial conditions. The upper part, with a maximum thickness of 275 feet, consists of green calcareous shales with thin beds of coquina and dense limestone, and some thin lenses of anhydrite. In the southern part of the province the top of the Melita formation is marked by a limestone bed composed of shell fragments and oolites.

Waskada Formation

The Waskada formation has a maximum thickness of 175 feet and occurs only as a tongue-like extension from North Dakota north to the Virden area. The lithology is variable, but the dominant rock type is shale of various colours and in part bentonitic. The formation was subjected to pre-Cretaceous erosion, and much of it was removed.

Cretaceous

Cretaceous rocks underlie the second prairie level, outcrop along the Manitoba escarpment, and form the bedrock under a deep drift cover in a narrow belt along the base of the escarpment. The strata dip gently to the west and southwest, and the escarpment has formed because the hard Odanah shale overlies softer rocks. The Cretaceous rocks unconformably overlie Jurassic and earlier rocks and, in the Turtle Mountain area, are overlain by Tertiary formations. The stratigraphic division of the thick Cretaceous section is listed in Table 11.

Swan River Formation

The Swan River formation is present in two main areas in Manitoba separated by a belt extending east and west from Brandon in which it is thin or absent. It is possible that the areas to the north and south of this belt are of different age and origin.

No outcrops of the Swan River formation are known in the southern area, but subsurface information indicates the formation ranges in thickness from 10 to 200 feet, and consists of grey calcareous shale overlain by unconsolidated pure quartz sand. Glauconite and shell fragments indicate a marine origin for at least part of the rocks, all of which are Lower Cretaceous in age.

In the northern area, where the type outcrop is present (in the Swan River valley) the thickness and lithology are more variable. The formation is at least 300 feet thick in the Duck Mountain area, and consists of unconsolidated sand, sandstone, grey shale, carbonaceous shale, and some thin lignite beds. The rocks appear to be of non-marine origin and may be the equivalent of marine Jurassic rocks in the southern area.

In the subsurface, the Swan River formation consists of grey to black non-calcareous shale and sandstone composed of poorly consolidated coarse quartz grains, and in places containing pyrite.

Ashville Formation

Outcrops of the Ashville formation are known only in the area northward from Kelwood. The formation is 150 feet thick along the northeast edge of its occurrence, and increases regularly southwestward to 375 feet along the west boundary of the province. It consists of a lower dark grey clayey shale containing some glauconite and an upper greasy black carbonaceous shale. In the northern area a few bands of silt and bentonite are present within the upper shale.

In the subsurface, a silt or sand member, the "Ashville sand," occurs between the two shales in an area northeast of Virden and Killarney and extending as far as Clear Lake and Neepawa. Its thickness is generally 5 to 25 feet but increases in several places to over 70 feet.

Favel Formation

The Favel formation consists mainly of a grey shale speckled with white calcareous material. In subsurface correlations, this section is called the "second specks" and forms an excellent marker bed throughout the western Canadian prairie region. The formation has a fairly uniform thickness, ranging from 90 to 125 feet in the south and 70 to 100 feet in the north. Outcrops have been found only in the Assiniboine River valley and to the north.

Limestone occurs in thin lenticular zones near the top of the formation; in the northern area some impure grey limestone occurs near the middle of the formation. The formation also contains some thin bentonite partings.

Vermilion River Formation

The Vermilion River formation has been divided in ascending order into the Morden, Boyne, and Pembina members.

The Morden member consists of dark grey non-calcareous shale which in places is fairly soft and somewhat fissile. It is about 200 feet thick in the southern outcrop area along Pembina Mountain, but only 30 to 50 feet thick in the area north of Vermilion River. The beds contain: numerous concretions of calcareous clay; pyrite as concretions, irregular masses, or thin layers; and selenite (gypsum) crystals scattered through the shale. A yellow iron sulphate mineral occurs as crusts or thin partings in the shale. The shale is very carbonaceous and oil and gas can be distilled from it, although their concentration is much below economic quantities. Near Learys, on the northeast edge of Pembina Mountain, the top few feet of the Morden member have been used in making face brick.

The shale of the Boyne member is distinguished from that of the Morden member by an increase in lime content. On exposure to the atmosphere the Boyne shale becomes grey and numerous small specks of limy material appear on the surface; the member is called the "first specks" and is a useful stratigraphic marker bed. The Boyne member is well exposed in numerous outcrops along Pembina Mountain, and is 150 feet thick in that area. It thins northward to 40 feet at Porcupine Mountain, and has a lower lime content there. In the southern area a 7- to 8-foot bed of hard, highly calcareous, buff-weathering shale is present in the middle of the section, and was formerly used in the production of natural cement. Thin bentonite beds and partings occur throughout the Boyne member.

The basal part of the Pembina member has a striking banded appearance caused by alternating layers of dark grey to black shale and pale yellow non-swelling bentonite. The bentonite is quarried along the edge of Pembina Mountain, (see fig. 38) where 11 bands of bentonite, ranging in thickness from 1 inch to 12 inches with an aggregate maximum thickness of 35 inches, occur within a 5- to 7-foot section. The bentonite beds have been observed in the northern area also, but there they are considerably thinner. The bentonite has formed by the alteration of ash beds, believed to be a product of volcanic activity associated with mountain building to the west. Some fossil remains of Cretaceous plesiosaurs, a class of large reptiles, have been found in the bentonite section. The upper part of the Pembina member consists of brownish, non-calcareous shales, which grade upward into shales of the Millwood phase of the Riding Mountain formation. The Pembina member has a maximum thickness of 80 feet in the Pembina River valley.

Riding Mountain Formation

This uppermost Cretaceous formation has been divided into the soft Millwood beds and the overlying hard Odanah shale.

The Millwood beds consist of 50 to 70 feet of soft greenish grey shale with a high bentonite content; the shale breaks down rapidly under weathering to a colloidal sticky clay. In Pembina Mountain, the Millwood beds form isolated buttes, capped by a thin layer of hard Odanah shale, along a fairly level belt one to three miles wide. Some harder layers containing numerous clay ironstone concretions occur within the Millwood beds. One thin bed of green waxy bentonite is present near the top of the member.

The Odanah shale is a grey hard siliceous shale which forms the cap rock of the Cretaceous escarpment throughout southwest Manitoba. The thickness of the shale, controlled mainly by the amount of later pre-glacial and glacial erosion, increases from less than 100 feet at the escarpment edge to about 1,100 feet in the southwestern corner of the province. The Odanah and Millwood beds may grade laterally into one another. In the northern area, much of the upper part of the Riding Mountain formation is missing.

CENOZOIC (?) ERA

Deposits possibly of Cenozoic age, other than Pleistocene and Recent deposits, occur only in the Turtle Mountain area. The deposits may be either Upper Cretaceous or Palaeocene in age, and have been divided into the Boissevain and Turtle Mountain formations.

Upper Cretaceous (?) to Palaeocene

Boissevain Formation

The Boissevain formation outcrops along the base of Turtle Mountain and is estimated to be 100 feet thick. It is composed of a greenish grey unconsolidated impure sandstone that weathers to a somewhat rusty colour. Some parts are consolidated by calcareous cement and have been used locally as a building stone. The formation contains some white clay, and enclosed carbonized plant fossils indicate a continental or freshwater origin.

Turtle Mountain Formation

A series of shale, sandstone, and lignite beds, having a maximum thickness of about 400 feet, overlies the Boissevain formation and forms the upper part of Turtle Mountain. The formation outcrops near Goodlands, and consists of fine-grained sand or sandstone with a few thin concretionary layers. Some shaly bands and thin beds of lignite are present. Fossil plant remains indicate a probable Palaeocene age. A small tonnage of lignite was once recovered for local domestic use in the Deloraine-Goodlands area.

EXPLANATION OF PLATE XIV

Ordovician — Red River formation

1. Maclurites, gastropod (snails)
2. Armenoceras, cephalopod (molluscs, including nautiloids, ammonoids, squids, and others)
3. Halysites, chain coral
4. Isotelus, trilobite
5. Streptelasma, horn coral
6. Receptaculites, "sunflower" coral.

Ordovician — Stony Mountain formation

7. Rhyncotrema, brachiopod (bilaterally symmetrical shelled marine bivalves)
8. Dinorthis, brachiopod.

Silurian — Interlake Group

9. Virgiana, brachiopod

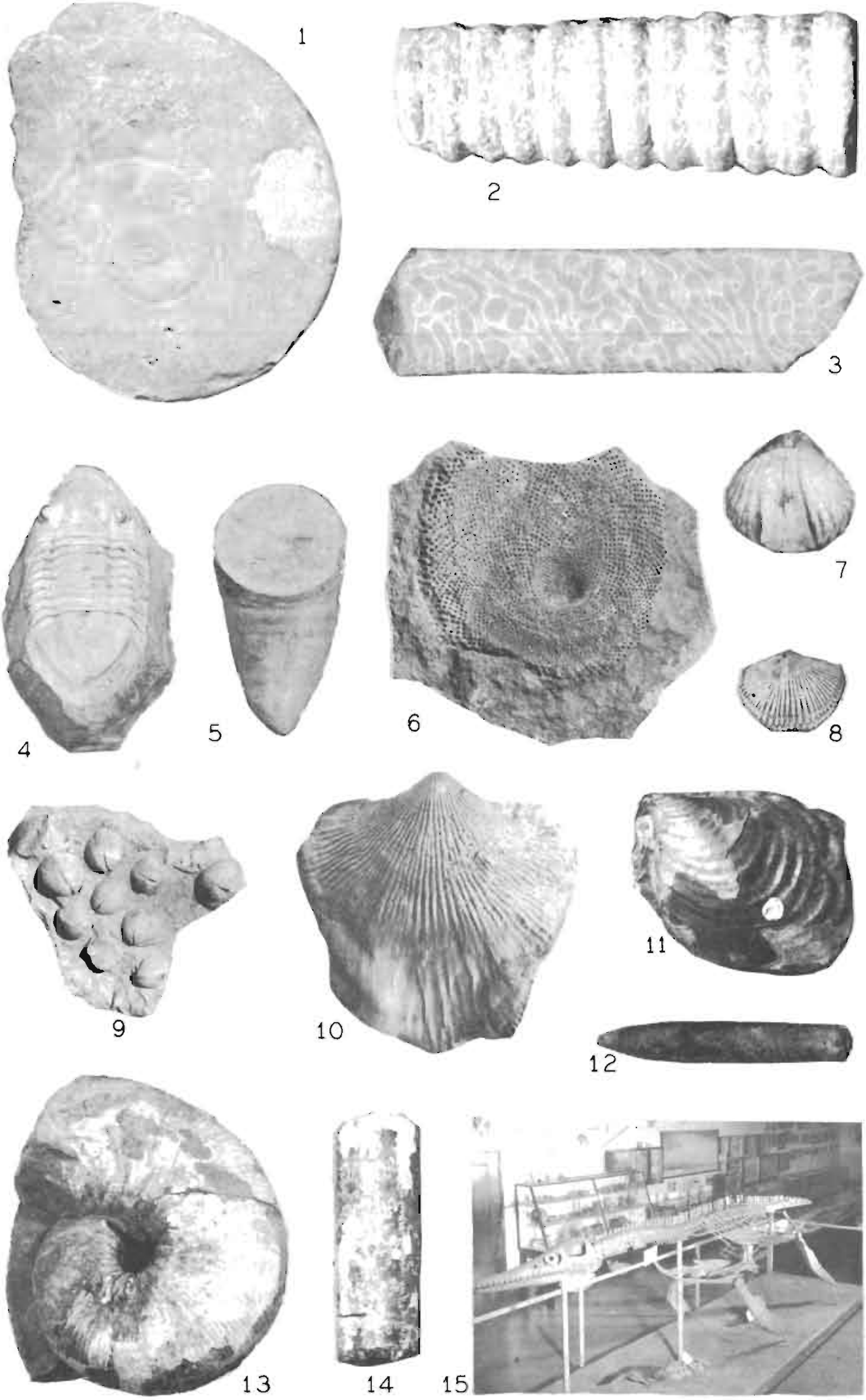
Devonian — Dawson Bay formation

10. Atrypa, brachiopod

Cretaceous — Various formations

11. Inoceramus, pelecypod (clams, and others)
12. Actinicamax, belemnite cephalopod (straight shells)
13. Scaphites var., ammonoid cephalopod (coiled shells)
14. Baculites, ammonoid cephalopod
15. Trinacromerum, plesiosaur (flippered marine reptiles).

PLATE XIV



Typical Manitoba Fossils. See opposite page for explanation.

THE HUDSON BAY LOWLAND

The Hudson Bay Lowland comprises an area of 25,000 square miles extending along Hudson Bay from Churchill to the Ontario boundary. The bedrock formations in this area are sandstones, limestones, and dolomites of early Palaeozoic age which overlie the Precambrian basement complex and dip toward Hudson Bay. Outcrops of the Palaeozoic strata are confined mainly to the banks of the major streams crossing the area — the North and South Knife, Churchill, Nelson, and Gods (Shamattawa) rivers; the inter-stream areas are generally low, swampy, and peat- and moss-covered. The following table of formations has been compiled from a preliminary survey in the area (Savage and Van Tuyl, 1919).

TABLE OF FORMATIONS: HUDSON BAY LOWLAND

FORMATION	AGE	LITHOLOGY	THICKNESS* (feet)	CORRELATION
Severn River	Silurian	Limestone (probably present under drift)	?	Interlake group
Port Nelson	Ordovician	Dolomite, even-bedded	35 - 40	Basal part of Stonewall formation
Shamattawa	Ordovician	Limestone, mottled dolomitic	75 - 80	Stony Mountain formation
Nelson River	Ordovician	Dolomite and mottled dolomitic limestone	70	Red River formation
"Winnipeg"	Ordovician	Sandstone, fossiliferous	3 - 12	Upper part of Winnipeg formation

Ordovician

The basal Ordovician sandstone crops out on the Churchill River and on North and South Knife rivers, and is in contact with Precambrian rocks. In places it is exceedingly fossiliferous; some exposures show small amounts of a basal pebble conglomerate. The sandstone is considered to be a northern extension of the uppermost part of the Winnipeg formation. (The bed of quartzite exposed at

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*Recent exploration drilling in the Hudson Bay Lowland area indicates that the formation thicknesses listed in this table, which were estimated from scattered outcrops only, are much lower than what are actually present. A drill-hole about 35 miles west of York Factory, at an elevation of 220 feet, intersected 533 feet of Palaeozoic rocks under 320 feet of overburden. The upper 100 feet of the section may be of Silurian age, and the remainder Ordovician, but contacts between the formations have not been definitely established.

Churchill, coincident with the expected outcrop belt of the basal Ordovician sandstone, is thought to be of Proterozoic age as it is metamorphosed, steeply folded, and non-fossiliferous.)

Overlying the basal Ordovician sandstone are fossiliferous dolomite, dolomitic limestone, and limestone which outcrop along the Churchill, Nelson and Gods rivers. These rocks, about 70 feet thick, are correlated with the Red River formation.

The Shamattawa formation, exposed along Nelson and Gods rivers, consists of 75 to 80 feet of fossiliferous limestone the upper half of which is, for the most part, mottled with brown dolomitized areas. On the basis of faunal and lithologic similarity, the formation is correlated with the Stony Mountain formation in the Lake Winnipeg area and was probably deposited in the same marine province or basin, connected with the Arctic Ocean; deposits in the intervening area have since been eroded.

The youngest strata exposed in the area are the yellowish-brown evenly bedded dolomites which outcrop on Nelson River, and have been named the Port Nelson formation. The rock is correlated with the lower part of the Stonewall formation.

Silurian

Although no outcrops of definite Silurian age are yet known from the Hudson Bay area, a study of strikes and dips of the formations suggest that they are probably present under the drift cover in the area east and southeast of the mouth of the Nelson River. A short distance across the boundary, in Ontario, outcrops of carbonate rocks along Severn River, have been correlated with the Silurian Interlake group of southern Manitoba.

PLEISTOCENE GEOLOGY OF MANITOBA

The northern part of the North American continent was covered at least four times by ice-sheets during the Pleistocene epoch. Although no definite evidence of the first three glacial periods has been found in Manitoba, it is probable that a least part or all of the province was covered each time and that the record of these three earlier periods has been destroyed by the fourth (Wisconsin) glaciation.

The glaciation of the Pleistocene epoch greatly modified the pre-existing topography of Manitoba and the deposits left following the retreat of the glaciers have been one of the major influences on the present topography. The pre-existing surface, probably deeply weathered, was scoured by the glaciers which exposed fresh bedrock. Broken material was carried forward during the advance of the glaciers and then dropped when they melted, forming large moraine, drumlin, eskers, and outwash deposits. During the final retreat of the glaciers, a thick ice-sheet blocked the natural drainage to the north, and vast glacial lakes formed in front of this barrier. Large deltas formed where major streams entered this lake, beach deposits formed along the shorelines at different levels during the successive stages of the lake, and lake silts and clays were deposited on the bottom.

In the part of the province north of the Churchill and east of the Nelson rivers, major glacial lakes did not form, as free drainage into Hudson Bay was possible when the ice-sheet had retreated that far. The surface there, probably already a

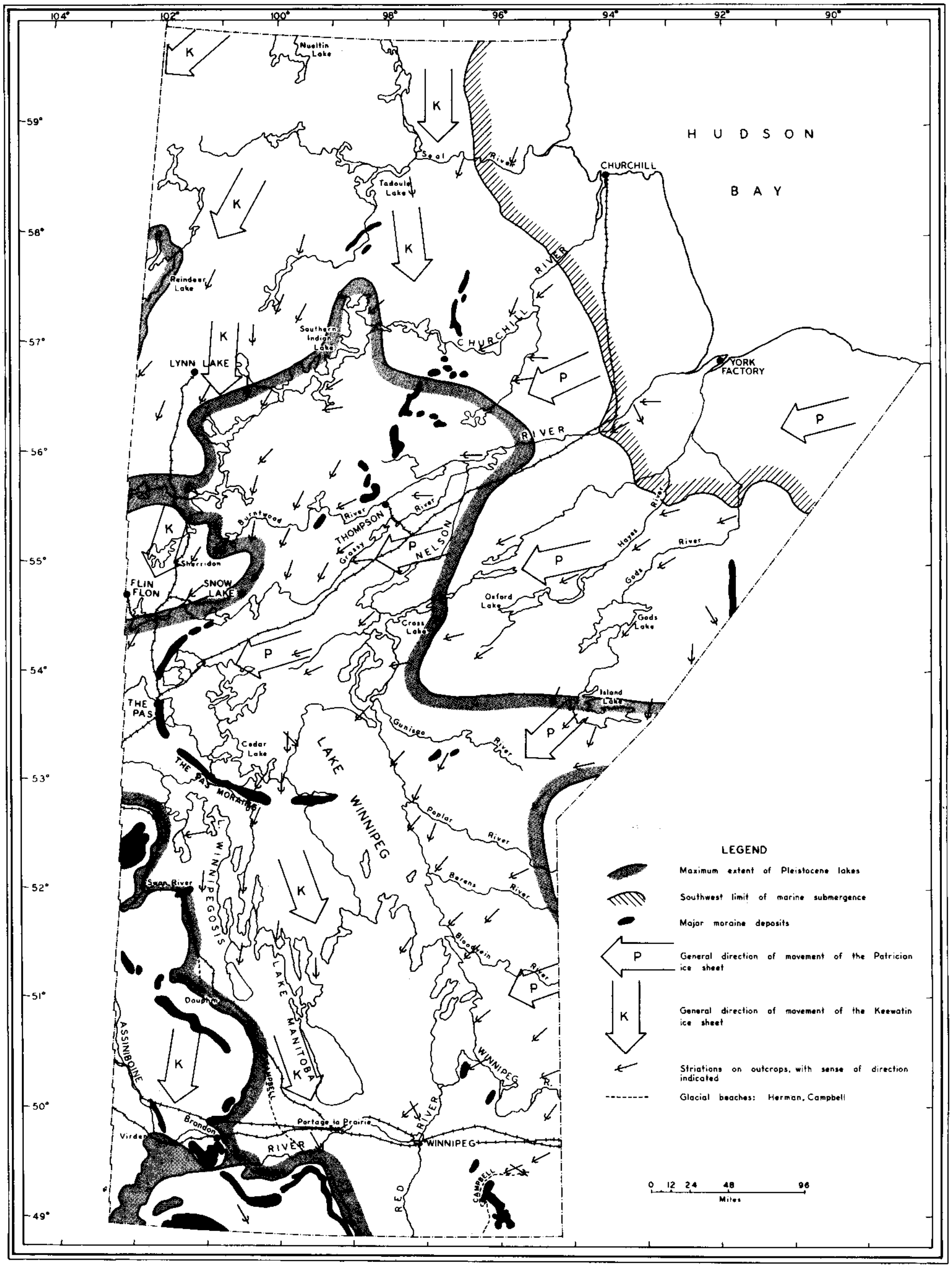

FIGURE 35 *Glacial Geology of Manitoba*

peneplain in pre-glacial times, was generally reduced to low relief by the glaciers, except for the glacial deposits of eskers, drumlins, and moraines.

Post-glacial time is relatively short in geological terms, and is of the order of only 5 to 10 thousand years. Thus the glacial deposits have not been greatly modified except along the courses of major rivers, where periodic flooding since glacial times has deposited a few feet of silt and mud, and in deltaic areas, where sand dunes have been formed. Numerous swamps were left in the shallower surface depressions and some are now extensive peat bogs. The only other major result of the recent weathering is the formation of a thin layer of topsoil on the glacial or bedrock deposits.

EARLY GLACIAL PERIODS

From evidence of interglacial deposits in the north central United States, geologists have postulated at least four major advances and retreats of the continental ice-sheets in Pleistocene time. During each of these periods of glaciation Manitoba was probably covered by the ice-sheets, and the pre-existing land surface was modified.

Evidence of these early glacial periods is obscure in Manitoba because the early drift deposits were for the most part removed or reworked by the subsequent glacial activity; the glacial drift now exposed is the result of the last or Wisconsin glaciation. The three main contributing sources of material for the glacial drift were the Precambrian rocks, the early Palaeozoic carbonate rocks, and the soft Cretaceous and Jurassic shales.

THE WISCONSIN GLACIATION

The history of the Wisconsin period of glaciation is known in considerable detail as evidence of its development is widespread. Regional studies of glacial striae, drumlins, eskers, and moraines indicate two main centers of accumulation for the ice-sheets which covered Manitoba — the Keewatin center in the Northwest Territories west of Hudson Bay, from which the ice flowed south, and the Patrician center southwest of James Bay, from which the ice spread to the southwest. From these centers the ice advanced and retreated, reworking the deposits of the previous glaciers and, in some places, grinding deeper into the bedrock.

In general, the Keewatin ice sheet spread south on a wide front along the west coast of Hudson Bay as far as Churchill, swung southwestward to The Pas, and then moved generally east of south along the base of and on top of the Cretaceous escarpment. The Patrician sheet, probably reinforced by ice from the Labrador sheet farther to the east, moved southwestward and covered the area between the Nelson River and the International Boundary, extending as far west as Lake Winnipeg and, in the northern area, as far as The Pas (see fig. 35).

During its maximum advance the Keewatin ice-sheet extended from Coronation Gulf to Iowa, and the Patrician sheet covered the area between the Great Lakes, Lake Winnipeg, and Hudson Bay. The two sheets may have culminated successively, but their relations appear complex. For example, in The Pas area, at the time of formation of The Pas moraine, the Patrician sheet extended west to The Pas and encroached on the Keewatin ice-sheet, but the Keewatin re-advanced over the area before the final retreat of both sheets. The Keewatin sheet retreated almost due north, and the Patrician sheet due east.

In its advance, the ice-sheet usually removed more than the loose material which lay on top of the bedrock; most of the drift was derived chiefly from glacial wearing of the bedrock, as is shown by rock surfaces polished, planed, and striated by glacial erosion. An enormous volume of material was deposited, as shown by the thickness of the glacial drift (fig. 36). When the 250,000-square-mile area of Manitoba is considered, the vast amount of material broken up, carried along, and deposited by the glaciers, as well as the amount deposited in the associated glacial lakes, is realized.

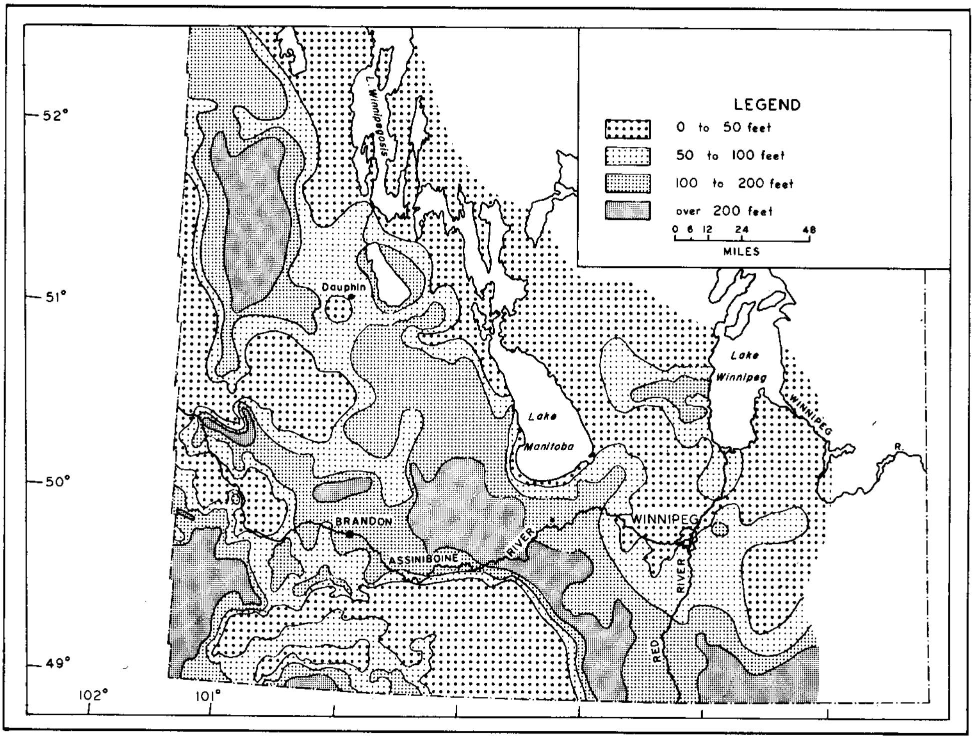

FIGURE 36 *Thickness of the Glacial Drift in Southern Manitoba*

The great weight of the ice-sheet, estimated to have had an average thickness of 3,500 feet, caused a depression of the land surface of the order of a few hundred feet, being greatest in the central part of the area covered by the ice-sheets and tapering off towards the margins. This had a great effect on the succeeding development of the land surface, as the depressed land rose gradually during and following the retreat and melting of the ice-sheets.

A detailed history of the recessional stage has been derived from studies of the numerous deposits left by the retreating ice sheet. The topography of the area is of particular significance in the consideration of this history. Manitoba is a land mass draining northeastward into Hudson Bay. Its western part is marked by the Cretaceous escarpment which rises 600 to 1,000 feet above the general plain level to the east, which, in the central area, is 700 to 850 feet above sea level. To the south of Manitoba, the height of land occurs at Lake Traverse in Minnesota, at a present elevation of 975 feet; prior to glaciation a barrier existed there at an elevation of 1,100 feet. To the east, the land rises to about 1,200 feet above sea level and the height of land extends from 60 miles west of Lake Superior north to the west end of Lake St. Joseph.

Thus most of Manitoba lies within a basin surrounded by heights of land ranging from 1,500 to 1,100 feet on the west, south, and east. The advance of the ice-sheet and the consequent depression of the land surface had altered this relationship somewhat, but as the recovery of the depressed land was relatively rapid during the melting of the glaciers, these general relations held. The significant result of this topography was that as the front of the ice-sheet melted, the water could not drain away, being trapped between the 3,000 to 4,000 foot-thick glacial sheet and the height of land. As a result, huge glacial lakes formed in front of the retreating glaciers, rising in level until they reached the height of land.

HISTORY OF THE GLACIAL LAKES

Lake Agassiz, which eventually became the largest of the glacial lakes (see fig. 35), began to form as soon as the front of the ice-sheet had retreated to the north of the height of land in Minnesota. The "retreat" of the ice-sheet was caused by the melting or wasting of the ice-sheet proceeding faster than its advance. In its early stage, Lake Agassiz covered the Red River Valley in Minnesota and North Dakota, and extended into Manitoba, continuously spreading as the ice-sheet retreated.

During this recessional stage, several types of glacial deposits were formed, including glacial beaches, outwash plains, deltas, moraines, and lake deposits. Some of the deposits formed simultaneously in different areas.

Glacial Beaches

The recessional stage of the glaciation was marked by a series of halts or of balanced wasting and advance, and also by occasional re-advances, of the ice-sheet. During the periods of stand-still, beach ridges formed along the existing shores of the glacial lakes. The beaches are long narrow ridges of sand and gravel, smoothly rounded, rising 10 to 20 feet above the surrounding land. In some places, gravel beaches were not formed, but the till surface of the lake bed was terraced by wave action.

The highest of the well-marked beaches in Manitoba is the Herman Beach. This beach, which forms a single ridge in Minnesota, when traced northward diverges into several strand lines; in the west central part of Manitoba 12 or 13 strand lines have been identified. This divergence was caused by the differential uplift of the land as the ice-sheet gradually melted. The land rose gradually as if a hinge line were present roughly along the south edge of the farthest advance of the ice-sheet; the amount of uplift increased northward, corresponding to the greater depression of that area during the advance of the ice-sheet.

Following the formation of the Herman beaches, the ice-sheet retreated, and erosion of the Lake Traverse outlet continued, but apparently was interrupted by periods of slow erosion (probably related to periods of stand-still in the ice-front of the glacier). As a result, a series of beaches formed around the lake, at successively lower levels. Tilting accompanying the decrease in ice load, again caused branching of the beaches to the north. The next series of beaches were the Norcross (with 2 strands), the Tintah (with 2 strands), and the Campbell (with 3 strands), all deposited in the period when Lake Agassiz drained to the south. During this period, the depth of water over what is now the south end of Lake Winnipeg decreased from 650 to 350 feet.

It is believed that a recession of the ice at the time of formation of the Campbell Beach resulted in the opening of an eastern outlet through which Lake Agassiz completely or almost completely drained. By this time, the ice-sheet had retreated by melting to the general area of The Pas. A re-advance of the ice-sheet closed the eastern outlet, and Lake Agassiz II was formed; when the Campbell beach level was reached, drainage was again to the south. The Campbell Beach is uniformly and strongly developed in both northern and southern Manitoba, indicating that conditions remained stable for a considerable time.

The Lower Campbell Beach was probably the last one formed while Lake Agassiz had its outlet to the south. Retreat of the ice-sheet resulted in new drainage openings at lower levels to the east, possibly through the Sturgeon Lake, Mattawa Lake, Lac Seul areas, and others. During pauses in the lowering of the lake level, the McCauleyville, Blanchard, Hillsboro, Emerado, Ojata, Gladstone, Burnside, Ossawa, Stonewall, The Pas, Gimli, and Grand Rapids beaches were formed. These beaches record the decrease in area of Lake Agassiz almost to the present day areas of the lakes in Manitoba (see fig. 37). The tilting of these later beaches is much less pronounced than that of the Lake Agassiz I beaches.

Once the ice-sheets had retreated as far as the mouth of the Nelson River, and access to the open sea was available, a sudden drainage of the remaining part of Lake Agassiz probably occurred, leaving behind the ancestral forms of the three large Manitoba lakes: Winnipeg, Manitoba, and Winnipegosis. The only changes in the area of Lake Winnipeg since glacial times have been brought about by the gradual lowering through natural erosion of the Nelson River outlet through a depth of about 20 feet.

Outwash Plains and Moraines, and Glacial Lake Souris

As the Keewatin and Patrician ice-sheets retreated by melting, the broken rock material held within them was deposited as outwash plains and moraines (see fig. 37). Where this material was released into the lake waters spreading in front of the ice-sheet, scattered outwash deposits of stratified sand and gravel were laid down. These deposits were later covered in part by lake clays, but are exposed in a belt extending from Winnipeg south and southeast to the International Boundary and Lake of the Woods. Where the material was deposited on land, as in much of the area west of the escarpment, or possibly in shallow water, as in the interlake area, a layer of unsorted drift or boulder till, composed of a mixture of boulders, gravel, sand, silt, and clay, was formed.

The periods of stand-still in the retreat of the ice sheets during which the glacial beaches were formed, were marked on the land areas by the formation of terminal moraines. The Tiger, Arrow, and Brandon hills are terminal moraines formed about the time of the uppermost in the series of Herman beaches. The ice-front at that time was along the north and east edges of Pembina Mountain, and the Tiger and Brandon hills formed re-entrants in the ice-sheet. Lake Souris, a

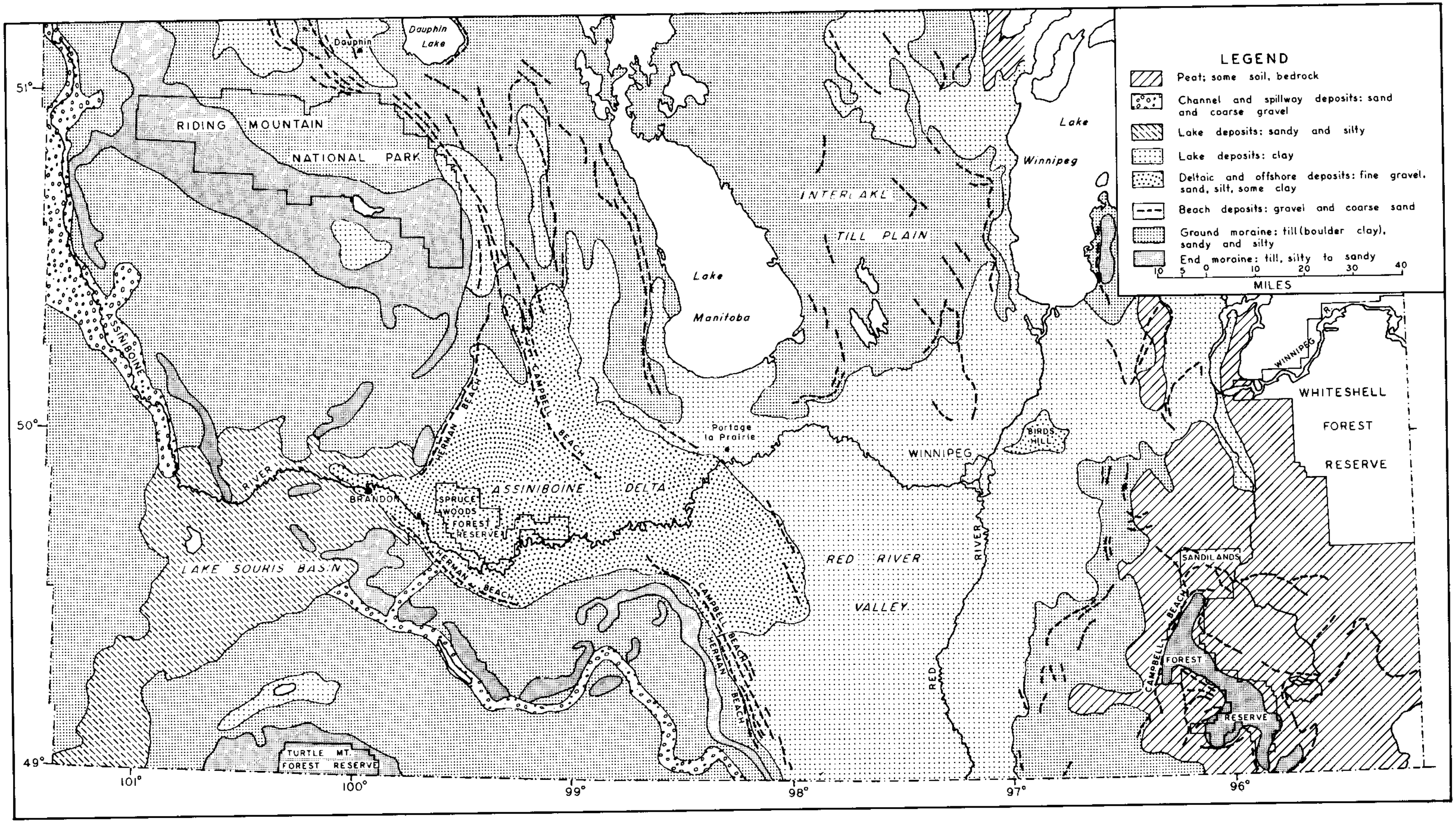

FIGURE 37 *Surface deposits of Southern Manitoba*

PLATE XV

Sand dunes along the Assiniboine River near Carberry. The dunes consist of wind-blown sand of the ancestral Assiniboine delta. Note the former courses of the Assiniboine River.

glacial lake separate from Lake Agassiz, was dammed on the upper level of the escarpment by this ice-sheet, and covered the southwest corner of the province and the neighbouring part of North Dakota. This lake drained into Lake Agassiz at first through outlets in the United States, and then through the Pembina Valley. As the ice retreated farther north, the narrow moraine of Tiger Hills was transected by erosion at Long's Valley, and Lake Souris was drained northward to the Assiniboine River.

Another glacial lake, situated in Saskatchewan, drained through the Qu'Appelle valley into Lake Souris, depositing an extensive delta extending from St. Lazare to

Souris. The bottom deposits in Lake Souris consisted of sandy and silty clay, much coarser in texture than the clays deposited in the larger Lake Agassiz.

Delta Deposits

A huge delta formed where the ancestral Assiniboine River emptied into Lake Agassiz east of Brandon. A great volume of sand and gravel was deposited, a large part of it during the time of formation of the Herman beach. Coarser gravel was deposited near Brandon, but the main part of the delta consisted of sand deposited in a triangular area bordered by Brandon, Neepawa, and Cypress River. The fine clay from the Assiniboine River was carried far out into Lake Agassiz.

The Assiniboine delta covers an area of 2,000 square miles (see fig. 37) and has an average depth of at least 50 feet. This represents a volume of 20 cubic miles of material derived mainly from the melting ice-sheet. It was supplied not only by the Assiniboine River but also by streams issuing from the melting ice-sheet covering the upper Assiniboine basin. A possibly equal volume of clay and silt was carried beyond the delta into the central part of the lake.

The sandy delta surface was heaped up by wind into dunes 25 to 100 feet high soon after the withdrawal of the glacial lake from the area, and before vegetation could get a firm hold. Today, this belt of sand hills borders the Assiniboine River, now deeply entrenched in its own delta, for nearly 60 miles from Brandon to Portage la Prairie. The sand is now stabilized for the most part, but a few "desert" areas of open dune sand still exist, as in the Carberry area.

Another deltaic deposit formed at Birds Hill, when the ice-sheets had retreated as far as Winnipeg. A short halt seems to have occurred, and 8 miles northeast of Winnipeg a huge deposit of sand and gravel was laid down at the mouth of a large stream issuing from the Keewatin ice front. The deposit starts as a 50- to 70-foot high narrow ridge at Birds Hill and extends 4 miles to the east. The ridge widens in its eastern part, spreading out in a fan-shaped plateau of sand and gravel, not as coarse as at the west end. To the northeast is a slightly elevated sandy plain extending over several square miles. Another high ridge of gravel, Moosenose Hill, occurs south of the central part of the Birds Hill deposit, and is oriented in a northerly direction. It may have been formed at the same time as Birds Hill from a river entering the area on the south side. Both deposits are stratified, indicating that the material issuing from the stream was dropped where the fast-moving water of the stream emptied into the still water of Lake Agassiz, which at that time was about 400 feet deep in the Birds Hill area. The deposit is thus of a delta type, with the coarse material concentrated at the west end. The finer gravel and sand were carried farther out, and the clay remained in suspension until it had travelled far out into the lake.

Lake Deposits

Large areas within the former Lake Agassiz basin are covered by thick layers of clay and silt that settled out from the water of the lake.

In the Red River basin, the sediments were deposited on top of till, or "hardpan," and consist of a lower clay unit, deposited in the deep water of Lake Agassiz I, and an upper silt unit, deposited in the shallower water of Lake Agassiz II. The lower clay unit is 20 to 40 feet thick in the Winnipeg area, and increases to the south to over 50 feet thick; it consists of a lower grey silty massive clay and an upper brown thinly laminated clay. The upper silt unit rests unconformably on the clay unit, and in places is separated from it by sand or gravel. Its composition ranges from silt to clay, and its colour is yellow to grey. At Winnipeg the silt unit is up to 15 feet thick, and increases to the south to 35 feet thick.

Other areas of lake clay occur along the Whitemouth and Winnipeg rivers, around Gimli and Riverton, between Lake Winnipeg and Island Lake, and in the South Indian Lake-Thicket Portage area. Varved clays, consisting of alternating thin layers of dark "winter" clay and light "summer" silt, are common in the northern clay areas, and are believed to have been deposited in Lake Agassiz II.

Some areas of the lake basin are not covered by clay deposits. A large area in the interlake region is almost devoid of clay, possibly because of being deglaciated under subaerial conditions, or because of remoteness from sources of sediment, or by erosion of a thin veneer of clay.

GLACIATION OF THE PRECAMBRIAN SHIELD

The Precambrian Shield was reduced by erosion to a peneplain before Palaeozoic time. In some areas, thin, almost horizontal, beds of early Palaeozoic age were deposited over the margins of the present area of the Shield, but erosion from early Palaeozoic to Pleistocene time has removed most of these beds. Thus, prior to glaciation, the Shield area was a peneplain in which areas of exposed rock were deeply weathered.

The advance of the Pleistocene ice-sheets resulted in the removal of most of the weathered material and also, in most places, some of the underlying fresh bedrock. Of economic significance was the removal of gossans, the yellow to brown oxidized zones which form over sulphide deposits and are of value in prospecting for ore deposits.

The surface of the Precambrian Shield now consists mainly of glacial deposits, muskeg, lakes, and rock outcrops. In the areas formerly covered by glacial lakes, particularly Lake Agassiz, clay and silt deposits are common, as well as associated beach and delta deposits of sand and gravel. In the areas not covered by glacial lakes, unstratified boulder till is generally present, as well as numerous prominent glacial features such as eskers, kames, and drumlins. The Pleistocene glaciation adversely affected the drainage of the Precambrian area; lake basins carved out of solid rock, sluggish streams, and large areas of peat and muskeg are part of the glacial legacy.

The area bordering Hudson Bay was once covered by marine water (see fig. 35) after the retreat of the glacier and before the complete recovery of the land depressed by the great weight of the ice-sheet. As the land slowly rose, marine beaches formed at successive levels down to the present shore-line.

RECENT HISTORY

Most of the deposits of the Wisconsin glaciation remain today virtually unaltered under their thin covering of soil and vegetation. The major changes since glacial time have been natural river erosion, the formation of alluvial deposits, and the development of peat bogs. The Assiniboine delta has undergone some alteration, mainly in the shifting of the sand dunes on its surface and in erosion by the Assiniboine River as it entrenched itself in the delta. The glacial clays of the Red River basin are covered in part by 3 to 15 feet of yellow calcareous silty clay, probably deposited during flood stages of the Red and Assiniboine rivers. Extensive peat bogs formed where glacial deposits or erosional patterns resulted in areas of poor drainage. Finally, the formation of a soil cover permitted the spread of vegetation over the land.

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CHAPTER VI

INDUSTRIAL MINERALS

INTRODUCTION

The southern part of Manitoba is the source of many industrial minerals, primarily those of use as structural materials. The major products are cement, and sand and gravel, which together account for 75 per cent of the value of Manitoba's industrial mineral production. Lime is another important product, and both high-calcium lime and magnesia lime are produced. Also of importance are clay products (including bentonite), building stone, peat moss, salt, and gypsum.

During past years, the proportionate value of these industrial minerals has varied widely, as is shown in table 12. Total annual production decreased to less than one million dollars in the depression years of 1933 and 1934, but rapid growth in value followed, especially in the post-war period of 1945 to 1960 when the annual value of production increased from 4 million to over 18 million dollars.

CEMENT

Since 1915, cement has accounted for about 50 per cent of the value of Manitoba's industrial mineral production. Canada Cement Company Limited operates a large plant at Fort Whyte, 5 miles southwest of Winnipeg. Formerly, natural cement was produced at Babcock (44)[1].

NATURAL CEMENT

At Babcock, 65 miles southwest of Winnipeg, an outcrop of the Boyne member of the Cretaceous Vermilion River formation includes an 8-foot bed of calcareous shale. The rock contains 39 per cent calcium oxide, and averages less than 1 per cent magnesium oxide. When burned for 12 hours at temperatures up to 1,800° F, a natural cement of a rapid hardening type is produced. The cement was used both separately as a mortar and mixed with an equal proportion of Portland cement for use in concrete for street and sidewalk construction. The Manitoba Union Mining Company first attempted production of natural cement in 1904 at Arnold, 7 miles southeast of Babcock. The Commercial Cement Company operated a mine and kilns at Babcock (44) from 1907 to 1924.

PORTLAND CEMENT

High-calcium limestone suitable for use in Portland cement is present in the Elm Point limestone, quarried at Steep Rock, and in the Point Wilkins member of the Manitoba group, quarried north of Mafeking. Both limestones are of Devonian age.

Steep Rock Quarry

The Elm Point limestone is quarried at Steep Rock (53), on the east shore of

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[1] Numbers in parentheses refer to locations on the map of Industrial Mineral Deposits of Manitoba (figure 38).

EXPLANATION OF FIGURE 38

(Numbers refer to localities shown on figure 38)

I. CURRENT PRODUCERS — 1960

Limestone and Cement
Fort Whyte 38
Mafeking 76
Steep Rock 53

Sand and Gravel
Arrow Hills 67
Beausejour 30
Birds Hill 35
Brandon Hills 63
Marchand 34
Monominto 32
Ste. Anne 33
Tiger Hills 62
Vivian 31

Building Stone
Garson 29
near Lac du Bonnet 12
Stony Mountain 25

Lime and Dolomite
Birse quarry 23
Grand Rapids 86
Inwood 21
Lillies farm 23
Little Stony Mtn. 26
Spearhill 50
Stonewall 24
Stony Mountain 25

Gypsum
Amaranth 56
Gypsumville 51

Clay Products
Portage la Prairie 45
St. Boniface 37
Thornhill-Miami 41
Transcona 36

Salt
Neepawa 57

Peat
Julius bog 11

II. OTHER DEPOSITS

Limestone and Cement
Babcock 44
Kinosota 55
Lily Bay 48
Waterhen Lake 72

Sand and Gravel
Carberry Hills 61

Building Stone
Boissevain 64
Bull Head 17
Clangula Lake 15
Cormorant Lake 79
East Selkirk 28
Falcon Lake 2
Glenn 3
Hodgson 18
Hudson Bay Rlwy. 80
Lower Fort Garry 27
Pine Falls 14
West Hawk Lake 1

Lime
Birse quarry 23
Broad Valley 20
Fairford 52
Gunton 22
Little Stony Mtn. 26
Lundar 47
Mafeking 76
Mulvihill 49
Oak Point 46
The Narrows 54
Winnipegosis 70

Gypsum
Charleswood 39
Dominion City 40

Clay Products
Arborg 19
Edrans 58
Firdale 59
Lac du Bonnet 13
La Riviere 42
Learys 44
Pembina Mountain 41
St. Boniface 37
Sidney 60
Swan River 74
Transcona 36
Whitemouth 10

Salt
Red Deer River 76

Peat
Pine Falls 14
Pointe du Bois 9
Cowan 73

Fuchsite
Oxford Lake 83
Winnipeg River 8

Amber
Cedar Lake 77
Moose Lake 78

Asbestos
Lake Athapapuskow 81
Clangula Lake 15
Garner Lake 4
Island Lake 85
Knee Lake 84

Chromite
Bird River Sill 6

Lignite
Turtle Mountain 65

Manganese
Porcupine Mountain 75
Riding Mountain 69
Roseisle 43

Pegmatite Minerals
Bernic Lake 7
Cat Lake 5
Herb Lake 82
Winnipeg River 8

Potash
Lazare 68

Silica Sand
Arborg 19
Pine River 71
Swan River 74
Black Island 16

NOTE: *Many other sand and gravel deposits and peat bogs, too numerous to plot on this map, occur throughout the province.*

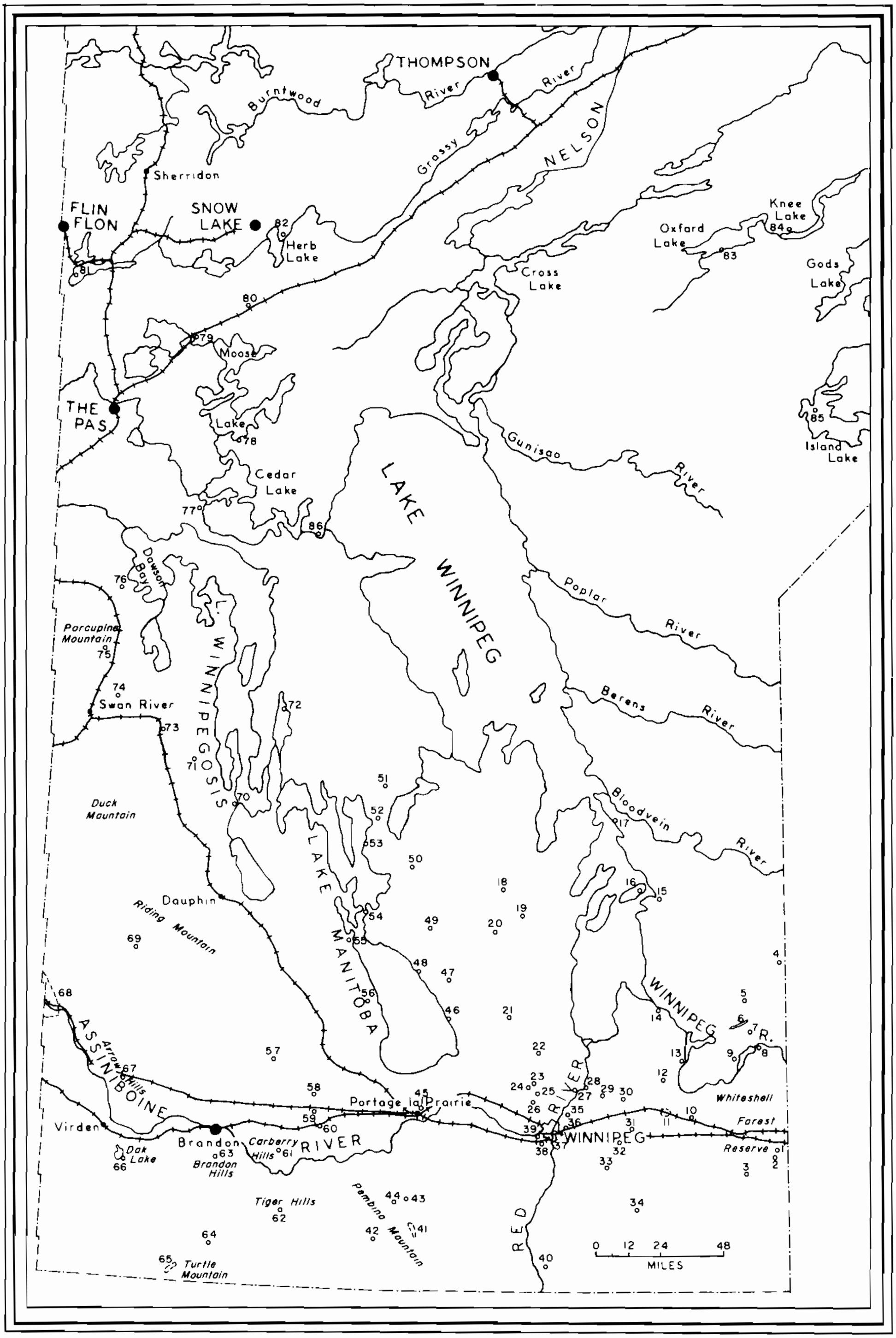

FIGURE 38 *Industrial Mineral Deposits of Manitoba*

PLATE XVI *Cement plant, Fort Whyte. Clay pits, filled with water, are shown on the left.*

Lake Manitoba, by Canada Cement Company Limited. Steep Rock is situated 155 miles by rail from the company's Portland cement plant at Fort Whyte.

The rock is a yellowish grey limestone that is strikingly mottled with slightly dolomitized light brown patches; fossils are abundant. The formation shows very little lithological change over its 50 foot thickness. The $CaCO_3$ content averages 95 to 96 per cent, ranging up to 97.65 per cent. The magnesium oxide content averages between 0.6 and 0.7 per cent. A crushing plant at the quarry reduces the limestone to a ¾-inch size or less for shipment to Fort Whyte. Present annual production (1960) from the quarry is about 550,000 tons.

Fort Whyte Plant

The Portland cement plant of Canada Cement Company Limited at Fort Whyte (38) uses the rotary kiln wet process. The raw mix consists of clay from a pit near the plant and limestone from Steep Rock. As the slurried mixture passes through the kiln, water is driven off at 800° F, carbon dioxide is expelled at 1,600° F, and the materials react and reach incipient fusion at 2,700° F, forming a clinker. After the addition of 3.2 per cent gypsum, obtained from the Manitoba deposits, the mixture is ground and pulverized; the resulting greyish white powder is Portland cement.

TABLE 12

VALUE OF INDUSTRIAL MINERAL PRODUCTION OF MANITOBA

(in thousands of tons and thousands of dollars)

YEAR	CEMENT		CLAY PRODUCTS[1]		GYPSUM		LIME		STONE[2]		PEAT		SAND AND GRAVEL		SALT	
	tons	$	*tons*	$	*tons*	$	*tons*	$	*tons*	$	*tons*	$	*tons*	$	*tons*	$
1900..........		—	—	25	—	—	?	?	—	—	—	—	—	—	—	—
1905..........		—	—	589	4	31	?	?	—	—	—	—	—	—	—	—
1910..........	3	22	—	782	19	195	21	101	?	332	—	—	—	—	—	—
1915..........	59	625	—	94	20	140	10	71	?	153	—	—	484	204	—	—
1920..........	?	920*	—	207	44	488	21	211	?	374	—	—	?	150*	—	—
1925..........	71	1,038	—	174	35	418	16	170	53	188	—	—	727	197	—	—
1930..........	171	2,269	—	216	34	298	24	260	147	1,085	—	—	1,253	454	—	—
1935..........	47	605	—	75	10	86	19	186	147	190	—	—	1,400	405	2	19
1940..........	100	1,288	—	103	23	137	22	218	49	78	—	—	1,852	840	3	46
1945..........	168	2,028	—	270	42	307	31	313	63	86	1	43	1,497	516	27	450
1950..........	288	3,963	—	691	115	1,038	49	673	240	459	1	23	2,721	721	17	378
1955..........	340	5,509	—	636	176	291	57	886	228	1,116	6	190	5,273	1,571	19	477
1960..........	430	8,106	—	813	122	366	48	835	674	1,051	12	468	10,861	5,908	22	561

* estimated

[1] includes bentonite

[2] mainly limestone; some granite and marble

NOTE: Other industrial minerals, produced intermittently or in small quantities, include: feldspar, lignite, quartz, and silica sand.

Current annual production is about 430,000 tons. About 120,000 tons of clay from the pit at Fort Whyte are used annually.

Mafeking Quarry

The Saskatchewan Cement Company Limited operates a limestone quarry 8 miles by rail north of Mafeking (76). The rock is a high-calcium limestone from the Point Wilkins member of the Manitoba group. It is yellowish grey, dense, and fossiliferous; the $CaCO_3$ content is 96 to 98 per cent, with an average of 0.80 per cent $MgCO_3$. The rock is quarried to a depth of 30 to 35 feet. The quarry was opened in 1956, and annual production is about 300,000 tons. The quarried rock is crushed on the property and loaded in railway cars for shipment to the company's cement plant in Regina.

Other High-Calcium Limestone Deposits

The Elm Point limestone extends from Oak Point (46) northwestward along the east shore of Lake Manitoba as far as Waterhen Lake (72). However, at the south end of this belt the magnesium content is too high to permit use of the rock in Portland cement. In the Lily Bay area (48), the rock occurs under a thin soil cover and is reported to be a high-calcium limestone in part. An outlier of this formation forms the mound at Spearhill (50), where it is quarried as a source of lime. Numerous outcrops occur around Steep Rock, and several have been reported between there and Waterhen Lake.

The Point Wilkins member is best exposed in the Dawson Bay area (76); a possible equivalent of it was quarried near the town of Winnipegosis (70). Further southeast, an outcrop of limestone on the west shore of Lake Manitoba at Kinosota (55) assayed 95.70 per cent $CaCO_3$ and 0.94 per cent $MgCO_3$.

SAND AND GRAVEL

Annual production of sand and gravel has increased from 2,500,000 tons in 1948 to almost 11,000,000 tons in 1960. Sand and gravel deposits are distributed throughout Manitoba, and all have been formed as a result of the glaciation of the Pleistocene epoch. The only areas in which they are practically absent near surface are parts of the Red River valley south of Winnipeg, where the bedrock is covered by thick deposits of clay.

The most productive deposit is Birds Hill (35), 8 miles northeast of the center of Winnipeg. A ridge of sand and gravel extends 4 miles eastward from Birds Hill, and an associated deposit, Moosenose Hill, is situated to the south. The ridges rise 50 to 70 feet above the level of the surrounding plain. At the west end, Birds Hill is long, high, and narrow and consists of very coarse gravel, with cobbles up to 8 inches in diameter. Dolomitic limestone makes up 75 to 85 per cent of the gravel pebbles and the remainder are granite or granitic gneiss. The pebbles decrease progressively in size to the east, accompanied by an increasing abundance of quartz grains. Such unstable minerals as feldspar and hornblende are common minor constituents. Towards the east the gravel is medium to fine in size. A low, gently rolling sandy plain stretches to the north and east of the four-mile ridge. The gravel deposit extends below the plain level, and at one time gravel was obtained over an operating height of 90 feet. The Birds Hill deposit is believed to be the delta formed around the mouth of a large river channel pouring out of the last Pleistocene ice sheet into the deep waters of Lake Agassiz.

In southeast Manitoba, sand and gravel deposits of both the glacial outwash and the glacial lake beach types are numerous. In general, the gravel contains much dolomite and limestone in the western part of the area, whereas igneous rock fragments are more abundant towards the east. One deposit of sand of particular interest occurs near Beausejour (30). The sand is mainly free quartz, with appreciable amounts of feldspar, limestone, and mafic minerals; it assays 76 to 90 per cent SiO_2. The sand was used at one time in making green bottle glass and sand-lime brick. The deposit is owned by Alsip Brick, Tile & Lumber Company Limited; some of the sand has been used at Fort Whyte in Portland cement. Other deposits of sand and gravel occur at Vivian (31), Monominto (32), Ste. Anne (33), Marchand (34), and elsewhere, with much of the production supplying part of the Winnipeg market. In addition, numerous other pits in southeast Manitoba have been opened as a source of gravel for road-building.

Gravel deposits, the result of glacial beaches and moraines, occur in the interlake area, along the face of the Cretaceous escarpment, and on top of the escarpment. In some areas, the long glacial beaches have served as natural beds for long stretches of both road and rail. In the Assiniboine delta area east of Brandon, extensive sand dunes are present in the Carberry Hills (61). Coarse gravel occurs near the west end of the Assiniboine delta near Brandon, and glacial beaches also are present. The gravels are composed mainly of dolomite, with some granite and gneiss, and contain abundant shale pebbles derived from the surrounding Cretaceous beds. Above the escarpment, gravel is present in the terminal moraines which form the Tiger (62), Brandon (63), and Arrow (67) hills.

In northern Manitoba, esker, drumlin, and moraine deposits are abundant, and supply the gravel required by the northern mining developments, and are of importance in railway, road, and air strip construction.

BUILDING AND DECORATIVE STONE

The major building stone of the province is the famous Tyndall stone, attractively mottled, and possessing sound structural qualities. In addition, deposits of granite, marble, mottled dolomite, sandstone, and serpentine have supplied small amounts of decorative stone.

TYNDALL STONE

The Tyndall stone is a mottled dolomitic limestone which forms the upper part of the Selkirk member of the Ordovician Red River formation. The rock is exposed at Garson (29), 23 miles northeast of Winnipeg and also at East Selkirk (28) and Lower Fort Garry (27). The last two deposits were worked in the early days of settlement in the Red River valley. At present, Gillis Quarries Limited and Garson Limestone Co. Ltd. quarry the stone at Garson and both companies operate dressing plants in Winnipeg. In the past, several other quarries were worked in the Tyndall-Garson area.

The rock is composed of a matrix of light buff limestone, in which occur tubular interconnected mottled areas of brownish dolomitic limestone forming one third of the rock, and distributed uniformly throughout it. The lower beds exposed in the quarry have a bluish or greyish cast, and are used also for stone. Large fossils, usually white, are scattered through the rock, but the stone can be cut to avoid these if desired. The Tyndall stone is in nearly horizontal beds, 1½ to 3 feet thick, 11 of which are workable (see Plate XIXB). In quarrying, the first vertical cut is made by a channeling machine; the second cut is made by drilling a series of shallow holes followed by wedging to split the rock. The block is then separated from the underlying bed by wedging along the bedding plane.

DOLOMITE AND MARBLE

Other carbonate rocks throughout the province have been used at various times for building stone. The dusky yellow argillaceous dolomite of the Penitentiary member of the Ordovician Stony Mountain formation is in places strikingly mottled to shades of pale red and purple. It is exposed in the City of Winnipeg quarry at Stony Mountain (25), and is used as a decorative building stone. Some of the greyish white dolomite of the Ordovician Stonewall formation from the quarry of The Winnipeg Supply and Fuel Company Limited at Stonewall (24) has been used locally for building stone.

The buff and red mottled dolomite of the Gunton member of the Stony Mountain formation takes an excellent polish and it was quarried south of Hodgson (18) by Winnitoba Marble Company Limited. Gunton dolomite was quarried for

PLATE XVII *Tyndall limestone quarries at Garson.*

"marble" also at Cormorant Lake on the Hudson Bay Railway (79) by Manitoba Marble Quarries Limited at intervals from 1929 to 1936. Hudson Bay Marble & Granite Quarries Limited quarried Ordovician dolomite for "marble" in 1930 and 1931 at mile 69.5 on the Hudson Bay Railway (80).

GRANITE

The Precambrian area of Manitoba is underlain predominantly by granitic rocks, and in several places these have been quarried for ornamental stone. Cold Spring Granite (Canada) Ltd. is quarrying red granite on a ridge (12) a few miles southwest of Lac du Bonnet and a stone dressing plant is in operation. In the Falcon Lake-West Hawk Lake area, Winnitoba Marble Company Limited obtained a medium-grained grey biotite granite from a quarry (1), and a coarse grained black diorite from the Fortune mining claim (2). The Shoal Lake Granite Company quarried a medium-grained black diorite 3 miles northeast of Glenn (3). On the east shore of Lake Winnipeg opposite Bull Head (17) a small quarry in dark greyish red granitic gneiss was worked about 1914.

Several varieties of granite occur in southeast Manitoba, and are easily accessible in the Lac du Bonnet-Pine Falls area (13-14), and in the Whiteshell Forest Reserve.

OTHER BUILDING STONES

The Boissevain sandstone of early Tertiary age outcrops in places near the base of Turtle Mountain (64), and at one time was the source of a fair-quality sandstone used locally for building stone. The rock is a hard, greenish grey quartzose sandstone with a calcareous cement.

Serpentine was quarried in 1929 near Clangula (Goldeye) Lake (15) by Manitoba Marble Quarries Limited, but only a small amount of stone, called "black marble," was produced.

Other rocks which may be of use as decorative stone are the green-black gabbro of the Bird River sill (6) and the translucent bluish-white anhydrite at Gypsumville (51).

LIME

Limestones and dolomites are of widespread occurrence in Manitoba and three types of lime are produced from them, each of value for certain uses. In addition, the rocks themselves are of value for crushed stone, rubble, and chemical and metallurgical uses.

HIGH-CALCIUM LIME AND LIMESTONE

The high-calcium limestone of the Devonian Elm Point formation is quarried at Spearhill (50) by The Winnipeg Supply and Fuel Company Limited. Over 22 feet of brownish, rather soft limestone, assaying close to 98 per cent $CaCO_3$, occurs under a thin drift cover. After the rock is quarried, it is sized; fragments from 2 to 6 inches are used in the kilns beside the quarry, those from 2 to 5 inches are shipped to sugar factories, and those from 6 to 15 inches are sent to pulp mills. Kiln products include lump lime, pebble lime, and pulverized lime. Quicklime is converted to hydrated lime at the plant of Gypsum, Lime and Alabastine, Canada, Limited in Winnipeg.

The Winnipeg Supply and Fuel Company Limited from time to time have operated a quarry west of Winnipegosis (70) in a high-calcium limestone of the Devonian Manitoba group. The cream-coloured limestone, which assays 98 per cent $CaCO_3$, has been shipped to a gypsum plant in Winnipeg where it was made into whiting substitute. A similar limestone, of the Point Wilkins member, was once quarried by L. K. McArdle about 14 miles north of Mafeking (76). The stone was processed for poultry and hog feed in crushers on the property.

MAGNESIAN LIME AND DOLOMITIC LIMESTONE

Magnesian lime, made by calcining dolomitic limestone, has been produced in the past using waste rock from the building stone operations at Garson (29) in kilns at the properties. Other uses for the waste material included rubble, rip rap, and material for use in sulphite pulp mills.

The Elm Point limestone at Oak Point (46) was used for making lime and for crushed stone. The rock contains between 5 and 13 per cent $MgCO_3$. The property was last worked in 1924.

HIGH-MAGNESIA LIME AND DOLOMITE

Dolomite is obtained from the Ordovician Stony Mountain and Stonewall formations, the Silurian Interlake group, and the Devonian Winnipegosis formation. Numerous quarries have been operated at one time or another, and current operations are at Stony Mountain, Stonewall, and Inwood.

The City of Winnipeg operates a quarry in the dolomite cap on the northwest side of Stony Mountain (25). The rock is used for crushed stone and asphalt filler. The almost pure dolomite is part of the Gunton member and is suitable for concrete aggregate. Several older quarries in the Gunton member were once worked at Stony Mountain, Little Stony Mountain (26), Gunton (22), Birse quarry (23), and near Hodgson (18). The chief products were crushed stone, rubble, curbstone, lime, and terrazzo. Most of these sites are being currently investigated and some are in production.

Dolomite in the upper part of the Red River formation has recently been reported in outcrop a few miles northeast of Stony Mountain, and production is being considered.

The Winnipeg Supply and Fuel Company Limited operates large quarries on the north and east sides of Stonewall (24), where 8 to 12 feet of light-coloured dolomite of the Stonewall formation is quarried for the production of white high-magnesia lime and, to a lesser extent, for building stone, crushed stone, and dolomite for chemical use. Recently the company opened a quarry on Lillies farm (23), 1 mile north and 2 miles east of Stonewall and also operate a quarry at Lilyfield (26); both are in the Gunton member. Standard Cartage and Machine Rentals Limited opened a quarry for crushed stone in 1961 immediately south of the old Birse quarry (23).

Silurian dolomite of high purity is quarried by Building Products & Coal Co. Ltd. one mile north of Inwood (21). The dense creamy white dolomite is

Gypsum mine at Amaranth. PLATE XVIII

processed at the quarry for high-magnesia lime and for crushed stone. Silurian dolomite underlies much of the interlake area, and has been quarried at various times at Broad Valley (20), Lundar (47), Mulvihill (49), Spearhill (50), and Fairford (52). Farther north, it has been quarried along the Hudson Bay Railway for rock fill. Recently, Silurian dolomite has been quarried for concrete aggregate at the Grand Rapids power site (86).

The reef-type dolomite of the Devonian Winnipegosis formation contains about 99.5 per cent pure dolomite and was once quarried near The Narrows of Lake Manitoba (54).

GYPSUM

From 125,000 to 200,000 tons of gypsum are extracted annually from deposits at Amaranth and Gypsumville. Most of it is manufactured into wallboard and plaster at Winnipeg, some is used at Fort Whyte as a retarder for Portland cement, and some is sent to Saskatchewan and Alberta.

Amaranth

Western Gypsum Products Limited operates a mine one mile south of Amaranth (56), where a 40- to 45-foot layer of gypsum occurs under 90 to 100 feet of glacial drift. The gypsum is part of the Jurassic Amaranth formation. A layer of anhydrite 2 to 5 feet thick occurs about 10 feet above the base of the gypsum bed; dolomite and clay form patches or thin layers scattered through the deposit. Both massive, very fine-grained white gypsum and translucent gypsum are present.

The gypsum is mined by the room and pillar method; it is reduced to 4-inch size in an underground crusher before shipment to Winnipeg. Production began in 1930.

Gypsumville

Deposits of gypsum occur as isolated ridges immediately north and northeast of Gypsumville (51). The largest ridge extends for three miles north from Gypsumville and averages about ½ mile wide. The ridges rise 20 to 50 feet above the surrounding swampy area, but the depth of quarrying is limited by the height of the water table. At present a quarry is operated in the northern part of this ridge, and a working face from 12 to 30 feet high extends for one half mile. The original quarry was opened in 1901 in the south part of the ridge. Since 1928, the property has been owned by Gypsum, Lime and Alabastine, Canada, Limited.

The thickness of the deposit is believed to be in the order of 100 feet. Anhydrite is present in some beds, although these beds show partial alteration to gypsum. Clay is present as an impurity in places. However, the rock in the main ridge above the water table is mainly pure white or translucent crystalline gypsum, with local selenite. To the east of the main quarry, a small quarry is worked in a ridge called Elephant Hill; the gypsum is a very fine-grained white alabaster. This ridge contains also coarse selenite in cleavage plates up to 2 feet across.

Although the Gypsumville deposit is situated within the outcrop belt of the Silurian Interlake group, its age is not definitely known because of absence of exposed contacts and fossils.

Other Areas

Exploration in 1911 indicated the presence of gypsum in the area east of Dominion City (40). The area was re-drilled in 1956, and beds of gypsum were reported to occur interbedded with red shale between the depths of 325 and 400 feet. However, the thickest single bed of gypsum was 14 feet. About 1929, gypsum was reported near the surface in the west part of Charleswood (39), but exploratory shafts revealed the gypsum occurred only as boulders, some 5 feet in diameter. The outcrop belt of the Amaranth formation extends from Dauphin Lake to Gretna and into the Ste. Elizabeth-Dominion City area east of the Red River (see fig. 34). The gypsum is present under a cover of glacial drift from 10 to 300 feet thick (fig. 36).*

CLAY PRODUCTS

The clay products industry began with the manufacture of common brick from local surface clays. Later, face brick, drain tile, and hollow blocks also were made, using higher grade clays and shales. Some kaolin-type clays have been used to a small extent for ceramic objects. The glacial Lake Agassiz gumbo clay is a good bloating clay and is used in the manufacture of lightweight aggregate. Bentonite from the Morden-Miami area is used as an adsorbent and bleaching clay of high efficiency. Canada Cement Company Limited obtains clay from a pit at Fort Whyte for use in Portland cement.

BRICK CLAYS AND KAOLIN

Surface clays of a calcareous type are found in abundance in southern Manitoba, and many were used locally for common brick. The most important plants using Red River valley surface clays were at Winnipeg, St. Boniface (37), Portage la Prairie (45), Whitemouth (10), and Lac du Bonnet (13). The clay is yellow, silty and calcareous, and forms a good buff brick when burned to about 2,000° to 2,100° F. Clay from the Assiniboine delta area, obtained at Edrans (58), Sidney (60), and Firdale (59), contains more iron and burns red. The only company at present producing brick from Manitoba clays is Alsip Brick, Tile & Lumber Company Limited who manufacture common brick at Portage la Prairie.

Cretaceous shales also have been used for brick. Face brick was made at Learys (44) from the carbonaceous shale of the Morden member. The hard, siliceous Odanah shale was used at La Riviere (42) for dry-press face brick. A grey plastic semi-refractory shale from the Swan River formation would be of use for higher-grade clay products such as stoneware or sewer pipe, but only limited production from a deposit 10 miles northeast of the town of Swan River (74) has been achieved.

Large deposits of kaolinite were discovered north of Arborg (19) in 1956 by Kaolin & Minerals Exploration Ltd. The kaolin is mixed with fine silica sand, some of which is in the silt to clay size range. The material is currently being tested to determine its suitability for use in higher-grade clay products.

LIGHTWEIGHT AGGREGATE

The grey to blue glacial lake clay found at depths of 10 to 20 feet in the Winnipeg area is a good bloating clay, and when flash fired at 2,200° F, it yields a light aggregate weighing 17 to 24 pounds per cubic foot. The clay is highly plastic,

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*Since this was written, Western Gypsum Products Limited have commenced shaft sinking on a gypsum deposit outlined by drilling, 30 miles south of Winnipeg.

finely laminated, and calcareous, and occurs in a bed of fairly uniform composition up to 50 feet thick. Atlas Light Aggregate Ltd. erected a plant in St. Boniface (37) in 1954, containing a rotary kiln with a capacity of 400 cubic yards of aggregate per day and a second kiln of similar size was added in 1960. Expanded pellets with a hard vitrified coating are produced for use in light concrete blocks. Winnipeg Light-Aggregate Ltd. opened a plant and quarry in 1956 at Transcona (36), but ceased operations the next year. A new plant was opened in 1961 near Transcona by Echo-Lite Aggregate Ltd.

The clay deposit underlies most of the Red River valley, and extends from Edrans (58) to Lac du Bonnet (13).

BENTONITE

A yellow non-swelling bentonite of use in the clarification of mineral and vegetable oils is obtained from the Thornhill-Miami area (41) by Pembina Mountain Clays Ltd. The waxy bentonite is interbedded with black carbonaceous shale near the base of the Pembina member of Cretaceous age, and occurs in at least 6 main beds from 2 to 10 inches thick. First large-scale production began in 1940 from a deposit 4 miles north of Thornhill. In 1954 a new pit was opened 4 miles southwest of Miami. Quarrying operations were moved again to the area north of Thornhill in 1960. Exposures of bentonite occur at intervals along the east face of Pembina Mountain from Babcock (44) to the International Boundary.

From 9,000 to 15,000 tons of bentonite are quarried annually. It is sent to a drying plant in Morden, and then shipped by rail to an activating plant in Winnipeg where the clay is treated with sulphuric acid to increase its adsorbent capacity.

Recently a semi-swelling bentonite from the Cretaceous Millwood beds has been shown to be of value, when slurried, in the aerial control of forest fires.

SALT

The production of common salt by the evaporation of brines was the first mineral industry in Manitoba, and began in 1800 or earlier. Until 1876, up to 1,000 bushels of salt per year were obtained from natural springs issuing from the Devonian Winnipegosis formation along the west shore of Lake Winnipegosis (76). The principal source was Monkman's Springs, 12 miles north of the town of Winnipegosis (70). The concentration of the brine is between 48,000 and 62,000 parts dissolved salts per million parts of solution, much too low for present commercial production.

In 1932, Neepawa Salt Limited began production of salt from more concentrated brines encountered in a deep well at Neepawa (57). Two brine horizons were intersected, one at a depth of 1,160 feet from a porous zone within the Souris River formation and the other at a depth of 1,453 feet from the Winnipegosis dolomite. The salt concentration is 170,000 to 180,000 parts per million, of which 85 per cent is sodium chloride. A plant was erected at Neepawa to produce coarse grades of salt for agricultural and packing house use. Canadian Industries Limited purchased control of the company in 1935, and a second well was completed 2,000 feet west of the first. A new plant using the vacuum pan evaporation process was built in 1941, and a full range of fine salt products, including table and dairy salts and pressed blocks, is marketed. In addition, the combined chlorides of calcium, magnesium,

A. Bentonite quarry near Miami. The bentonite (white) is interbedded with shale (black).

B. Face of a Tyndall stone quarry at Garson.

and potassium are recovered. Current annual production of the company, now The Canadian Salt Company Limited, is about 22,000 tons of salt.

Brines with salt concentrations up to 300,000 parts per million have been intersected at depths of 2,500 to 4,000 feet or more in deep wells in southwestern Manitoba. Rock salt up to 500 feet thick within the Prairie Evaporite is present at depths of over 2,600 feet in an area between townships 1 and 26 along the west boundary of Manitoba and extending to the east side of Oak Lake (60). The brines and rock salt may be of use eventually to the chemical industry.

PEAT MOSS

Peat moss is currently being produced from the Julius bog (11) extending along both sides of the Canadian Pacific Railway 45 miles east of Winnipeg. The bog covers several square miles and the depth of peat moss in the center of the bog is 15 feet, of which the top 10 feet is good quality sphagnum moss. The moss is light yellow, slightly humified, porous, and elastic, and has a high absorptive value. It is of use for poultry litter, horticultural purposes, insulation, fertilizer, and packing material.

The Julius bog was drained in 1940, and a shredding and baling plant erected at Moss Spur by The Winnipeg Supply and Fuel Company Limited. Production began in 1941 from that part of the bog north of the railway. The plant and holdings were purchased by Western Peat Company, Limited in 1949. At one time McCabe Grain Company worked the south part of the bog and set up a small plant at Shelley, but operations were discontinued in 1946. Since 1954, annual production has increased from 6,000 to 16,000 tons.

Numerous other peat bogs, some of vast extent, occur within the province, the largest being an area stretching for 300 miles south and southwest of Churchill along the Hudson Bay Railway. Other large bogs occur at intervals on either side of the Winnipeg River between Pine Falls (14) and Pointe du Bois (9). A small bog was worked at one time near Cowan (73).

DECORATIVE AGGREGATE

Mineral deposits in the province containing material suitable for use in decorative tile and building stone include fuchsite, rose-coloured quartz, white quartz, and coloured dolomite.

Fuchsite is a bright green chromium mica which has been used as stucco dash. About 150 tons of fuchsite-bearing rock were mined in 1926 from a deposit in a narrow band of silicified basalt near the Winnipeg River (8). Small occurrences of fuchsite have been reported recently along the south shore of Oxford Lake (83).

White to glassy quartz from the Chemalloy Minerals Limited mine at Bernic Lake (7) has been used by Supercrete Ltd. as an aggregate for decorative blocks. The rose-coloured quartz that occurs in a pegmatite north of Birse Lake, 3 miles east of Bernic Lake, may be suitable for similar aggregate.

Small quantities of buff, red, and purple "marble" for use as terrazzo have been obtained from the quarry near Hodgson (18). Some of the Silurian dolomite at Broad Valley (20) could be a source of yellow terrazzo.

OTHER INDUSTRIAL MINERALS

AMBER

Amber-like resin occurs as small pellets mixed with sand and woody material along the west shore of Cedar Lake (77) in an area extending 3 miles south from the discharge point of the Saskatchewan River into the lake. The resin is less transparent than true amber, and of slightly different chemical composition. Amber material has been reported also from some of the bays at the south end of Moose Lake (78). These areas will be flooded following completion of the power development at Grand Rapids.

ASBESTOS

Several small occurrences of short-fibre asbestos have been discovered in Manitoba, but no development work has been undertaken. Small veinlets of short-fibre asbestos, probably chrysotile, have been reported in ultramafic bodies at the west end of Knee Lake (84), on an island at the west end of Lake Athapapuskow (81), and at Garner Lake (4). Short, brittle fibres of tremolite asbestos occur as alteration patches in a peridotite east of Clangula Lake (15). Canadian Nickel Company Limited owns a nickel property on islands at the west central end of Island Lake (85), where very short-fibre chrysotile asbestos also occurs in the small serpentinite body.

CHROMITE

The chromite deposits of the Bird River sill (6) have been described in Chapter III. Large tonnages of low grade chromite ore have been outlined, but the low chrome:iron ratio, about 1.5:1, will require a special metallurgical process as chrome ores currently worked elsewhere have a 3:1 chrome-iron ratio.

COAL (LIGNITE)

Low-grade coal of the lignite variety occurs in 2 or 3 seams 2 to 4 feet thick within the Tertiary Turtle Mountain formation in the Deloraine-Goodlands area (65). Two small mines operated from 1896 to 1908; limited production for local consumption was attained from 1931 to 1943. From 1,000 to 4,000 tons of lignite were produced annually. The lignite has approximately the same calorific value as the Souris coal of Saskatchewan, but cannot compete with the large tonnages of easily mined lignite available there.

MANGANESE

Manganiferous ironstone nodules occur within the Cretaceous shales, and in places manganese bog deposits have been derived from them. The deposits were investigated during World War II, but no development work resulted. Nodules in the Porcupine Mountain area (75) contain 10 to 18 per cent manganese, but they form only 10 per cent of the formation. Bogs along the south flank of Riding Mountain (69) and near Roseisle (43) contain higher grade material but are of very limited tonnage.

PEGMATITE DEPOSITS

Pegmatites containing lithium minerals, caesium-bearing pollucite, beryl, quartz, feldspar, cassiterite, and tantalite-columbite occur in the Precambrian Shield (5, 7, 8, 82) and have been described in chapters III and IV.

POTASH

Beds rich in potash salts occur in the upper part of the Devonian Prairie Evaporite in a narrow area along the west edge of the province from township 4 to township 21. The potash occurs at depths ranging from 2,560 feet in the north to 4,400 feet in the south. S. A. M. Explorations Ltd. drilled the northern part of the area (68) from 1956 to 1958, and their 3 wells indicated a potash bed 6 to 8 feet thick, grading 25 per cent K_2O or better, consisting mainly of sylvite (KCl) and halite with small amounts of carnallite ($KCl.MgCl_2.6H_2O$) and clay. The property was acquired by Tombill Mines Limited in 1959, and 2 more wells indicated a bed of similar grade and thickness.

SILICA SAND

A deposit of silica sand, part of the Ordovician Winnipeg formation, has been worked at intervals along the northwest and southeast shores of Black Island (16), Lake Winnipeg. The sandstone is formed of loosely bonded rounded quartz grains, and has an SiO_2 content from 95 to over 99 per cent. In the early 1930's it was used in bottle glass and as a molding sand in foundries. The Selkirk Silica Co. Ltd. worked the deposit from 1956 to 1959, and erected a washing and screening plant at Selkirk.

Other deposits containing silica sand have been reported from Swan River (74), Pine River (71), and north of Arborg (19).

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CHAPTER VII

PETROLEUM IN MANITOBA

HISTORY

The history of mineral exploration in southwestern Manitoba dates from 1873 when the Geological Survey of Canada drilled a series of geological test holes, However, these and most other wells drilled in Manitoba prior to 1900 were mainly to test for water, coal, or other mineral deposits, and the stratigraphic information obtained was largely incidental. Between 1900 and 1949 drilling devoted solely to oil and gas exploration was carried out by a number of companies, and wells were drilled as deep as 2,000 feet into the Mesozoic and Palaeozoic sedimentary rocks in the southwestern part of the province. Insignificant gas accumulations, sufficient only for limited domestic use, were encountered in a few wells; such occurrences were limited to minor gas pockets in the Cretaceous shales of the Favel and Riding Mountain formations. Gas was found also in Pleistocene sand and gravel beds overlying the Cretaceous shales; apparently this gas had migrated into the sands from the underlying shales. Traces of helium have been reported in gas from a well near Lundar; small amounts occur in several other places in Manitoba.

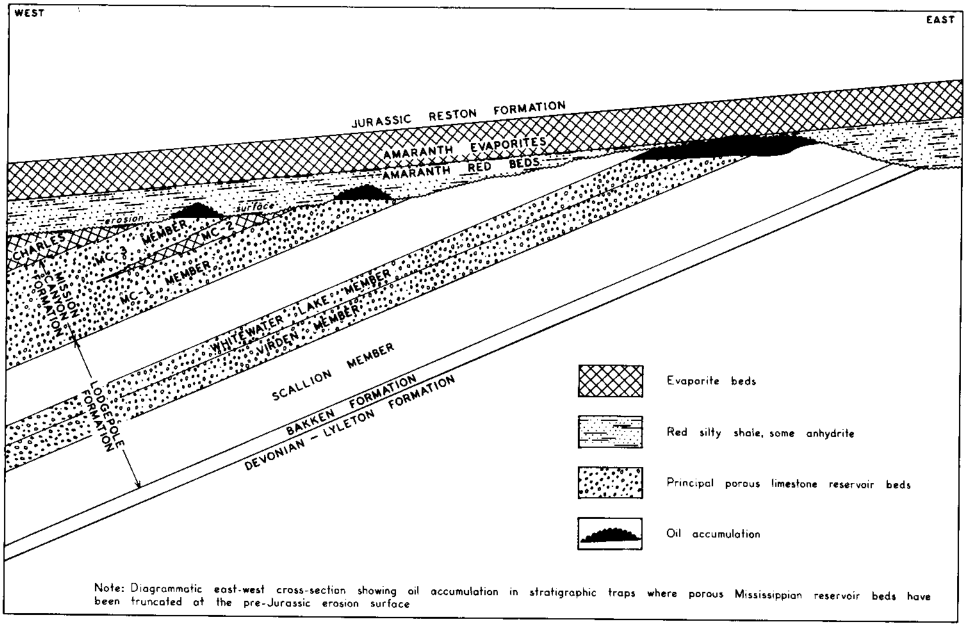
In 1949, the first significant deep test hole was drilled in the extreme southwestern corner of the province. The Souris Valley Gordon White 5-14-1-28 well penetrated over 5,000 feet of Mesozoic and upper Palaeozoic strata, and indicated the presence of a maximum thickness of 7,000 feet of sedimentary rocks in this area. Although no oil "shows" were reported, samples revealed the presence of a thick section of Mississippian limestone containing porous beds. As Mississippian rocks were known to be absent to the northeast, it was evident that a thick erosional wedge of Mississippian strata was present below the Mesozoic formations, as shown in Figure 3. This wedge of sedimentary rocks forms a stratigraphic trap, and the knowledge of the existence of this trap led to intensified exploratory drilling which resulted in January, 1951 in the first producing oil well in Manitoba.

The discovery well was Calstan Daly 15-18-10-27. Although only limited oil was produced from this well, its presence eventually resulted in development of the 175-well Daly Field, now the third largest in Manitoba, with total cumulative oil production of more than 8,200,000 barrels to December, 1961.

Exploration continued at a rapid pace following the original discovery and by December, 1961 fourteen separate oil fields had been defined; oil also occurs in 21 other "producing areas" which are not of sufficient size to be classed as fields. The three main fields are, in order of production, North Virden Scallion, Virden-Roselea, and Daly, each of which has yielded production in excess of 8,000,000 barrels of oil. The names and locations of the fields are shown in Figure 34, and the value of the annual oil production is shown in Figure 1.

THE OCCURRENCE OF OIL

All oil production in Manitoba has been from strata of Mississippian age, and only slight oil shows have been reported from any other formations. The Mississippian oil fields occur in stratigraphic traps where individual porous limestone reservoir beds are truncated at the pre-Jurassic erosion surface (Fig. 39), and oil has accumulated beneath the impermeable Jurassic shales and evaporites at depths ranging from 1,900 to 3,300 feet. The occurrence of the Mississippian strata where they "subcrop" at the pre-Jurassic unconformity is shown in Figure 34. The principal reservoir beds are the MC-1 and MC-2 members of the Mission Canyon formation, and the Virden, Whitewater Lake, and uppermost Scallion members of the Lodgepole formation (Fig. 39). The source of the oil trapped in these reservoir beds presumably is the thick sequence of dark bituminous Mississippian limestones found deep in the central part of the Williston Basin. Oil migrated up-dip from these source areas until it was trapped below the impermeable beds at the Mississippian erosion surface.



Note: Diagrammatic east-west cross-section showing oil accumulation in stratigraphic traps where porous Mississippian reservoir beds have been truncated at the pre-Jurassic erosion surface

FIGURE 39 *Mississippian Cross-Section and Oil Traps*

Although the principal factor controlling oil accumulation is the truncation of the porous formations at the erosion surface, it is evident from Figure 34 that oil does not occur everywhere along the subcrop belts, but is localized in certain areas. The principal factors controlling oil localization in southwestern Manitoba are: differential dolomite and anhydrite alteration of Mississippian beds immediately below the pre-Jurassic erosion surface; structure; palaeotopography; and primary lithologic or facies changes.

DOLOMITE AND ANHYDRITE ALTERATION

Although the Mississippian oil fields occur at or near the truncated edge of the reservoir beds, the impermeable cap rock which prevents escape of oil from these beds is not, in most cases, the overlying Jurassic shales, but rather the closely associated zone of secondary dolomite and anhydrite alteration of the uppermost Mississippian beds. This alteration of the Mississippian limestones occurred during deposition of the Amaranth Red Beds and Evaporites (Fig. 39), and is related to the saline conditions prevailing at that time. The alteration zone varies considerably in thickness and oil accumulation is possible in those areas where the alteration zone is thinner than normal. In some instances the thickness of the alteration zone has been controlled by the presence of topographic highs on the pre-Jurassic erosion surface (i.e., palaeotopography); these highs may have tended to either increase or decrease the thickness of the dolomitized zone.

In addition to controlling the location of oil accumulation, this secondary alteration zone has affected greatly the reservoir performance within the field areas. In some instances porosity and permeability have been reduced by dolomitization and anhydrite infilling; in others, leaching has occurred, resulting in the development of intergranular to coarse vuggy porosity as in the North Virden Scallion Field. However, there does not seem to be any predictable pattern to these secondary alteration effects, and this has made both exploration and field development more difficult.

STRUCTURE

Structurally high areas, especially at or near the subcrop of the porous beds, normally afford excellent sites for oil accumulation. However, very few structural highs are known to exist in Manitoba and with the possible exception of the Daly field area have had little effect on oil accumulation. Most of the known structures are synclinal lows, and even these probably are purely "superficial" structures resulting from solution of deeply buried Devonian salt beds, with resultant collapse of the overlying strata. These lows are unfavorable for oil accumulation and in the Daly and Virden areas, where they are particularly numerous, they have to a considerable extent delimited the areas of oil accumulation.

A further possible important factor controlling oil accumulation is the relationship between the regional southwest dip of the erosion surface and the trends of the subcrop belts on this erosion surface; the Mississippian subcrop belts do not parallel the structure contours. In the case of the Lodgepole strata, the elevation of the subcrop belts rises to the northwest; consequently, any oil that had been trapped at the unconformity would have tended to migrate up the subcrop belt until trapped by some structural and/or stratigraphic barrier. This may possibly account for the large oil accumulation in the Virden area, and the relative lack of accumulation in the same porous Lodgepole beds to the southeast. In the case of the Mission Canyon strata, the situation is reversed, and the subcrop belts rise to the southeast rather than to the northwest.

PALAEOTOPOGRAPHY

Palaeotopography refers to the relief developed on an ancient surface of unconformity that subsequently has been buried by younger strata. Palaeotopographic highs form favorable sites for oil accumulation as in the Whitewater, Lulu Lake, Tilston, and Pierson field areas. In some instances, the palaeotopographic features are controlled purely by "accidental" variations in the amount of erosion; in other instances, they are controlled by the nature of the strata occurring at the erosion surface. The presence of either highly resistant or easily eroded strata causes differential erosion and results in formation of ridges or escarpments. Finally, palaeotopography may be controlled by structure. Where deformation has occurred prior to erosion, the structure is truncated and little or no evidence of the structure is discernible on the erosion surface but, where deformation has occurred during erosion, a structurally controlled palaeotopographic feature is formed. All of these types of palaeotopographic features have been noted in Manitoba, and all have been important factors in controlling oil accumulation.

LITHOFACIES VARIATIONS

Definite lateral variations in type of sedimentary deposit occur within the Mississippian strata, especially in the Lodgepole formation. To the east, the Lodgepole sediments, calcarenites and fossil-fragmental limestones, are generally fairly coarse grained and porous. To the west, they are finer grained, more argillaceous, and consequently less porous. The trends of these "facies" are approximately north whereas the subcrop belts trend northwest. This results in a general decline in porosity of the reservoir beds to the northwest, along the subcrop belt, and possibly determined the northwestward limit of oil accumulation along the Virden-Whitewater Lake subcrop belt.

OIL POTENTIAL

Although more than 1,500 wells have been drilled to test Mississippian strata, the potential areas have not been exhausted, and some further exploration may be expected along the favourable subcrop belts. However, future exploration in Manitoba will also involve testing Ordovician, Silurian, and Devonian strata. Production is obtained from these rocks in the deeper parts of the Williston Basin, in North Dakota and Montana. The traps in these areas are primarily major structural anticlines; although similar anticlines are not expected in Manitoba other suitable structures may be present. Possibility of economic oil accumulation in the Jurassic and Cretaceous strata of Manitoba is considered slight, although lenticular Jurassic and Cretaceous sands offer some possibility for oil entrapment.

To date, only about 90 test holes have been drilled through the Devonian strata, in a total area of over 70,000 square miles; 73 of these have penetrated the entire Palaeozoic section. The remaining holes test only the Mississippian or the uppermost beds of the Devonian. Oil shows have been reported in the lower Palaeozoic strata in a few wells. Stratigraphic conditions for the upper part of the Devonian are essentially the same as for the Mississippian, with porous beds truncated at the pre-Jurassic surface and overlain unconformably by Jurassic shales and evaporites. Accumulation in stratigraphic truncation traps should, therefore, be possible (see Figure 34). The younger (Jurassic and Cretaceous) strata, however, are exposed at the present day erosion surface or are covered by only a thin mantle of glacial deposits and accumulation of oil at the exposed edge of these rocks is virtually impossible because of the lack of an impermeable cap rock.

Because of the relative lack of deep drilling, the structure of the lower Palaeo-

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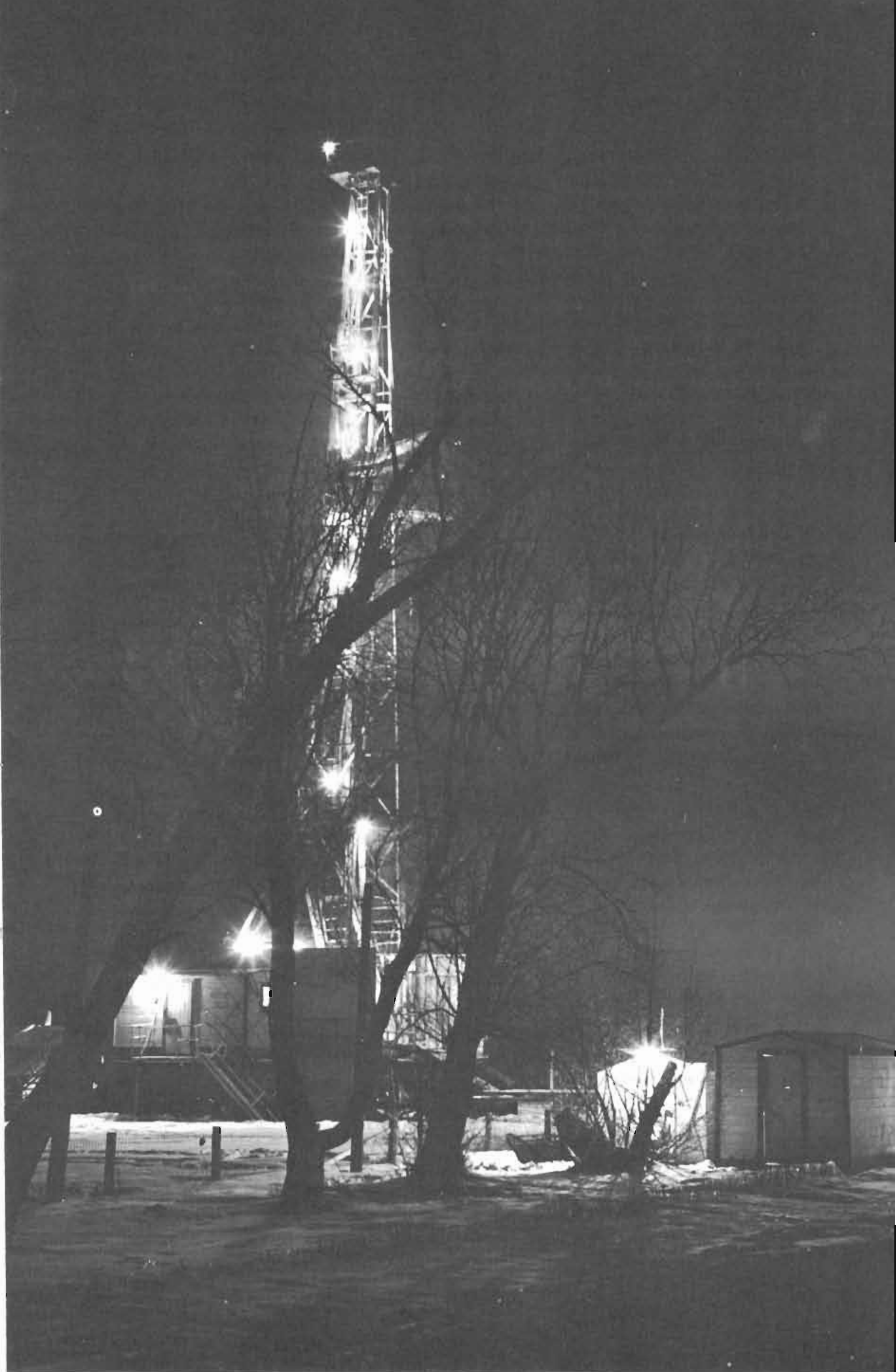
PLATE XX

Oil drill rig at night, Virden. ⋙——➤



zoic strata is not well known. As indicated previously, the complex local structures in the Mississippian and upper Devonian may be due to Devonian salt collapse, and may not reflect lower Palaeozoic structures; no definite lower Palaeozoic structures have been defined as yet.

Stratigraphic traps due to lithologic or facies changes appear to offer some possibility for oil accumulation in the lower Palaeozoic rocks although, with but two notable exceptions, the Lower Palaeozoic strata of Manitoba are noted more for uniformity than for facies changes. The two most promising exceptions are the Devonian Winnipegosis dolomite and the Ordovician Winnipeg sandstone. Although the Winnipegosis is relatively uniform in the shelf areas, marked variations in thickness, due to local reef development, occur in the western part of the province, at the edge of the Devonian Elk Point Evaporite Basin. Reefs up to 335 feet thick have been encountered in the general Winnipegosis-Swan River area, but to date no promising oil shows have been reported, either in Manitoba or in similar reefs along the northeastern edge of the basin in Saskatchewan. In these areas, the associated Prairie Evaporite salt beds apparently have been removed by post-Devonian salt solution, and possibly the remaining strata do not form a sufficiently impermeable cap rock. However, in the area of the Imperial Madeline Prov. 16-18-18-29 well, a thick reef section was encountered where the overlying salt has not been removed. Although no oil shows were indicated in this well, it is possible that structurally higher parts of the reef, or other similar reefs, could be oil-bearing.

The other unit showing pronounced lithofacies changes is the Winnipeg formation. Thick discontinuous sandstone lenses occurring within the Winnipeg shale have high porosity and permeability but little evidence of oil staining has been reported from these strata, and their potential is uncertain. Other less well-defined stratigraphic (facies) traps may occur within the other Lower Palaeozoic strata.

In addition to the 70,000-square mile area of sedimentary rocks in the southwestern part of the province, a second area comprising roughly 25,000 square miles of Lower Palaeozoic rocks occurs in the Hudson Bay Lowlands, in the northeastern part of the province. Very little is known about these strata because of the inaccessibility of the area and the generally thick drift cover, but they probably represent what was originally an extension of the Lower Palaeozoic shelf carbonates of southwestern Manitoba. The area remains virgin territory for oil exploration. During 1960 and 1961, several diamond drill holes were drilled through the Palaeozoic rocks to test geophysical anomalies in the underlying Precambrian. These holes indicated a thickness of more than 500 feet of Palaeozoic strata, including more than 50 feet of Winnipeg sandstone in one area.

In 1962 a syndicate was organized to acquire oil exploration rights in an area near York Factory. Exploration both within the boundary of the province and under the adjacent parts of Hudson Bay is planned.

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INDEX

NOTE: Common rock and mineral names, such as andesite, basalt, granite, etc., which occur on innumerable pages of the text, and many locality names have been omitted from the index.