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DEPARTMENT OF MINES AND NATURAL RESOURCES

PROVINCE OF MANITOBA

MINES BRANCH

EXPLORATION TRENDS IN MANITOBA[1]

by

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The object of this review is to invite attention to the vast untapped mineral resources that await exploration and development in Manitoba's Precambrian regions. The rich and extensive copper-zinc deposits of the Flin Flon-Snow Lake belt are now well known and more recently, the Thompson Belt is being revealed as one of the world's major sources of nickel. Nickel-copper ores in Manitoba already contribute 22% of Canada's nickel production which represents 80% of world output. Both the Flin Flon-Snow Lake area and the Thompson Nickel Belt are now the scene of intensive exploration and development that will undoubtedly continue for many years. Development of new mines in Manitoba will receive great impetus from Manitoba Hydro's Nelson River - Churchill River engineering project that will supply power to the entire mining industry in the 1970's, following capital investments of the order of one third of a billion dollars. Construction of the main dam at Kettle Rapids on the Nelson River is now in progress.

The present paper touches upon some of the less explored regions that will become of increasing interest as development plans proceed in the next few years.

CHURCHILL PROVINCE

The Manitoba portion of the Churchill geologic province includes the NE-SW Nickel Belt which is parallel to the Churchill-Superior tectonic contact. The Churchill province with a maximum known age of 1750 million years is younger than the Superior province to the southeast from which it differs significantly in lithology, structure and metamorphism as illustrated by the following comparisons (Davies 1962, 1967):

1. The Churchill province contains a lower proportion of volcanic rocks and its stratified rocks are predominantly of sedimentary origin.

2. Its stratified rocks are more complexly folded than those of the Superior province.

3. In spite of their generally younger age, the Churchill stratified rocks appear to be more highly metamorphosed than those of the Superior.

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1 A paper presented with the permission of the Honourable Donald W. Craik, Minister of Mines and Natural Resources, Manitoba, at the Thirty-sixth Annual Convention of the Prospectors and Developers Association, March 10 to 13, 1968, at the Royal York Hotel, Toronto, Canada.

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Present producing mines in the Churchill Province are: (Cu-Zn) Hudson Bay's Flin Flon, Schist Lake, Chisel Lake and Stall Lake, with Osborne Lake scheduled to commence this year; (Ni-Cu) Inco's Thompson, with Birchtree and Soab due this year; and Sherritt Gordon's (Ni-Cu) Lynn Lake "A", Farley and new openpit. The main developers are: Inco's (Ni-Cu) Pipe Lake; Hudson Bay's (Cu-Zn) Anderson Lake and possibly Dickstone copper; and Sherritt Gordon's (Cu-Zn) Fox Lake.

An exploration trend in recent years has been the recognition that while volcanic and associated intrusive rocks are favourable hosts for primary mineralization, subsequent metamorphic and deformational processes have led to reconcentration of the metallic minerals. The metamorphic contrast between relatively low-grade volcanic rocks at Flin Flon and the Kisseynew gneisses at the old Sherridon mine has long been known, but this has been emphasized by more recent mining developments in the Snow Lake area: the host rock of the Chisel Lake zinc orebody, for example, is garnetiferous biotite gneiss, but a volcanic source is suggested by the nearby andesite contact. Ore deposits in metamorphic rocks do not necessarily require a high grade of metamorphism, but rather retrogressive hydrothermal metamorphism of the type that causes liberation of iron and associated metals from the ferromagnesian minerals. This type of metamorphism is common in granitized terrain and an idealized sequence of events that can be relevant to metallic mineralization includes:

(i) Initial fixation of metallic elements in volcanic rocks near volcanic centres.

(ii) Concentration of metallics in the course of propylitization (and related lowgrade hydrothermal alteration) of early volcanics by later flows and hypabyssals.

(iii) Dispersal of metallics during regional metamorphism with possible fixation in ferromagnesian minerals.

(iv) Breakdown of high-grade metamorphic minerals during retrogressive metamorphism at late granitization stage, and reconcentration of metallics in hydrothermal environment.

Lynn Lake Area

Of the three major mineralized zones so far known in the Churchill province, the Lynn Lake region has been the least explored and, therefore, warrants present attention.

In the 1930's, reconnaissance mapping by the Geological Survey of Canada was concurrent with the early gold prospecting which led to activity 20 miles southeast of Lynn Lake by Sherritt Gordon Mines Limited just before the war; after considerable drilling in this area, Sherritt Gordon became active at Lynn Lake with geophysics and diamond drilling in the late 1940's and by 1950 had outlined 14 million tons in 11 orebodies. By the time the 144 miles of railway had reached Lynn Lake in 1953, Sherritt had moved almost the whole town and mine plant of Sherridon to Lynn Lake by tractor train and had the first concentrate ready for shipment.

By 1956 the Mines Branch had completed 14 maps of the Lynn Lake and adjacent areas at 1 mile to the inch. In 1957 Milligan revised and enlarged upon this work in his regional study of the structure, metamorphism and mineralization covering 3,630 square miles. Meanwhile the extensions of the greenstone belt for 50 miles southeast of Barrington Lake were being mapped (1955-61) and the results were published as six 1-mile sheets. As yet, relatively little exploration has been done in this large extension, but the recent completion of a 30-mile all-weather highway (open in 1968) by the Manitoba Government from Lynn Lake to Hughes River will give easy access to favourable areas.

Milligan summarized the geological sequence in the Lynn Lake area as:

(i) Deposition of the Wasekwan volcanic group.

(ii) Intrusion by gabbro, tonalite and biotite granite.

(iii) Deposition of Sickle sedimentary group.

(iv) Intrusion by diorite, tonalite, microcline granite, pegmatite, quartz-feldspar porphyry and late lamprophyres.

Metamorphism of parts of the Sickle and Wasekwan groups gave rise to gneisses of the Kisseynew type. The Lynn Lake Ni-Cu orebodies occur in gabbro plugs that have intruded Wasekwan volcanics and sediments; the sulphides are mainly pyrrhotite, pentlandite and chalcopyrite and the host rocks are extensively altered to talc, serpentine and amphibole. From Milligan's description, one interpretation could be that the gabbro plugs have late volcanic affinities and that they were hydrothermally altered and mineralized during retrogressive metamorphism at a later granitization stage.

Fox Lake (Copper-Zinc)

Plans have recently been announced to bring the Fox Lake copper-zinc property into production in 1970. This lies 28 miles southwest of Lynn Lake and its discovery, credited to airborne geophysics, was announced by Sherritt Gordon in 1961. The deposit was outlined by 41 drill holes totalling 26,292 feet to an effective depth of 1,000 feet. It is located in greenstones and interbanded sediments one mile west of the Snake Lake gabbro. The orebody consists of a lenticular mass of pyrite with subsidiary chalcopyrite and sphalerite, about 1500 feet long and 80 feet wide, dipping steeply north. Drill-indicated reserves are 12,269,000 tons averaging 1.74% copper and 2.35% zinc. Planned mill output is reported to be 3,000 tons per day and a concentrator is to be constructed at the mine. Significant amounts of gold and silver remain in the copper concentrate. The production shaft reached 1400 feet in January and is to be extended to 2350 feet. In addition to the main orebody, there is a large tonnage of massive pyrite containing an estimated 0.41% copper and 2.38% zinc per ton; plans for the recovery of sulphur from pyrite have been reported. Davies (1962) wrote that other copper-zinc occurrences are present in the general vicinity of Fox Lake and, indeed, in almost all the greenstone horizons of the Lynn Lake area. He also pointed out an extensive gold potential.

Agassiz (Gold)

Development of a new gold property is sufficiently unusual nowadays to attract attention, and background information concerning the gold-bearing deposit five miles northeast of Lynn Lake, owned by Agassiz Mines Limited, is therefore included here to illustrate the multi-metallic nature of the mineralization in this area. The earliest available information records ground magnetic surveys by Noranda in 1947; anomalies were attributed to magnetite and this was confirmed by Agassiz when they drilled the property in 1955, but two of their holes encountered gold, silver, zinc and nickel. A Loop-Frame electromagnetic survey then indicated several weak conductors, five of which were drilled, revealing sulphides low in gold, while a sixth gave interesting gold values. Nine more holes were then drilled in this vicinity confirming significant gold values. A resistivity survey in 1956 was followed by 6 drill holes, one of which yielded scattered gold values attributed to a southeast extension of the 1955 discovery.

The general geology was reported as a broad belt of andesites, volcanic fragmentals, greywacke and argillite. Massive older granite was recorded to the southeast and also numerous stocks of younger granite, including one only half a mile northwest of the claims. On its contact, massive pyrrhotite, pyrite, chalcopyrite and sphalerite were reported in volcanics and sediments, and it was noted that all country rocks except the younger granite were intruded by basic plugs, some of which, as at Lynn Lake, were hosts for nickel-copper-cobalt sulphides.

The mineralized zone at the Agassiz claims appeared to be in a plug-like mass of amphibolite, slightly elongated parallel to the regional strike, plunging steeply and widening with depth. Shears and fractures are filled by carbonate and quartz with relatively abundant sphalerite and galena, and subsidiary pyrrhotite, pyrite, arsenopyrite and chalcopyrite. The carbonate is finely brecciated and native gold and silver were occasionally visible. A second type of ore was described as massive, fine-grained arsenopyrite with high gold values and remnants of carbonate gangue. A third type was fine, banded pyrite with minor chalcopyrite and arsenopyrite, replacing tuff bands in the amphibolite and carrying gold values.

Intensive drilling of the ore zone in 1966 recorded the host-rocks as amphibolite, andesite and amphibolitized andesite; minor diorite and quartz diorite did not appear to carry appreciable gold. The ore zone is dominated by numerous mineralized veins trending northeast-southwest and cutting a series of northerly faults. Nine sub-zones have been reported by Agassiz to have an aggregate tonnage of over 1 1/2 million, and an additional 900,000 tons is inferred by the company. In February 1968, Agassiz announced plans for shaft-sinking to 300 feet, to be followed by 2000 feet of lateral development at two levels. Drilling from underground sites is planned to test the depth extensions.

SUPERIOR PROVINCE

Dr. Davies (1967) indicated that the Superior Province is characterized by easterly trending volcanic-sedimentary belts with associated east-west faults, and a mean orogenic age of 2500 million years. He pointed out that the conception of Superior as a "gold province" may be a generalization based on insufficient

evidence because, apart from the extreme southeast, metallic exploration has been very limited. Indications that the Superior province contains other metallic concentrations (apart from gold) appear at: God's Lake and Oxford Lake - copper; Island Lake - nickel; Bird River - chromium, nickel, lithium and tantalum.

Further indications that a region of 10,000 square miles east of Lake Winnipeg warrants exploration for base metals are arising as a background to the Project Pioneer work (described below). Professor H.D.B. Wilson, in a recent progress report, states that related regional geophysical and geological work by the University of Manitoba is revealing great fractures and previously unrecognized metamorphosed volcanic-sedimentary belts that may well be mineralized. He points out that existing geological maps of this region were compiled 35 years ago by a single survey geologist using largely non-geological summer assistants, and that mapping standards of that time are now obsolete in highly metamorphosed rocks. This region is especially attractive as regards situation and access, and re-mapping is urgently needed as a basis for mining exploration.

A significant development in 1967 was the formation of the Tantalum Corporation of Canada to mine deposits of tantalum in the extreme southeast at Bernic Lake. Interest in tantalum arose from a re-examination of the extensive lithium pegmatites in this area, which had (according to company sources) indicated lithium reserves of approximately 6 million tons grading 2.14%. Exploration by companies associated with the Corporation led them to report tantalum reserves of two million tons running between 0.24% and 0.25% tantalum pentoxide; 300,000 tons of pollucite ore had previously been reported with more than 20 per cent cesium oxide.

A major exploration company has investigated a strong northwest structural and magnetic trend along a zone containing some serpentinite bodies near the east shore of Lake Winnipeg. The greenstones of Horseshoe Lake have also been the scene of some activity. Lastly, in the extreme southeast, south of the Trans-Canada Highway, anomalies due to pyrite-pyrrhotite have been drilled.

Manitoba's plans to stimulate development of this vast region include:

1. The Mineral Exploration Assistance Act, for which 1967 was the first operative field season. Agreements have been initiated concerning 9 exploration programs totalling $103,000.00. Upon completion of these programs, Crown grants will cover 50% of the approved costs.

2. Project Pioneer (Davies 1966).

3. Long-term plans for extended geological mapping.

Project Pioneer

Manitoba's only producing gold mine, San Antonio, is situated in the Bissett greenstone belt, in the southeast part of the Superior province. Two years ago, Dr. Davies described the initiation of the Pioneer joint research project along this belt by geologists of the Manitoba Mines Branch and the University of Manitoba. To date something like 600 square miles have been intensively mapped by five government geologists and their assistants, with particular attention to structural,

petrological, metamorphic and related problems. Concurrently the university has undertaken four types of geophysical investigation: seismic, magnetic, gravity and radiometric. The Geological Survey of Canada has recently commenced an airborne electromagnetic research program over 260 square miles of the area, involving 700 line miles. Detailed studies are being made of the economic geology in order to evolve principles and techniques that could be generally applied.

Laboratory work and interpretation of field data are now in progress, utilizing punched cards and computer analyses. Overall conclusions can only be made when all these various lines of research have been completed and co-ordinated, a task that will take another two or three years. Meanwhile, I am indebted to Professor Bruce Wilson for the following commentary, taken from a recent progress report.

Seismic Research

The seismic program applies explosion seismology techniques to a Precambrian mining area. These techniques, which outline geological formations and structures, were developed largely by petroleum companies for near surface exploration, but they have now been applied to a depth of some 25 miles in and adjacent to the Pioneer area. A seismic refraction method was first employed, recording at distances up to 150 miles. Initially, the Pioneer area was co-ordinated with a survey in Ontario where the seismic group was already working.

The studies have indicated greater relief than had been expected in the major crustal layers. The new continuous coverage method should make it possible to detect and measure large faults, to observe what happens to large granitic intrusions at depth, and to determine the depth of the volcanic-sedimentary greenstone belts. This method lends itself to the construction of a "record section" similar to those used in oil prospecting. The recording is on tape, which allows playback with optimum gain and frequency characteristics to produce high-quality record display. The tape records are converted into digital form suitable for computer processing. By means of a computer plotter system it may be possible to transform the original record section into a seismic interpretation of the subsurface.

The regional programme has produced detailed depth measurements to the Conrad and Moho discontinuities indicating that the Pioneer area overlies a depression in the intermediate layer of the crust, resulting in an abnormal thickness of the upper or granitic layer which is bounded by fairly steep sides.

Several tests were made in 1967 to determine the velocity of earthquake waves in the various rock types of the Pioneer area. These velocities are required for the projected detailed interpretation of rock type distribution along the continuous profile and will be applicable elsewhere in the Canadian shield.

Magnetic Investigations

Oriented specimens have been collected and magnetic susceptibility of the rock formations has been measured. The magnetic attraction of the various rock units was tested by ground traverses to aid in interpretation of the new aeromagnetic data.

A computerized smoothing technique applicable to aeromagnetic maps has been developed to delineate regional magnetic anomalies. Thus it is now possible to separate regional from local magnetic anomalies on all aeromagnetic maps being published by the joint Federal-Provincial aeromagnetic survey.

Magnetic interpretation has been extended outward from the Pioneer area to show the magnetic background as well as regional variations within the area. The resulting magnetic map covers a major portion of the Superior province, extending from longitude 92° to 97° between latitudes 49° and 55°. Similar smoothing techniques have been applied to the remaining published aeromagnetic sheets in Manitoba south of latitude 56°. The technique is now developed to the stage where unspecialized staff can select magnetic values from a map grid. These are then fed to the computer which draws the regional magnetic map. Thus it will be a simple procedure to complete such a map for the whole province of Manitoba.

The separation of regional from local magnetic attraction which has been established from Project Pioneer is a basic requirement for the new mathematical research for interpretation of magnetic anomalies. It is hoped that such interpretations will establish the form and nature of the magnetic material, so that test-holes can be sited for suspected ore anomalies.

The Pioneer Work has shown that some regional anomalies reflect shallow crustal structure, while others are related to deep crustal structure. Depth to the Conrad discontinuity can be calculated from the regional magnetic data. This gives a cheap, effective way of extending the more costly seismic work as an aid to interpreting regional geology.

The magnetic work in the Pioneer area is now considered complete except for co-ordination of the results with data from the other studies still in progress.

Gravity Studies

These studies determine variations in the earth's gravitational field and interpret them in terms of sub-surface rock distribution. The instrument used is the Worden Gravimeter (Master Model) which is sufficiently sensitive to detect changes in gravitational attraction of 1 part in a total field of 24 million.

The Pioneer data will bear on the dimensions and orientation of the intrusive bodies and the rocks they have intruded, and the amounts of dislocation on major faults. Coupled with regional surveys carried out by the University and the Dominion Observatory, these studies will also add to our knowledge of the gross structure and composition of the earth's crust in Manitoba. Possible economic applications are exemplified by the University's regional gravity work in northern Manitoba which established a relationship between nickel deposits and a major gravity anomaly; this relationship has served as an important exploration principle for many of the companies now exploring for nickel.

The Pioneer work has established gravitational data at 650 observational sites, and the data obtained has been fully reduced by computer programmes developed at the University. This work will continue during 1968, after which the interpretation phase will begin.

Radiometric Survey

The gamma-radiation scintillation spectrometer is the newest tool yet devised for the detection and measurement of radioactivity. It possesses a three-radiation-level discriminator to measure radiation from high energy sources such as uranium, medium energy sources such as thorium and low energy sources such as potassium. This three-fold discrimination makes this instrument useful both as a uranium-thorium prospecting tool, and as a means of studying the potash content of various rocks.

This instrument was designed and manufactured in Winnipeg for the University, and 405 readings have been recorded to date in the Project Pioneer area.

A test survey has been made across one of the intrusive bodies and radiation levels have been compared with the gravity measurements.

A regional survey of the southwest portion of the area is planned for 1968.

Volcanology

It is apparent that most base metal orebodies in the Canadian shield are associated with volcanic rocks, but few Precambrian geologists have specialized knowledge of volcanology.

In 1967 a volcanologist joined the Pioneer team to study Precambrian volcanism after receiving his training and mapping experience in recent volcanic rocks. Primary volcanic features such as tuff breccia, crystal tuff, lithic tuff, lahar deposits, aquagene breccias, accretionary lapilli, ropy lava, volcanic pipes, and landslide and flow breccias have been identified and such features will be traced through the various metamorphic stages in order to establish the complex volcanic sequence of the Pioneer area. Chemical and petrographic studies, applicable to petrogenesis and ore exploration, have been commenced. This work will also provide supplementary data on regional structure, geomorphology and glacial geology.

Photogeology

Photolineament maps have been compiled for most of the Pioneer area and it is intended to extend the coverage into peripheral areas. These studies are designed to enlarge the scope of photointerpretation in Precambrian terrain. A prime purpose has been to test the validity of observed photolineament patterns with respect to bedrock structure, and considerable correlation has been established.

Petrology and Structure

While the bulk of this work is being done by Mines Branch geologists, supplementary theses are in progress at the University dealing with:

(1) Petrography of a quartz-diorite pluton in the Rice Lake District.

(2) Carbonate and geothermometry study of some quartz veins in the Pioneer area.

(3) Sedimentation and sedimentary structures of the Pioneer area.

(4) Geometric and kinematic analysis of the structure of the Long Lake volcanic-sedimentary sequence.

(5) Structure of the Rice Lake-San Antonio formation in the vicinity of Little Rice Lake.

Age Dating

A recently constructed, solid source, mass spectrometer (10-inch radius of curvature, 90° sector) will be used for age determination and other isotopic studies to support the Project Pioneer investigations. Calibration and checking is now in progress. Rock samples have been collected for age determination with particular reference to metallogenesis.

Economic Geology

Because gold is the only metal that has been produced in significant amount in the Pioneer area, other exploration possibilities have been underestimated during the post-war gold depression; thus it is time to look for other possibilities. Synthesis of all geological and geophysical data will aim to assess the entire mineral potential of the Pioneer area, in order to provide basic data and new concepts useful to mining and exploration companies. Progress along these lines can be reported and it is hoped that exploration for base metals will follow publication of the results. Study of the gold deposits is proceeding concurrently in post-graduate theses.

Base Metals

The shield is a base-metal geological province which contains two principal types of ore, copper-zinc and copper-nickel. These ores have characteristic associations with specific rock types of limited distribution. Most of the copper-zinc occurs in acid volcanic rocks, while copper-nickel is associated with basic and ultrabasic intrusions. Ores also tend to be associated with great earth fractures. Thus, target selection is largely dependent upon one or more of these three features.

Acid volcanic formations favorable for copper-zinc are abundant in the area, and numerous ultrabasic intrusions, favorable for nickel-copper, are being mapped with the aid of aeromagnetic data - some of the basic plugs could be old volcanic centres, crucial for primary ore deposition.

An important crustal fracture strikes southeast across the central part of the area. Its extension probably connects with the east-west fractures of the English River gneissic belt which extends 400 miles to the east; and the north-west end connects with the northerly trending fractures that pass through the narrows of Lake Winnipeg.

Thus the area possesses the main features - acid calc-alkaline volcanics, basic and ultrabasic intrusions, and great fractures known to be favorable for ore accumulation. It also contains several gold orebodies. These were significant features in the Timmins area, where gold was produced for fifty-five years with little

evidence of base metals until suddenly, in 1964, the Texas Gulf zinc-copper-silver deposit was located with its known metal values already in excess of 1 1/2 billion dollars. The Project Pioneer volcanic belt is only one-tenth as large and chances of ore are correspondingly smaller, but the geological analogy persists and undoubtedly the area is worth exploring for base metals.

Gold

Two theses concerning gold are being prepared dealing with the geology and geochemistry of certain gold-bearing quartz veins, and the gold mineralization of the whole district.

Uranium

Several uranium prospects are known in the southwest half of the Pioneer area. One of the objects of the radioactive survey is to determine whether the southwestern gneisses would be attractive for uranium exploration. This survey is not yet complete but uranium oxides have been observed in magnetite-rich pegmatites, associated with hornblendic potassic granite. Selected magnetitic anomalies may therefore warrant radioactive investigation, in addition to detailed surveys of known uranium occurrences.

CONCLUSIONS

In the foregoing review, attention has been given to a few of the lesser known areas that warrant exploration in Manitoba, with only brief mention of the major established mining zones such as Flin Flon-Snow Lake and the Thompson Nickel Belt. In the last few years Manitoba has emerged as Canada's second largest nickel province, while copper and zinc are also booming.

In preparation for the massive exploration and development that lies ahead in metallic mining, Manitoba Hydro has commenced construction of its vast Nelson River - Churchill River engineering project that will within a few years supply cheap electric power to all mines in northern Manitoba, thus encouraging extended exploration. An accelerated rate of geological mapping and research by the Manitoba Mines Branch will accompany this forthcoming expansion.