# PRELIMINARY MINERAL RESOURCE STUDY OF THE RED LAKE INDIAN RESERVATION, MINNESOTA

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## CONCLUSIONS

The Red Lake Indian Reservation and adjacent lands in Beltrami, Koochiching, Lake of the Woods, and Roseau Counties, Minnesota, have an excellent potential for the discovery of buried massive sulfide deposits containing zinc, copper, and lesser lead and silver. Exploration for such deposits in this region has been carried out intermittently since the late 1960's by several established mining companies, but no economically viable deposits have been encountered. Experience in areas such as this has shown that search for massive sulfide deposits is costly and time consuming and requires highly sophisticated techniques, because the mineral deposits being sought are in the bedrock (or solid rock) beneath an almost continuous mantle of unconsolidated materials (glacial drift) and soil. The region also contains one of the largest peat reserves in the United States (Soper, 1919). as well as some sand and gravel that can be used for construction purposes.

## INTRODUCTION

### Purpose

Through an interagency agreement, the Bureau of Indian Affairs commissioned the U. S. Geological Survey and the U. S. Bureau of Mines to summarize the mineral potential of certain Indian lands. Sources of data used include published literature, data files, unpublished reports and other available information. No field work was authorized or conducted.

### Location and Accessibility

The Red Lake Indian Reservation includes approximately 564,447 acres in the northern part of Minnesota (Figure 1). At one time the reservation was much larger, being approximately 132 miles (north-south) by 100 miles (east-west). In the late 1880's, the Tribe agreed to cede certain Indian lands north of Upper Red Lake to the U. S. Government for sale. In 1945, by order of the Secretary of the Department of the Interior, those ceded lands that had not been sold were restored to the Tribe. An area about 27 miles (north-south) by 40 miles (east-west), in the immediate vicinity of the Red Lakes, was not included in the agreement to cede lands. This "Diminished Portion" is now the largest block of Indian-owned land in Minnesota. The second largest block of Indian ownership is in the Northwest Angle, adjacent to Lake of the Woods; it is a rectangular area about 16 miles (north-south) by 10 miles (east-west). The only land access to this block is through Canada; there are a number of private ownerships within the block.

The present scattered ownership in the reservation is distributed in eight Minnesota counties, as follows (all lands are tribal-owned, including mineral rights):

| County | Acres |
|---|---|
| Pennington | 129 |
| Red Lake | 47 |
| Marshall | 240 |
| Koochiching | 23,036 |
| Lake of the Woods | 110,062 |
| Beltrami | 302,773 |
| Clearwater | 120,911 |
| Roseau | 7,249 |
| | 564,447 |

Minnesota highway 11 crosses the northern part of the reservation connecting Roseau, Warroad, and Baudette, and State highway 72 runs along the eastern edge of the reservation, connecting Warroad with points to the south. State highway 89 extends south from Roseau 38 miles, turns east and connects with State Highway Nos. 89 and 219, which connect Roseau with State Highway 1. Highway 1 crosses the reservation on the south side of Lower Red Lake. These are all-weather roads; but load limitations are placed on state highways during the spring thaw. Within the reservation are a few gravel roads and unimproved roads passable in good weather,

The Canadian National Railroad crosses the U. S. border near Warroad and again at Baudette. The Burlington Northern connects with the Canadian National at Warroad and runs south about 30 miles west of the reservation. Another line of the Burlington Northern runs northeasterly near the southeast corner of the reservation.

Regular airline service is available at International Falls, 90 miles to the northeast, connecting with Winnipeg, Canada, and Minneapolis.

## Services and Communities

Northwest-trending pipelines from 3 companies are about 7 miles southwest of the reservation. The Great Lakes Gas Transmission Co. has a 36 in. line; the Lakehead Pipeline Co. has oil pipelines which are 18 in., 26 in., and 34 in.; and the Portal Pipeline Co. has an oil line 16 in. in diameter.

Power transmission lines cross the reservation from Baudette to Warroad, and to Redby on the south shore of Lower Red Lake.

The largest community in the region is Bemidji, population 11,490; about 27 miles south of Lower Red Lake. Baudette, population 1547, is in the northeastern corner of the reservation; Warroad has a population of 1,086; and Thief River Falls, 30 miles to the west, has a population of 8,618.

## Landscape

The present landscape of the region is inherited largely from the Ice Age. As the continental glaciers retreated northward, about 10,000 years ago, they left a variety of unconsolidated materials (called glacial drift, or, simply drift) on the solid rock, and in this region glacial deposits reach thicknesses of more than 350 feet. Most of the region lies within the bed of Glacial Lake Agassiz, which left its principal mark on the flat expanses of the Red River Valley, but at one time extended eastward across northern Minnesota nearly to Ely. When the lake was drained, by melting of ice that had blocked its outlet, thick deposits of clay and silt were left. This surface has been little disturbed since the Ice Age, and today it forms a vast lowland that is poorly drained and consequently supports little agriculture. The surface is interrupted on the north by the dissecting tributaries of the Rainy River. That part north and west of Upper Red Lake constitutes what is probably the largest contiguous wetland in the world.

Bedrock is exposed locally in those parts of the region where the glacial drift is relatively thin, and consists mainly of small, isolated, rounded, smooth knobs of rock that protrude above the wetlands. Most bedrock outcrops are within a few miles of

Rainy River or Lake of the Woods, and many are in the valleys of the streams that flow northward into these bodies of waters. Rock outcrops are shown on the Roseau sheet (Sims and Ojakangas, 1973).

## PRESENT INVESTIGATION AND ACKNOWLEDGMENTS

This report concerns the main block of contiguously-owned land in the Red Lake Indian Reservation, in Beltrami County, and the area containing the scattered tribal lands in northern Beltrami, Lake of the Woods, and northwestern Koochiching Counties. Accordingly, a substantial part of the region discussed in this report consists of state, federal, and privately owned lands that are adjacent to and, in part, interspersed with tribal lands.

The geologic map of the bedrock accompanying this report (Figure 2) was prepared mainly by the Minnesota Geological Survey (Sims and Ojakangas, 1973), based on available outcrop and drill hole data. That part of the map south of 48° N. latitude was prepared by Sims specifically for this report. The geology in the vast areas covered by glacial drift was interpreted largely from existing aeromagnetic (scale 1:250,000) (Bath and others, 1964) and gravity (McGinnis and others, 1973) maps. Accordingly, the geology is generalized, and is useful mainly for regional planning and for determining broad target areas for mineral exploration. A more detailed geologic map would require grid drilling to bedrock at a spacing of perhaps five miles and more detailed geophysical data than now is available.

The mineral potential of the region was assessed by studying the geology in relation to that of productive mining areas in many parts of Ontario, Canada, and by examining the record for reports of any mention of mineral deposits. The principal sources of data were the regional geologic map (scale 1:250,000) referred to above and a more detailed geologic map (1:62,500) of the Birchdale--Indus area (Ojakangas, 1973). Data on these maps were supplemented by miscellaneous information in open files at the Minnesota Geological Survey and the Minnesota Department of Natural Resources. In particular, records from drilling on State of Minnesota lands in the region were a valuable aid in determining the geology in covered areas and in assessing the mineral potential. The drill cores are stored at the Hibbing core storage facility of the Minnesota Department of Natural Resources.

We thank Dr. Matt Walton and Dr. G. B. Morey of the Minnesota Geological Survey, Mr. David G. Meineke of the Minnesota Department of Natural Resources, and Mr. Robert H. Schoewe, Area Realty Officer of the U. S. Bureau of Indian Affairs, for assistance in the compilation of data used in this report. Drafting of the illustrations was done mainly by Richard E. Schoenfeld of the U. S. Geological Survey, Denver, Colorado.

## GEOLOGY

### Setting

The Red Lake Indian Reservation and adjacent lands, in northern Minnesota, lie on the southern

margin of the Canadian Shield, a vast region of Precambrian rocks that comprises the exposed part of the North American craton. Accordingly, the geology of the region is grossly similar to that in adjacent areas in Canada.

The bedrock consists of crystalline rocks that are lower Precambrian, or Archean in age. Radiometric dating of similar old rocks in the nearby Rainy Lake area (Peterman and others,1972) indicates that the rocks are about 2,600 million years old -- some of the oldest rocks in North America. The geology of the bedrock in this region must be largely inferred by indirect means and extrapolation from areas having good outcrops, because of the widespread cover of unconsolidated glacial material. Outcrops of bedrock are limited to three areas: (1) south of Rainy River, east of Baudette; (2) south of Lake of the Woods, in a broad area near Zippel Bay State Park; and (3) in the area southeast of Upper Red Lake, where outcrops are sparse. Several drill holes have penetrated to the bedrock, but these are widely scattered and confined largely to the northern part of the region.

## Rock Units

The Precambrian rocks in the region (Figure 2) are typical of the greenstone-granite complexes in the southern part of the Canadian Shield, and consist of four broad groups of rocks: (1) mafic volcanic rocks, (2) felsic volcanic rocks; (3) graywacke-type sedimentary rocks; and (4) granitic intrusive rocks. Banded iron-formations are associated with the volcanic and sedimentary rocks. The volcanic rocks in the northern part of the region are the southwestward extension of the Wabigoon belt of northwestern Ontario, as defined by Goodwin (1970), and the volcanic rocks in the vicinity of Lower Red Lake are the westward extension of the Wawa belt of Ontario (Riley and others, 1971). Except in those areas having relatively good rock exposures, as near Birchdale, detailed knowledge of the rocks is lacking; thus, only broad groupings of rock types are delineated on the geologic map (Figure 2). Except for the granitic rocks, all the rocks are metamorphosed to some degree; in most areas, the rocks were metamorphosed at relatively low temperatures and pressures, but in the area south of Lake of the Woods the rocks were metamorphosed at moderate temperatures and low pressures.

The mafic volcanic rocks are dominantly pillowed and massive lava flows, but include massive metadiabase, which represents shallow intrusive rocks emplaced at the base of extrusive lavas. Probably some ultramafic lavas or intrusive sills also are present. The existence of ultramafic rocks is suggested in T. 158 N., R. 34 W., and T. 159 N., R. 35 W., in southern Lake of the Woods County, and in T. 156 N., R. 38 W., in western Beltrami County, by the strong positive gravity anomalies on the regional gravity map (McGinnis and others, 1973). The anomalies are comparable to those over known ultramafic rocks in Itasca County, to the south (Sims and others, 1970).

Felsic volcanic rocks are abundant in the area between Birchdale and Baudette. Several types of felsic volcaniclastic rocks are distinguished, but most are massive lavas or pyroclastic (fragmental)

rocks, probably originally deposited as ash falls or avalanche debris. The amount of felsic volcanics in the areas covered by thick glacial drift is not known, for felsic volcanic rocks and graywacke have similar gravity and magnetic expressions and cannot be distinguished separately by these means alone.

Thin, banded iron-formations have been identified at places in the volcanic rocks by drilling, and others can be inferred from the local strong, linear, magnetic anomalies. The major iron-formations are in eastern Lake of the Woods County and western Koochiching County (Figure 2). The iron-formations consist dominantly of magnetite and hematite, but sulfide-facies iron-formation also is present. They are similar to the Soudan Iron-formation (Sims, 1972a) exposed in the Soudan-Ely area, northeast Minnesota, but may differ in lacking high-grade hematite ores.

The volcanic rocks and the associated graywacke and iron-formations were deposited in water, probably in an ancient ocean. This interpretation is based on the presence of pillowed lavas and of graded beds in the graywacke sedimentary strata, both of which are indicative of a subaqueous (probably submarine) environment. The volcanic and sedimentary rocks resemble those in modern island arcs, such as Japan, and it is generally conceded that the old Precambrian rocks formed in similar geologic environments.

The granitic rocks in the region (Figure 2) are more or less circular or elliptical bodies, and they were intruded into the volcanic and sedimentary rocks about 2600 m.y. ago, shortly after the volcanic and sedimentary rocks were deposited. The outer contacts of the granitic bodies are steep.

The youngest rocks in the region are dikes of diabasic gabbro and diorite (Figure 2). The dikes occupy northwest-trending fractures in the bedrock and form locally conspicuous northwest-trending ridges, and commonly are the best exposed rocks in the region.

## Structure

All the Precambrian rocks are steeply inclined to the land surface, and are folded on steep axial surfaces and steeply-plunging axes; also, they are transected by high-angle faults, some of which are major crustal structures, now inactive. The structural grain of the rocks is indicated on Figure 2 by geologic contacts and the trends of aeromagnetic anomalies.

Based on aeromagnetic mapping, folds in the southern part of the region, south of the Vermilion fault, trend northeast or east-northeast; the iron-formation on the south shore of Lower Red Lake, which was drilled in 1964, probably is near the axial region of a major northeast-trending fold. Northeast-trending folds also are present in the area south of Birchdale (Ojakangas, 1973). In the area south of Lake of the Woods, however, the rocks have a northwest-trending grain, reflecting folding on northwest-trending axial surfaces. Scattered outcrops near the lake indicate the limbs of the folds are nearly vertical.

The Precambrian rocks are transected by numerous high-angle faults having both large and small displacements. Except for a few small faults,

such as the one in T. 159 N., R. 26 W., east of Birchdale, which transects and offsets a diabase dike, the faults are not exposed; their presence is inferred from apparent discontinuities of magnetic and/or gravity anomalies and, less commonly, of geologic units or beds. The larger faults break the terrane into separate segments, which are difficult to correlate.

The Rainy Lake fault, a northeast-trending fault in the eastern part of the map area (Figure 2) in Koochiching County, is the inferred southwest extension of a major high-angle fault in the Rainy Lake area, east of International Falls, which separates biotite schist and granite (Vermilion granite-migmatite massif of Southwick, 1972) on the south from less metamorphosed volcanic rocks on the north (Ojakangas, 1972). The fault is inferred to be a dip-slip fault, with the north side having moved down relative to the south side.

The major fault in the region is the Vermilion fault, which transects the central part of the map area (Figure 2). Movement is strike-slip and is inferred to be about 30 miles, the north side having moved eastward relative to the south side. Accordingly, the contact northwest of Upper Red Lake between the "ms" unit and the mv" unit is inferred to be equivalent to the dip-slip (Rainy Lake) fault discussed above.

## MINERAL RESOURCES

Relatively small amounts of sand and gravel have been mined from the Red Lake Reservation and adjacent lands, and moderate reserves remain. The region contains very large reserves of peat, which could be the basis for a viable peat industry. Moderate quantities of marl occur in lakes south of the reservation.

The potential for undiscovered mineral deposits in the bedrock of the region is excellent, especially for massive sulfide deposits containing copper, zinc, lead, and silver. Exploration for buried deposits of this type has been carried on in the broad region of this report since the late 1960's, and is continuing, although no deposits of commercial significance have been found.

### Geologic Controls

The Red Lake Reservation and adjacent lands have two geologic environments favorable for mineral deposit occurrences: (1) the bedrock (or solid rock) and (2) the glacial drift (unconsolidated material left by the glaciers), which mantles the bedrock over most of the region and in the vicinity of Lower Red Lake is as much as 350 feet thick.

The mineral deposits that have been identified -- sand and gravel -- and most others that are known -- peat and marl -- occur within, or on the glacial drift. Sand and gravel is found mainly in outwash plains and moraines. In the region of this report, these glacial deposits stand topographically above the wetlands as low hills mainly along the eastern margin of the vast Red Lake Bog. In addition, deposits of sand and gravel occur in ancient beach ridges of Glacial Lake Agassiz, mainly in the southwestern part of the region. The former beaches typically are low linear ridges, 5 to 15 feet high.

Peat deposits, which are beds of vegetable remains that have accumulated over a long period of time, have been built up in this region since the close of the Ice Age, about 10,000 years ago. One. essential condition for the formation of peat is a profuse growth of plants, the decay of which, normally caused by oxidation and bacterial action, has been arrested. Since decay is retarded by immersion in water to the exclusion of air, peat occurs most abundantly in poorly drained wetlands.

Marl is an unconsolidated earthy material composed essentially of calcium carbonate, and is formed in lakes by the precipitation of calcium carbonate that has been leached from nearby glacial deposits. Generally, it is grayish white or buff, but if it is contaminated with peaty material it may be dark gray or brown. In some lakes, marl deposits are covered by several feet of peat. Conditions generally were unfavorable for deposition of marl in the Glacial Lake Agassiz plain, which underlies most of the Red Lake Reservation; many deposits are present immediately south of the reservation, however, in southern Beltrami and Clearwater Counties, where the drift contains substantial amounts of limestone and other forms of calcium carbonate.

The bedrock in the region is similar to that in adjacent parts of Canada; it contains scattered iron-formations and is locally favorable for the occurrence of massive sulfide deposits. Both the iron-formation and the massive sulfide deposits are associated with volcanic rocks. The granites that intruded these rocks, on the other hand, are apparently barren of metallic mineral deposits.

The iron-formations in the region are of Algoma (term used in Canada) type, and are similar in gross aspects to the Soudan Iron-Formation, in northeastern Minnesota. They consist mainly of fine- grained silica (commonly jasper) and iron oxides, magnetite and/or hematite, and commonly are thinly banded. At least some of the iron-formations in the region consist mainly of the iron sulfides, pyrite and pyrrhotite, and are sulfide facies. Iron-formations that contain 20-30 percent magnetite and/or hematite belong to the oxide facies and are commonly called taconite. Where the original iron-formation (taconite) has been enriched by surface processes to high grade hematite ore, as at mines in Soudan and Ely, Minnesota, it is more desirable because of its higher iron content. The iron-formations in the region are thin (generally less than 50 feet thick), but they possibly are thickened locally by repetition due to folding.

In a review of Precambrian volcanogenic massive sulfide deposits in Canada, Sangster (1972) listed several criteria that he considers favorable for the occurrence of massive sulfide ores in volcanic belts: (1) Presence of felsic (acidic) volcanic rocks; (2) presence of coarse pyroclastic, deposits, possibly with sulfide fragments, formed by fragmentation of the rocks during explosive volcanism; (3) presence of quartz porphyries; (4) presence of rocks that are transitional between true volcanic rocks and sedimentary rocks, such as reworked tuffs or volcanic sediments; (5) presence of chemical sediments of predominantly volcanic origin, such as chert and iron-formation; (6) presence of altered zones characterized by chlorite and sericite; and of course

(7) presence of visible sulfide minerals. These criteria and their relationship to the Red Lake Indian Reservation and adjacent lands is discussed below.

1. Felsic volcanic rocks, and associated volcanic sedimentary rocks -- mainly graywacke -- are abundant in the area south of Birchdale. They can be expected to occur, at least locally, also in certain parts of the area covered by glacial drift, as for example, the western part of Beltrami County, northwest and west of Upper Red Lake.

2. Moderately coarse pyroclastic rocks have been noted in the Birchdale-Indus area (Ojakangas, 1973), but their extent is not known. Possibly similar rocks occur in all areas that are underlain by felsic volcanics. No sulfide fragments have been reported in the pyroclastic deposits of the region.

3. Quartz porphyry, of either volcanic or intrusive origin, occurs sporadically in the felsic volcanic rocks south of Birchdale, and could be present elsewhere in similar buried volcanics.

4. Reworked tuffs have been identified in the area south of Birchdale. These rocks are considered by Sangster (1972) as the second most common host rock of massive sulfide ores.

5. Chemical sediments, particularly iron-formations, are common in the areas, south of Birchdale and Baudette and in the vicinity of Lower Red Lake. A hole drilled on state land in the southeast part of T. 159 N., R. 33 W., in Lake of the Woods County, penetrated a thick sulfide iron-formation; such deposits locally are considered "favorable horizons" for the occurrence of more valuable massive sulfide deposits, as, for example, in the Noranda and Matagami areas in Canada (Sangster, 1972, p. 9). Probably, similar sulfide iron-formations are present at places along buried magnetic iron-formations in the region of this report.

6. Zones of altered rocks such as those found stratigraphically beneath known massive sulfide deposits in Canada and elsewhere have not been recognized in the region of this report.

7. Massive pyrite ($FeS_2$) and pyrrhotite (FeS) containing traces of base metals (copper and zinc) have been exposed in two test pits adjacent to a metadiabase dike near Birchdale. Other deposits, including potentially commercial ones, should be present elsewhere in the region, but because of their high susceptibility to weathering and erosion, it is improbable that such sulfide deposits would be exposed anywhere at the surface; instead, they can be expected to occur in lower parts of the region, in the wetlands.

In general, massive copper-zinc-lead-silver sulfide deposits of the Canadian shield volcanogenic type are commonly tabular or pod-like and approximately conformable to bedding in the enclosing volcanic rocks. A typical economic occurrence is 2,000 to 5,000 feet long, 50 to 100 feet thick, and extends to depths of at least 1,000 feet.

## Production

No metallic mineral production has been recorded from the counties included in the Red Lake Reservation, but small quantities of sand and gravel have been produced. The U. S. Bureau of Mines records of sand and gravel production from

the four counties with the greatest Indian ownership for the years 1970-1973 show the four-year county totals as: Beltrami County, 350,750 tons valued at $200,250; Clearwater County, 222,150 tons at $175,500; Koochiching County, 138,000 tons at $143,500; and Lake of the Woods County, 110,000 tons at $74,250. The amounts of sand and gravel produced from the Tribal lands is recorded in Bureau of Indian Affairs files. There are no value figures for the production; however, the royalty income to the Indians is recorded as follows:

| Year | Quantity (Cubic Yards) | Royalty Income |
|---|---|---|
| FY 1970 | 26,210 | $2,621.02 |
| FY 1971 | 1,900 | 190.00 |
| FY 1972 | 20,200 | 3,145.00 |
| FY 1973 | 1,450 | 340.00 |
| FY 1974 | 41,000 | 6,294.00 |

## Description of Identified Resources

Resources that have been identified in the region include sand and gravel, peat, and marl.

### Sand and Gravel

Most deposits of sand and gravel are in the low moraines in the eastern part of the region; these moraines extend discontinuously northward along the eastern part of Beltrami County into eastern and northern Lake of the Woods County.

### Peat

Minnesota has about 50 percent of conterminous U. S. peat reserves (Soper, 1919), but it accounts for a very small fraction of U. S. production. A large part of these reserves are on and adjacent to the reservation. The peat is used mainly as a soil conditioner and for potting soils.

A study by the Minnesota Iron Range Resources and Rehabilitation Commission (Farnham, 1966) indicated 3,800 acres of high-quality sphagnum peat moss that is 5 feet or more thick in the Red Lake bog, north of Upper Red Lake (Figure 3). This is equivalent to 60,800,000 standard 6-cubic-foot compressed bales for agriculture or soil improvement use.

Features of this deposit that are favorable for its development include uniformity of analysis and high fiber content over a large continuous area. The bog is an elevated one and can be easily drained.

### Marl

Several marl deposits have been identified and in the area around Bemidji; two of these are very close to the original reservation boundary (Schwartz, 1959). A large deposit, reported to be several hundred acres in extent and 20 feet thick is in secs. 25 and 26, T. 147 N., R. 36 W. A 20-acre marl bed, 20 feet thick, is present south of Bemidji in T. 146 N., R. 33 W. Also small deposits have been reported in Koochiching and Lake of the Woods Counties near the reservation boundary.

Generally, marl is not found below the peat in the large Red Lake bog.

## Exploration for Undiscovered Deposits

Three types of mineral deposits have been actively sought in the bedrock of the region: (1) massive sulfide deposits, (2) iron-ores, and (3) radioactive materials. Of these, only the massive sulfide deposits have been intensively explored.

### Massive Sulfide Deposits

Volcanic rocks favorable for the occurrence of volcanogenic massive sulfide deposits are known in the area. Because of this, potential parts of the region have been explored rather intensively, and although no deposits of commercial significance have been found, exploration can be expected to continue. Exploratory drill hole locations are shown on the Roseau sheet (Sims and Ojakangas, 1973).

Exploration for massive sulfide deposits has been stimulated by the leasing policy of the State of Minnesota. The state lands leased for exploration of copper-nickel are shown on Figure 4. It should be noted that within each lease area only a small percentage of the state lands actually have been leased and fewer yet have been explored.

In 1970, the BIA issued prospecting permits to Humble Oil Co. (now Exxon Corp.) for exploration in northern Beltrami County. Four separate permits were issued, as follows:

Unit #1 -- Approximately 1,746 acres in parcels in secs. 2, 3, 10, 11, 14, and 15, T. 157 N., R. 33 W., and parcels in sec. 34 and 35 in T. 159 N., R. 33 W.

Unit #2 -- Approximately 1,880 acres covering parcels in secs. 19, 20, 29, 30 , 31, and 32, T. 158 N., R. 33 W., and parcels in sec. 25 and 26, T. 158 N., R. 34 W.

Unit #3 -- Approximately 1,196 acres covering parcels in secs. 5, 8, 18, 20, 21, 22, 27, 28, and 30, T. 157 N., R. 34 W.

Unit #4 -- Approximately 3,422 acres in parcels in secs. 7, 8, 9, 16, 17, 18, 20, 21 and all of sec. 19, T. 158 N., R. 34 W.

All permits have been surrendered except Unit #1. No reports are available on the work of Humble Oil Co. The BIA currently is negotiating with Exxon Corp. for a prospecting lease on some of the Indian lands.

The first step in the search for massive sulfide deposits is the selection of broad "target areas." Regional geologic maps at a scale of 1:250,000, are particularly useful for their selection. More detailed maps at 1:62,500 [such as the map of the Birchdale-Indus area (Ojakangas, 1973)] or 1:24,000 provide additional pertinent geologic detail. Exploration of these areas by industry has included airborne geophysical surveys, ground geophysical surveys, geologic mapping where possible, and diamond drilling. The airborne surveys employ magnetometer and EM equipment; both induced and natural EM are used for the follow-up of the airborne surveying.

## Iron Ore

Exploration for iron ore has been carried out unsuccessfully in two areas within the region since about 1950 (Sims, 1972a). The first exploration was by a private mining firm on an iron-formation in T. 158 N., R. 27 W., and T. 159 N., R. 27 W. Three drill holes tested the iron-formation; evidently the results were insufficient to warrant further testing.

In 1963, the Bureau of Indian Affairs contracted with Burns & Roe, Inc. (Anonymous, 1964) to conduct a mineral resources study of eight Indian reservations in Minnesota and Wisconsin, including the Red Lake Reservation. As a part of the study, a hole was drilled to test a magnetic anomaly on the south side of Lower Red Lake. Unfortunately the steeply inclined hole paralleled the iron-formation and yielded little useful information of the unit. Drill core samples were analyzed and tested at the Bureau of Mines Twin Cities Metallurgy Research Center by Frommer (1965). Following is a summary of the test work prepared by Frommer (1965), Supervisory Research Metallurgist:

> "Three composites having the composition given in Table 1 were made on an equal weight per foot basis from core made available through the Minneapolis Office of Mineral Resources. The drill core used in preparing the composites was essentially a fine grained mixture of quartz, iron silicates, and specular hematite.

TABLE 1
Composition of Drill Core Composites

| Composite Number | Footage Interval | Analysis, percent | | |
|---|---|---|---|---|
| | | Fe total | $Fe^{++}$ | $SiO_2$ |
| 1 | 202 - 234.5 | 40.0 | 3.2 | 37.3 |
| 2 | 234.5 - 264 | 37.3 | 2.9 | 40.1 |
| 3 | 264 - 304 | 35.9 | 2.1 | 42.2 |

> "Each of three composites were given a 15-minute grind in the laboratory rod mill (estimated ± 95 percent passing 325- mesh)., and subjected to a modified petroleum-sulfonate float, using a tall oil pitch-kerosene mixture as the chief modification. Iron oxides were collected in the froth from an acid circuit, and cleaned three times to make the final concentrate.
>
> "Four tests were made on Composite 1: In the best of these tests, the ground sample was deslimed prior to flotation. This desliming did not affect batch recovery, and resulted in a

concentrate containing about 1 to 2 percent less $SiO_2$ than was otherwise obtained. Metallurgical results from the best of these tests are given in Table 2.

"Similar results were obtained on Composites 2 and 3, as are shown in Table 3 and Table 4, respectively.

TABLE 2

Metallurgical Results, Composite 1

| Product | Weight, percent | Analysis, percent Fe | Analysis, percent $SiO_2$ | Distribution, percent Fe |
|---|---|---|---|---|
| Concentrate | 40.2 | 63.0 | 5.9 | 63.7 |
| Middling 3 | 7.0 | 45.5 | --- | 8.0 |
| Middling 2 | 8.2 | 34.6 | --- | 7.1 |
| Middling 1 | 10.5 | 25.4 | --- | 6.6 |
| Tailing | 20.2 | 15.2 | --- | 7.8 |
| Slime | 13.9 | 19.4 | --- | 6.8 |
| Composite, H.S. | 100.0 | 39.8 | --- | 100.0 |

TABLE 3

Metallurgical Results, Composite 2

| Product | Weight, percent | Analysis, percent Fe | Analysis, percent $SiO_2$ | Distribution, percent Fe |
|---|---|---|---|---|
| Concentrate | 38.3 | 62.3 | 6.6 | 64.0 |
| Middling 3 | 8.1 | 43.4 | --- | 9.4 |
| Middling 2 | 9.5 | 30.5 | --- | 7.8 |
| Middling 1 | 14.6 | 21.5 | --- | 8.4 |
| Tailing | 29.5 | 13.2 | --- | 10.4 |
| Composite, H. S. | 100.0 | 37.3 | --- | 100.0 |

TABLE 4

Metallurgical Results, Composite 3

| Product | Weight, percent | Analysis, percent Fe | Analysis, percent $SiO_2$ | Distribution, percent Fe |
|---|---|---|---|---|
| Concentrate | 37.2 | 62.8 | 7.2 | 64.5 |
| Middling 3 | 6.0 | 39.5 | --- | 6.5 |
| Middling 2 | 8.4 | 29.1 | --- | 6.7 |
| Middling 1 | 15.2 | 20.5 | --- | 8.6 |
| Tailing | 33.2 | 15.0 | --- | 13.7 |
| Composite, H.S. | 100.0 | 36.3 | --- | 100.0 |

"The results given in Table 2, Table 3, and Table 4 should be considered as providing a basis for a preliminary evaluation only. Since the drilling penetrated the iron formation parallel to the bedding, the samples tested do not necessarily provide information relative to the whole formation. Because of this singular characteristic of the drill core, further flotation testing to develop a reagent suite does not seem justified at the time. However, the composites were evaluated further by reduction roasting and magnetic separation, with results as given in Table 5. These data indicate the ore contains a high percentage of recoverable iron, and by inference, has a potential for yielding high grade concentrates, especially if flotation were used to upgrade the magnetic concentrates."

TABLE 5
Results of Reduction-Roasting and Magnetic Separation

| No. | Product | Weight percent | Analysis, percent Fe | Fe | Fe total | Distribution, percent $SiO_2$ | $Fe^{++}$ | $Fe^{+++}$ | total |
|---|---|---|---|---|---|---|---|---|---|
| | Magnetic | 58.0 | 18.12 | 47.46 | 65.58 | 7.34 | 90.4 | 94.6 | 93.4 |
| 1 | Non-magnetic | 42.0 | 2.65 | 3.70 | 6.35 | --- | 9.6 | 5.4 | 6.6 |
| | Composite | 100.0 | 11.62 | 29.09 | 40.71 | --- | 100 | 100 | 100 |
| | Magnetic | 53.4 | 21.59 | 44.22 | 65.81 | 7.78 | 89.6 | 93.4 | 92.1 |
| 2 | Non-magnetic | 46.6 | 2.88 | 3.58 | 6.46 | --- | 10.4 | 6.6 | 7.9 |
| | Composite | 100.0 | 12.87 | 25.28 | 38.15 | --- | 100 | 100 | 100 |
| | Magnetic | 55.5 | 16.97 | 45.60 | 62.57 | 12.1 | 92.9 | 94.3 | 93.9 |
| 3 | Non-magnetic | 44.5 | 1.61 | 3.47 | 5.08 | --- | 7.1 | 5.7 | 6.1 |
| | Composite | 100.0 | 10.14 | 26.85 | 36.99 | --- | 100 | 100 | 100 |

The test work indicated a potential for producing an acceptable grade of iron concentrates. However, the samples were not representative of the deposit and additional samples are needed to properly evaluate the iron-formation. In 1966, the BIA invited bids for exclusive prospecting permits with option to lease for mining on the reservation. The area included the magnetic anomaly and the site of the drill hole. No bids were received.

## Radioactive Materials

Some prospecting for radioactive materials during 1955-56 was in the Northwest Angle, in Townships 167 and 168 North, Ranges 34 and 35 West. In February 1956, W. A. Cole, Bureau of Mines engineer, examined a test pit and took samples in NW¼NW¼ sec. 3, T. 167 N., R. 34 W. Table 6 (Cole, 1956) summarizes the results, which did not encourage further work.

In May 1956, a permit was issued to Louis J. Glick for prospecting on Indian lands, from May 29, 1956 to May 27, 1957, in parts of secs. 2, 3, and 11, T. 167 N., R. 35 W., and parts of sec. 36, T. 168 N., R. 35 W. Results of this prospecting are not available, but probably are negative.

In August 1955, the U. S. bureau of Mines took four samples of bedrock about 24 miles west of the reservation in SW¼SE¼ sec. 3, T. 167 N., R. 26 W. Three of the samples were of pegmatite and one of biotitic gneiss. One of the pegmatite samples assayed 0.04 percent $U_30_8$ equivalent, (Table 6).

## Potential Resources

There are no reserves of metallic mineral deposits in the region of this report; that is, there are no identified deposits of mineral-bearing rock from which the mineral or minerals can be extracted profitably with existing technology and under present economic conditions.

TABLE 6

Data on Radioactive Samples from Northwest Angle

| Sample No. | Description | Location | $U_30_8$ equivalent (in percent) |
|---|---|---|---|
| 0614 | Metamorphosed greenstone | 12'-15 ft. southwest of point of discovery | less than 0.01 |
| 0615 | Graywacke | At point of discovery, 3-4 ft. depth in blasted trench | 0.01 |
| 0616 | Graywacke and pink granite contact | Approximately 300 ft. N. 59°E. and 48 ft. NW from point of discovery | less than 0.01 |
| 0617 | Pink granite | Same location as sample 0616 | 0.01 |
| 0618 | Metamorphosed sediments | From rock pile at point of discovery | less than 0.01 |
| 0619 | Banded graywacke | From rock pile at point of discovery. Reported blasted out about 2 ft. above sample 0615 | 0.20 |
| 0620 | Banded graywacke | From other hot spots along trench on contact | 0.04 |

However, the region is favorable for the occurrence of commercially valuable mineral deposits, and these can be classed as resources, following the definition given in U. S. Geological Survey Professional Paper 820 (Brobst and Pratt, 1973). Resources include mineral deposits that may eventually become available either known deposits that are not economically or technologically recoverable at present, or unknown deposits that are inferred to exist but have not yet been discovered. With respect to the classification of resources shown in Figure 5, the resources in the bedrock estimated for this region are classed as speculative; that is, deposits of probable economic grade that are thought to be present but have not yet been discovered. Possibly one or more viable deposits will be found in the region if exploration is sufficiently intensive.

The relative favorability for the occurrence of massive sulfide deposits--the principal potential resource--in the region is shown on Figure 6. The most favorable area, based on present knowledge, is the area south of Birchdale and Baudette. The rocks in this area contain several of the criteria favorable for massive sulfide deposits. They are reasonably well exposed, and the glacial drift is relatively thin. A second area considered favorable for the occurrence of massive sulfide deposits is the northwestern part of Beltrami County, including a part of the main reservation. This area probably contains the same general rock types as the Birchdale area, although the bedrock is buried beneath about 150 feet of unconsolidated materials. Except for areas underlain by granitic rocks, which are unfavorable for the occurrence of commercial mineral deposits, the remaining parts of the region are classed as "possibly favorable." This category is used because uncertainties exist in the classification of specific rock types at particular localities, and the rocks designated as "metasedimentary rocks, undivided" and "schist-rich migmatite" on Figure 2 are not considered particularly favorable for the occurrence of massive sulfide deposits.

The method used to estimate resources of buried massive sulfide deposits in this region is adapted from a method used by D. F. Sangster (oral commun., 1974) in Canada. He developed the concept, based on known massive sulfide occurrences in the Canadian Shield, that each volcanic center, distinguished by the presence of felsic volcanics, should contain massive sulfide deposits; further, these deposits can be expected to be clustered within an area 10-15 miles in diameter. He calculated from past production data that each volcanic center should yield about 4 million tons of metal (copper, zinc, lead and silver) ±45 percent and about 65 million tons of ore ±50 percent. Further, he reasoned that approximately two-thirds of the ore is likely to be contained in one deposit.

Using the technique of D. F. Sangster, we estimate that the Birchdale area, which is considered as being a volcanic center, has the potential for containing massive sulfide deposits having about 4 million tons of metal (copper, zinc, lead, and silver), which is classed as a speculative resource (Figure 5). This material would have a gross value of several billion dollars. It should be reiterated that these resources are speculative.

The potential for iron ore in the region is low. Although several iron-formations are known or can be inferred from pronounced aeromagnetic anomalies (Bath and others, 1964) in the region, the iron-formations apparently are thin. Also they dip steeply, and probably could be mined only by costly underground methods. The steep dip, relative thinness of the deposits, and the widespread overburden will discourage serious exploration of the iron-formations for commercial taconite or iron ore within this century. Instead, the next major class of iron ores to be developed commercially probably will be the non-magnetic taconite on the major iron ranges, where mines and plant facilities presently exist.

The potential for radioactive materials in the region also is low. Although projections for uranium show that future demands will increase dramatically (De Carlo and Shortt, 1970), there is little possibility that economic deposits exist on the reservation. The few reported occurrences on or near the reservation were small and low in grade. We recommend that no effort be made to develop a uranium mine.

## Economic Appraisal of Identified Resources

### Sand and Gravel

Sand and gravel deposits on the reservation are not large nor abundant. Marketing areas are limited to short distances from a deposit. Accordingly, because of the low population density in the area and consequent low demand, sand and gravel does not constitute a resource of significant future economic value.

Environmental problems should not be a major consideration in extracting sand and gravel, for the pits probably will be relatively small and any disturbed area can recover rapidly if properly regraded and reseeded.

### Marl

As noted earlier, significant deposits of marl are not present in the reservation, so far as known, and accordingly we do not recommend further work on marl.

### Peat

Peat is the only identified mineral resource on the reservation for which significant information is available to plan a mining or harvesting operation. Two major factors should be considered: (1) assurance that there is a demand in this region for additional peat, and (2) recognition that a new product must compete with those having established outlets and recognized trade names. A marketing study made in 1968 (Anonymous, 1968) indicated an expanding market for peat; hence, the peat on the reservation may warrant reexamination.

A detailed cost study of producing dried packaged peat for agricultural use was made by the Minnesota Iron Range Resources and Rehabilitation Commission in 1966 (Brower, 1966). Since that time, costs have increased substantially. The capital costs for a 500,000-bale-per-year plant were

presented in the report and if these capital costs are increased at a rate of 4¼ percent per year compounded through 1973 and increased by 25 percent for 1974, the following comparison can be made:

Capital Costs for a 500,000 Bale/Year Plant

| | IRRRC, 1966 | Escalated to 1974 |
|---|---|---|
| Cost of bog preparation | $136,441 | $232,096 |
| Plant and machine costs | 201,675 | 513,172 |
| Harvesting equipment | 65,000 | 110,570 |
| | $403,116 | $855,838 |

Labor costs also have risen since 1966, as by the Minnesota Department of Employment Services (Anonymous, 1974):

| | 1966 IRRRC/hr. | 1974 Minn. Employment Services/hr. |
|---|---|---|
| Foreman | $3.00 | $6.40 |
| Mechanic | 2.50 | 5.00 (heavy equipment) |
| Laborer | 2.00 | 3.63 |
| Heavy Cat Operator | 3.00 | 4.32 (heavy equip. oper.) |
| Watchman | 1.50 | 4.05 (includes guards) |

Mining of the Red Lake bog would require drainage, which might have some affect on the wildlife. Also, during the mining or harvesting operation, high winds occasionally could pick up some of the dried peat and cause minor dust clouds. Because the area is so remote from established communities and because most windstorms are small, no significant problems are anticipated.

After a pit or field is completed, it might become flooded, depending on its depth and the level of the ground water table. Perhaps the flooded pit could be used for raising wild rice or commercial sod for landscaping in urban areas. It should not be difficult to reestablish vegetation.

## Economic Appraisal of Iron Ore

Analysis and beneficiation tests are available on only one of several possible iron ore deposits. The dimensions of these deposits are not known. Geophysical data indicate they are narrow and steeply dipping. The ore must be mined by underground methods and would require beneficiation. A rail haul of approximately 180 miles to the Duluth harbor, as compared to about 75 miles from current operations at Hibbing, would be a competitive disadvantage. Also, rail haulage would require about 30 miles of rail construction. Because of these factors and the large reserves of taconite available on the productive Mesabi range, the reservation deposits cannot be considered economical at the present time. They may warrant a reexamination as possible sources of iron ore by the year 2000.

Environmental factors should not be a major problem if underground mining were undertaken. Depending on the mining method, caving of the surface from underground workings would have to be considered in planning an operation. There would also be stockpiles of waste rock to be landscaped. Tailings ponds from a beneficiation plant could be designed to eliminate dust problems. Revegetation after completion of the opera-

tion should not be difficult. No toxic waste would be expected from mine drainage. Waste water from beneficiation plants could be recirculated in a closed circuit, thereby preventing silt from entering the natural drainage system.

## RECOMMENDATIONS FOR FURTHER WORK

Because of the availability of modern geologic maps of the reservation and adjacent areas (Sims and Ojakangas, 1973; Ojakangas, 1973) no further geologic mapping is recommended at this time. However, as exploration for massive sulfide deposits continues in this and adjacent areas, the data should be systematically accumulated. These data will steadily increase knowledge of the bedrock and glacial geology in the region, and eventually lead to the discovery of significant massive sulfide deposits in the region.

Drill cores from State of Minnesota lands are being stored at the Hibbing core storage facility of the Minnesota Department of Natural Resources. It would be desirable also to arrange for storage of drill core from tribal lands at this facility.

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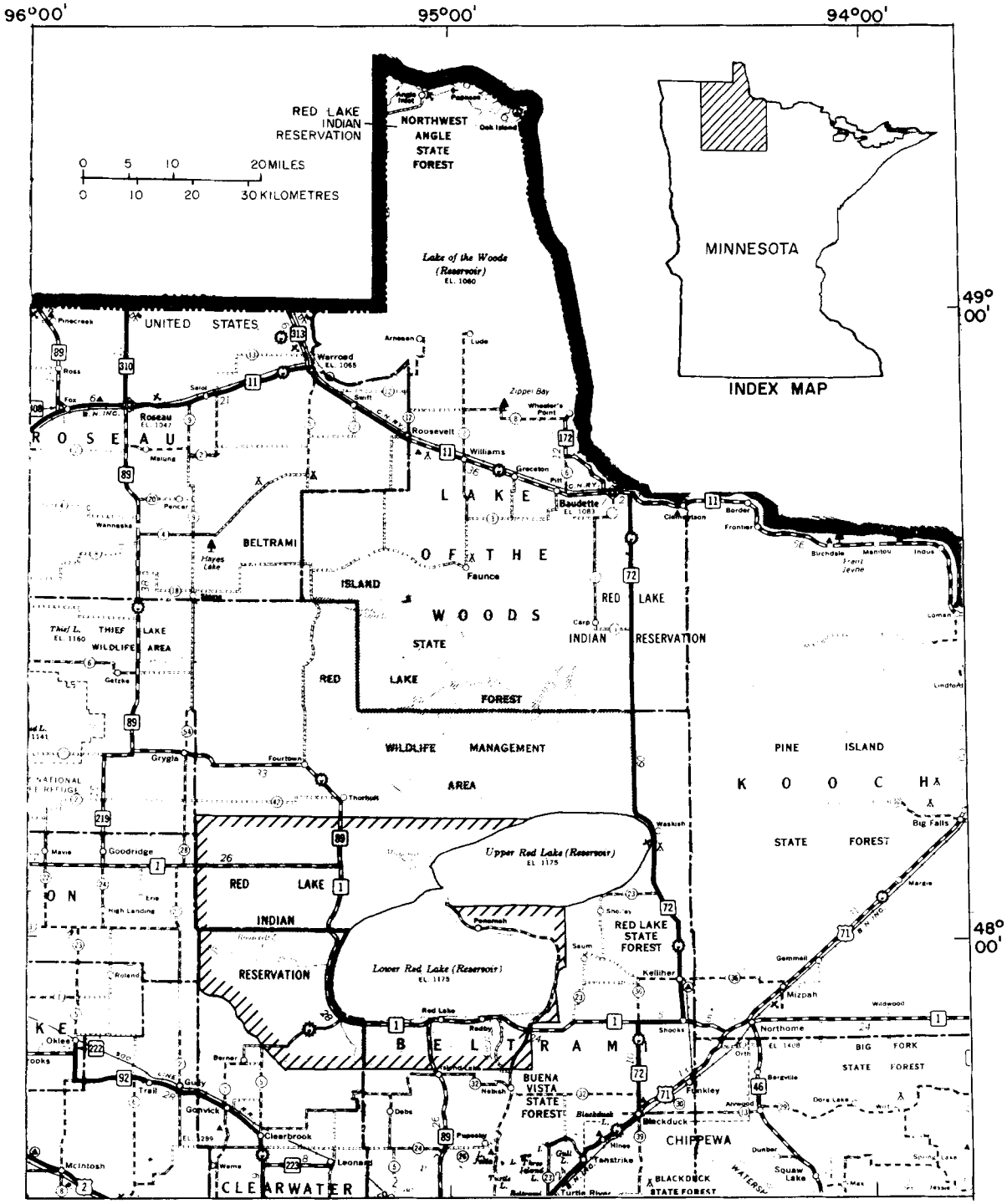
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RED LAKE INDIAN RESERVATION
NORTHWEST ANGLE STATE FOREST
0 5 10 20 MILES
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MINNESOTA
INDEX MAP
Lake of the Woods (Reservoir)
EL. 1060
UNITED STATES
ROSEAU
LAKE OF THE WOODS
BELTRAMI ISLAND
RED LAKE INDIAN RESERVATION
RED LAKE STATE FOREST
WILDLIFE MANAGEMENT AREA
THIEF LAKE WILDLIFE AREA
PINE ISLAND
KOOCHA
STATE FOREST
Upper Red Lake (Reservoir)
EL. 1175
Lower Red Lake (Reservoir)
EL. 1175
RED LAKE INDIAN RESERVATION
BELTRAMI
BUENA VISTA STATE FOREST
BIG FORK STATE FOREST
CHIPPEWA
CLEARWATER
BLACKDUCK STATE FOREST
Roseau
Warroad
Roosevelt
Williams
Baudette
Graceton
Zippel Bay
Faunce
Hayes Lake
Thief L.
Grygla
Fourtown
Thorsdale
Goodridge
Mavie
Red Lake
Redby
Waskish
Kelliher
Gemmell
Mizpah
Northome
Funkley
Blackduck
Bemidji
Tenstrike
Clearbrook
Gonvick
Leonard
Bagley
Big Falls
Squaw Lake
Dunbar
Buchdale
Manitou
Indus
Lomen
Lindford
Frontier
Border
Clementson
Arnesen
Lude
Pinecreek
Ross
Fox
Malung
Pencer
Wannaska
Getzke
Oklee
Erie
High Landing
Roland
Trail
McIntosh
Wema
Turtle River
Shevlin
Solway
Shooks
Alvarado
Bergville
Dora Lake
Max
Jesse
Spring Lake
Wildwood
Marcie
Seum
Sheehan
Nebish
Debs
Puposky
Rosby
Blackduck
Nimrod
Pinewood
Oak Island
Angle Inlet
Penasauk
Sarot
Swift
Malung
Pencer
Wannaska
Hayes Lake
Thief L.
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Clementson
Graceton
Pitt
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Roosevelt
Swift
Warroad
Arnesen
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Zippel Bay
Wheeler's Point
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Redby
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Shevlin
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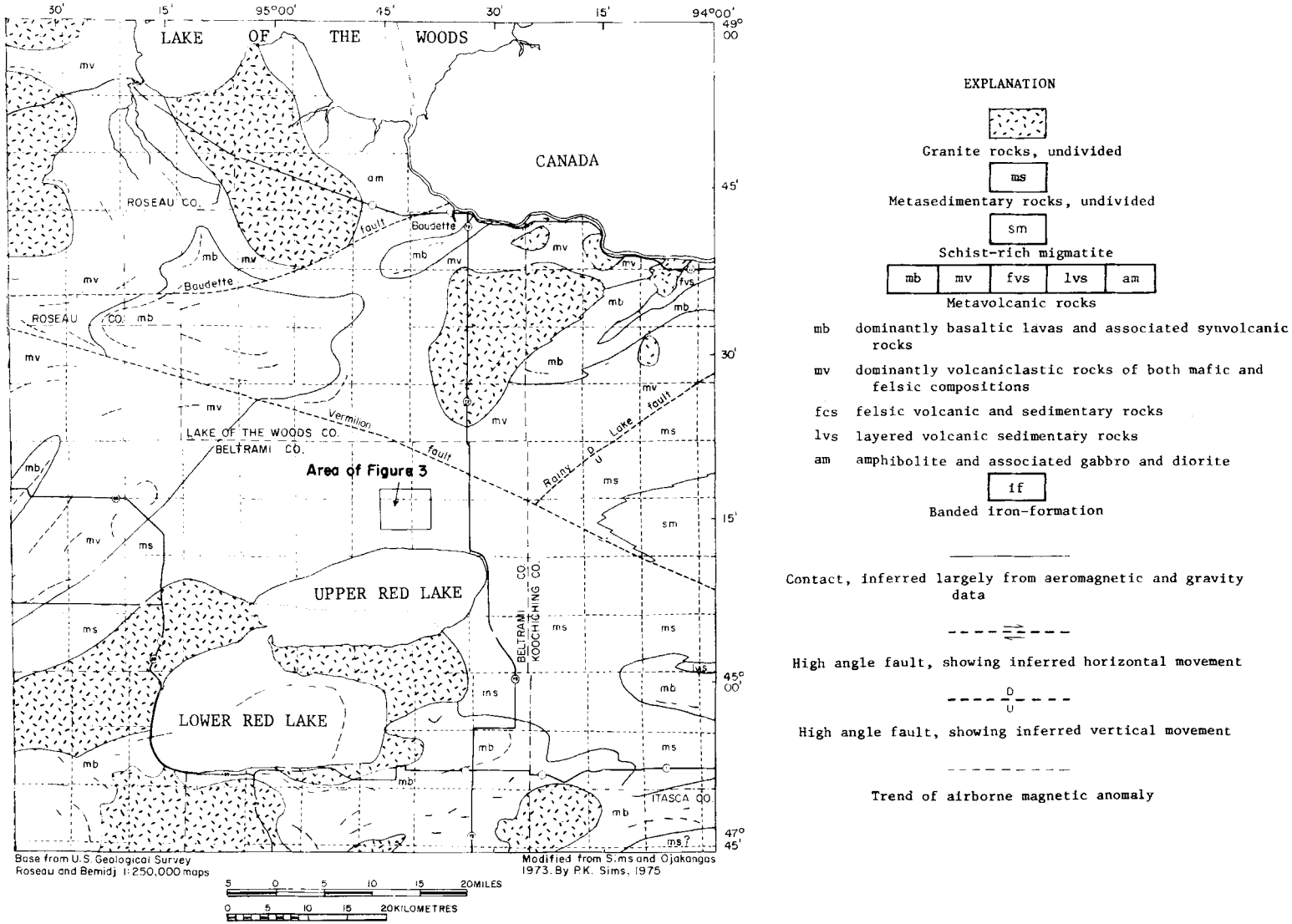


**Figure 2.** Geologic map of Red Lake Reservation, exclusive of Northwest Angle, and adjoining areas, northern Minnesota.

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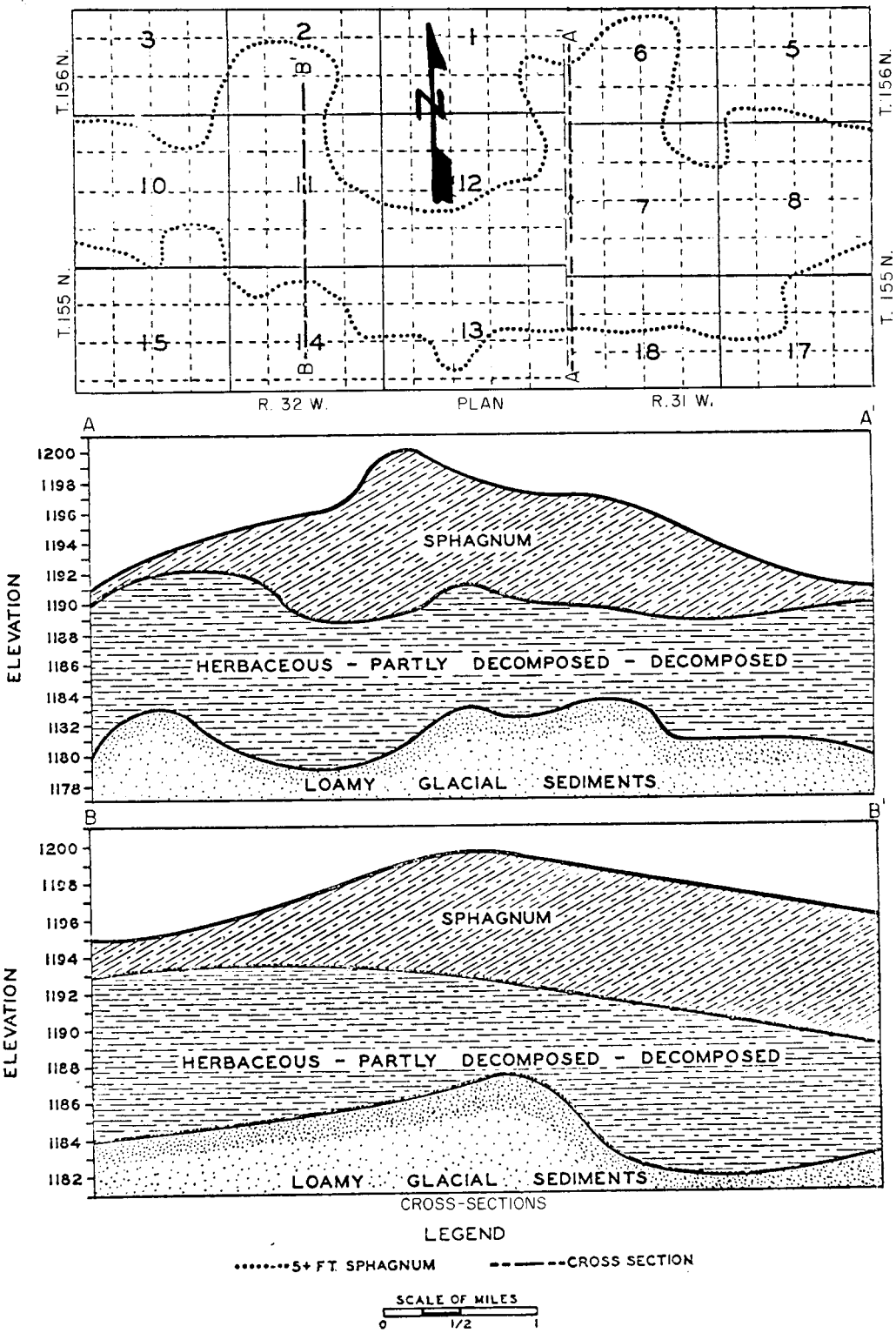


**Figure 3.** Area of thick sphagnum in Red Lake Bog, Beltrami County, Minnesota.

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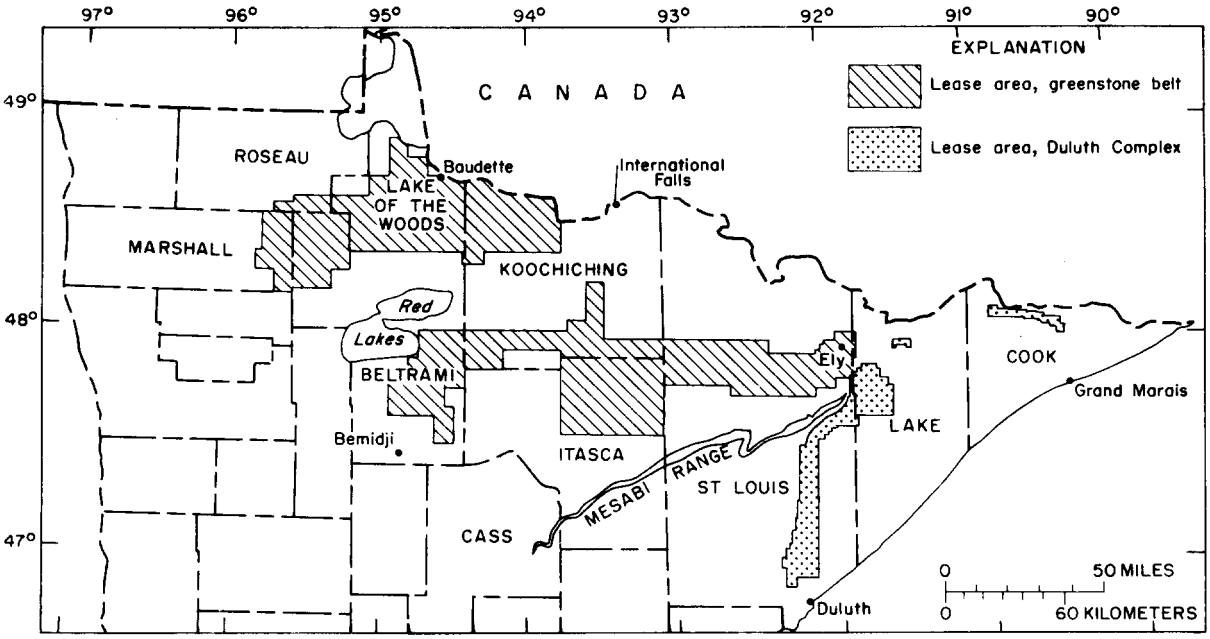


**Figure 4.** Areas offered for copper-nickel leases by the State of Minnesota.

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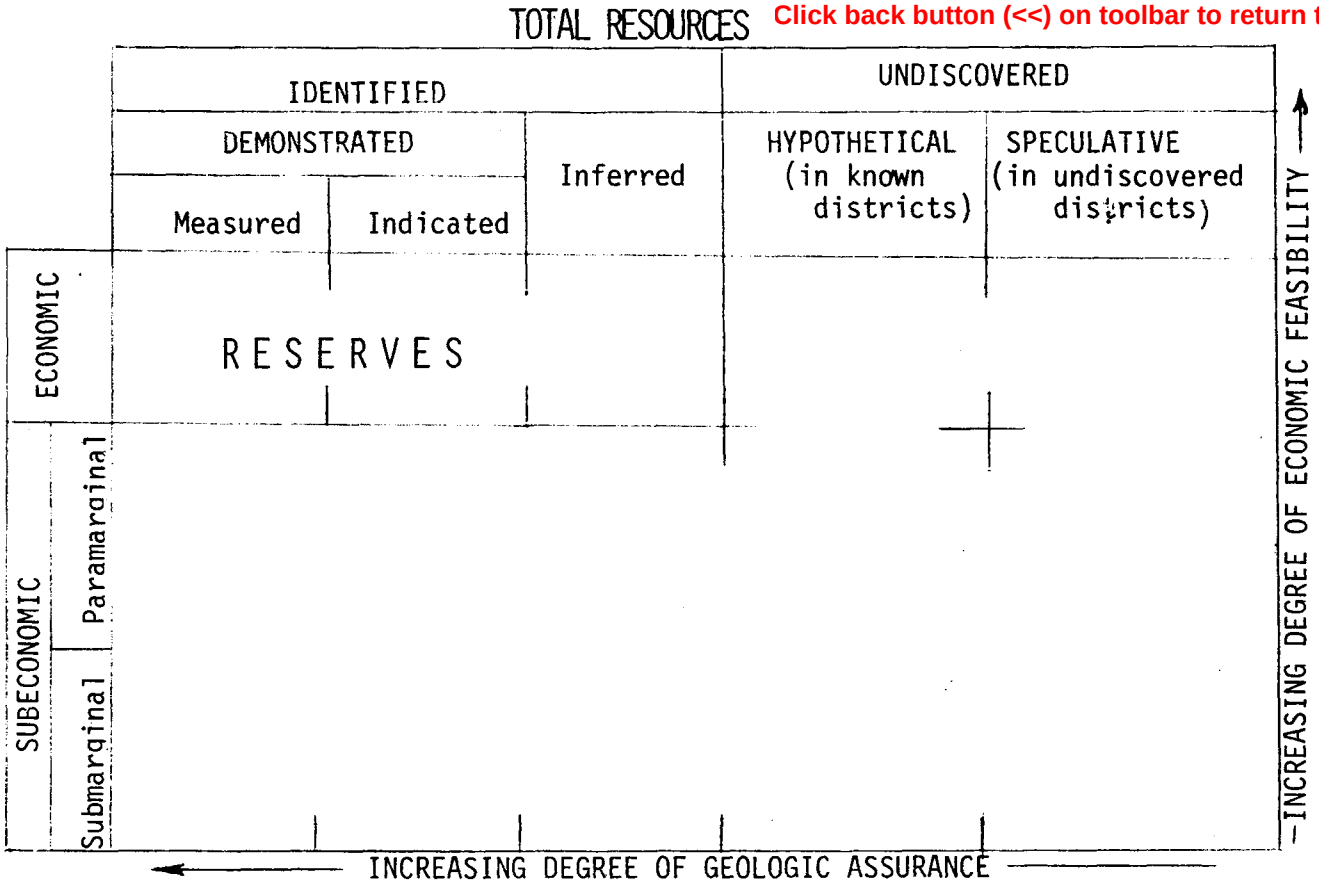


**Figure 5.** Classification of mineral resources (modified from Brobst and Pratt, 1973, Figure 1).

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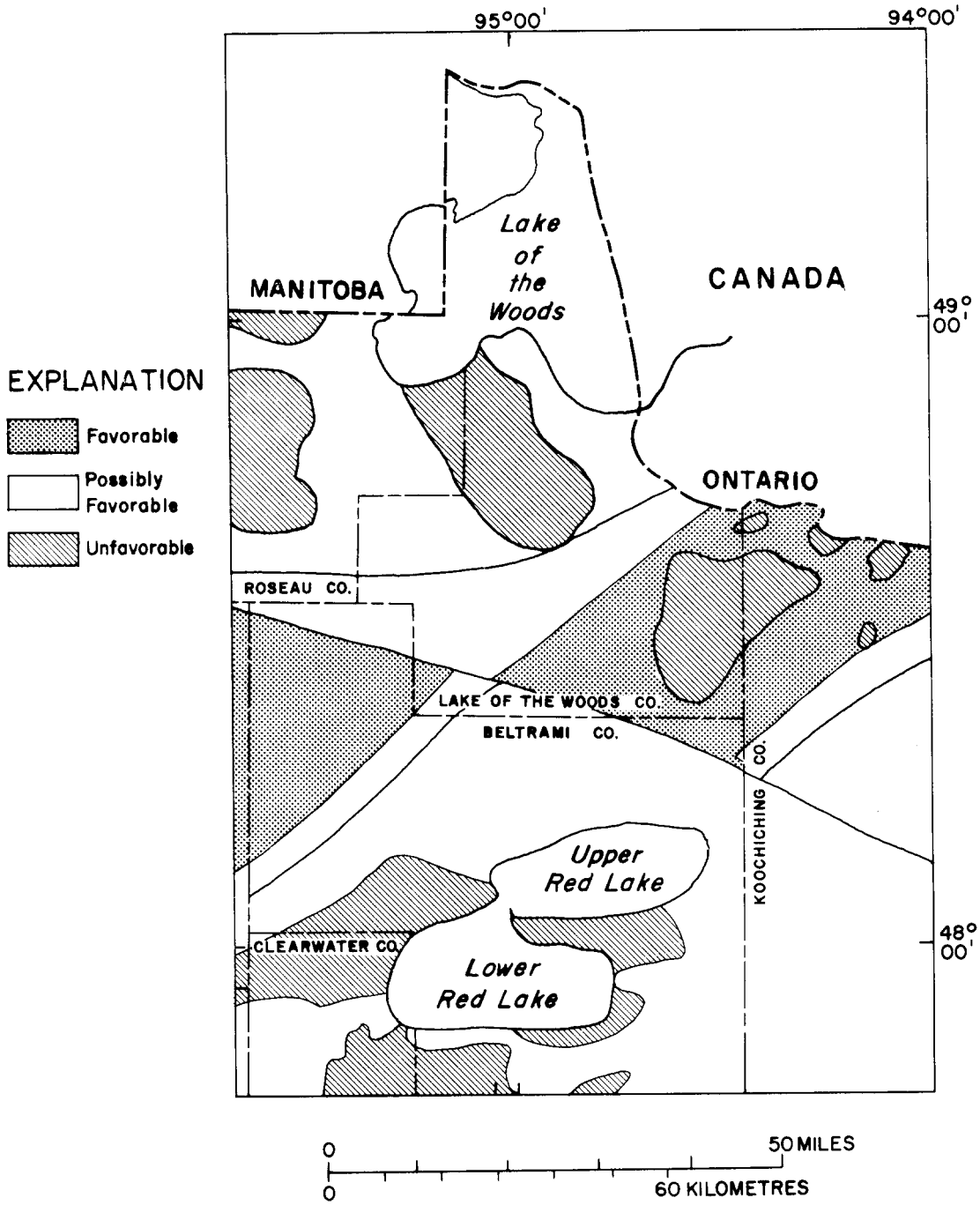


**Figure 6.** Map showing relative favorability for occurrence of massive sulfide deposits in region.