MINNESOTA GEOLOGICAL SURVEY

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GEOLOGIC INTERPRETATION OF MAGNETIC MAP OF MC LEOD COUNTY, MINNESOTA

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ABSTRACT

A ground magnetometer survey of McLeod County, Minnesota has delineated 3 structural blocks in the buried Precambrian basement rocks. The sources of the anomalies in each of the blocks have not been identified definitely because of a lack of subsurface data, but are interpreted qualitatively from an analysis of the anomalies and considerations of the regional geology.

An anomaly in the northwestern part of the county, near Hutchinson, is interpreted to represent a folded, magnetic rock unit. Probably this unit is a magnetite-bearing schist, but the possibility of its being an iron-formation of the Cuyuna-type should be investigated further.

INTRODUCTION

The discovery of anomalous magnetic readings in south-central Minnesota by airborne magnetometer traverses made by the U. S. Geological Survey in September, 1961 led to the investigation of some of the anomalies by ground magnetic surveys. Reconnaissance ground traverses were made in 1962 in parts of McLeod, Wright, Meeker, Carver, Sibley, and Renville counties, between longitudes 94°00'W. and 94°30'W., to delineate the anomalies further and to determine insofar as possible the sources. This preliminary work showed that anomalies in McLeod County were of particular economic and geologic interest; accordingly, McLeod County was systematically surveyed. This report presents the magnetic map of McLeod County and discusses the geologic interpretation of the anomalies. The Hutchinson anomaly in the northwestern part of the county is of particular significance, and should be investigated further to determine if it represents a buried Precambrian iron-formation.

The ground magnetic survey was made by Austin in July and August, 1962. Sims is largely responsible for the geologic interpretation of the data presented herein and preparation of the text.

McLeod County is in the Central Lowland physiographic province, which borders the Canadian shield in the Lake Superior region. The county is situated about midway between the Mississippi River and the Minnesota

River, in a region in which the Precambrian bedrock, which is exposed locally in the valleys of these rivers, is completely mantled by Pleistocene glacial materials. Water wells in the county have penetrated sedimentary strata that lie beneath the drift on the Precambrian basement rocks, but have not penetrated the crystalline basement itself.

MAGNETIC SURVEY

Method

The magnetic survey of McLeod County was made with a Jalander magnetometer, which measures the vertical component of the earth's field. The general highway map of McLeod County was used as a base. A base station was established in NW1/4 of the NW1/4 of the SW1/4 of Sec. 36, T. 116 N., R. 30W., at a point 82 feet east and 23 feet south of the intersection of county road 54 and the first east-west road north of Lake Marion. Readings were made along the numerous roads in the area, and were related to the base stations by loop traverses. In most of the county, readings were taken along north-south roads spaced 2 to 5 miles apart and along east-west roads at more widely spaced intervals. The intervals between readings were 0.1, 0.2, or 0.5 miles, depending on local magnetic variations. In the northwestern part of the county more detailed information was obtained. Traverses were spaced about a mile apart and readings were taken each 0.1 mile. The error in the magnetic observations is less than 50 gammas and the error in locations of stations is less than 200 feet.

Data

The magnetic data obtained during this survey are presented as magnetic contour maps (pls. 1 and 2). The locations of the stations at which magnetic readings were made are shown by dots on the more detailed map (pl. 2), but are not shown on plate 1. The magnetic contour lines on the maps are lines connecting points of equal magnetic anomaly. The shape, position, and spacing of the lines are due to local variations in the magnetization of the rocks underlying the area; the magnetic attraction of the earth itself is essentially uniform and is eliminated by use of a local base station located in an area of no anomaly.

GENERAL GEOLOGY

Because of the ubiquitous glacial deposits that mantle the surface and the scarcity of subsurface data, only the gross features of the bedrock geology are known for McLeod County. It is probable that Cretaceous strata lie directly on the Precambrian crystalline rocks in the western part

of the county and that Paleozoic (Cambrian) strata occur above the Precambrian rocks throughout the eastern part. The crystalline basement rocks, which lie at relatively shallow depths in the western part of the county, become increasingly deeper in the eastern part, and in the extreme eastern part are overlain by younger Precambrian sedimentary rocks.

Cretaceous sediments, the youngest stratified rocks in the State, are inferred from known occurrences in adjacent Sibley and Meeker counties to underlie the glacial drift west of the center-line of R. 28W., as indicated earlier by Thiel (1944, fig. 56). The lithology and thickness of the strata are not known, as the rocks have not been penetrated by drilling so far as known. Probably, however, the strata consist of a lower regolith of intensely weathered Precambrian rocks overlain by marine shale and sandstone; the aggregate maximum thickness probably does not exceed about 100 feet.

Strata of lower Paleozoic age have been penetrated in 3 wells in the southeastern part of the county. In the city well at Glencoe, 190 feet of shale and sandstone of the Cambrian Dresbach Formation were cut, as shown in the log below:

City well, Glencoe, Minnesota
(Altitude of collar: 1,897 feet; total depth: 1,640 feet)
Logged by Peter Kirwin

		Depth (in feet)	Thickness (in feet)
Pleistocene	Drift	0-354	354
Paleozoic	Dresbach Formation	354-544	190
Precambrian	Hinckley Formation	544-936	392
	Fond du Lac Formation	936-1075	139
	Sioux Quartzite(?)	1075-1545	470+
	(No samples)	1545-1640	95

It is probable that Paleozoic strata underlie the entire eastern part of the county and wedge out along a line extending from just west of Glencoe northeastward to about Winsted, as shown by Thiel (1944, fig. 56). This marks the western edge of the Paleozoic basin of southeastern Minnesota.

Precambrian rocks comparable to the metamorphic and intrusive rocks exposed near St. Cloud in the Mississippi River valley and its tributaries and in the Morton-Granite Falls-Montevideo area in the Minnesota River

valley have not been penetrated in the county so far as known. However, at Buffalo Lake in Renville County, 6 miles to the west, granitic rocks of Precambrian age are reported at a depth of 340 feet (Thiel, 1944, 292), and at Winthrop in Sibley County, 13 miles south of Brownton, similar rocks occur at a depth of about 400 feet. The surface of the Precambrian granitic rocks in central and western McLeod County, therefore, probably lies at a depth of 400 feet or less. Eastward, this surface becomes increasingly deeper, and at Glencoe it lies below a depth of 1640 feet (see log above). The Precambrian sedimentary rocks penetrated in the well lie near the western margin of the Keweenawan basin of southeastern Minnesota (Zietz and Sims, in press), and wedge out a short distance west of Glencoe. They overlie a quartzite with some intercalated siltstone and shale, which possibly is the Sioux Quartzite (as interpreted in the log above), but conceivably could be a quartzite layer within the Fond du Lac Formation. If the quartzite is the Sioux Formation, this is its most northerly known occurrence.

INTERPRETATION OF MAGNETIC MAP

The sedimentary rocks and the unconsolidated glacial deposits that overlie the Precambrian basement rocks are virtually nonmagnetic, and the anomalies shown on the magnetic maps reflect the inherent magnetic properties of the basement rocks. Although the sources cannot be identified directly, they can be inferred with some degree of certainty from the known gross geologic framework and by comparison of actual anomalies with those obtained above known sources. The data are interpreted empirically in this report; no attempts have been made to analyze the information mathematically, although a few simple depth calculations have been made.

Most of the known Precambrian basement rocks in the State contain sufficient magnetite to yield magnetic anomalies. The actual anomaly recorded is mainly a function of magnetite content, the relation of induced to remanent magnetization, the geometric form of the rock body, and the distance from the point of measurement to the magnetic poles of the rock mass. Actual measurements on magnetic properties and analysis of magnetic data from known rock outcrops by Gordon Bath and others of the U. S. Geological Survey (written communication, 1963) and Mooney and Bleifuss (1953) have shown that induced magnetization, which is related directly to the magnetic content of the rocks, dominates the total magnetization of intrusive and metamorphic rocks of intermediate and felsic composition whereas remanent magnetization is an important component of the total magnetization for iron-formations and igneous rocks of mafic composition. Slates and schists are vir-

tually nonmagnetic. The data also show that anomalies given by intermediate or mafic intrusives can resemble those produced by iron-formation (Bath, 1962). Iron-formations often can be distinguished from intrusive rock bodies, however, by greater linear continuity as well as by a strong magnetic attraction.

The magnetic patterns of plate 1 indicate that the Precambrian rocks of the county belong to 3 structural blocks, an eastern block with a northerly trend, a southern block with a west-northwesterly trend, and a northwestern block with irregular anomalies, some of moderately high magnetic attraction.

The north-trending magnetic anomalies in the eastern block lie above Keweenawan rocks, and from regional magnetic and geologic studies (Zietz and Sims, in press) it can reasonably be inferred that the positive magnetic ridge reflects a layer of basaltic volcanic rocks intercalated with clastic sedimentary rocks. Zietz and Sims (in press) have calculated that the basaltic layer is about a mile thick and is covered by about 5,000 feet of nonmagnetic sedimentary rocks. The western margin of the Keweenawan rocks, as indicated on plate 1, is inferred from combined magnetic and geologic data.

The northwestern part of the quadrangle is marked by a horseshoe-shaped anomaly of moderate intensity that represents a magnetite-rich unit and small "highs" that probably reflect buried intrusive rocks of intermediate or mafic composition. The major anomalies of this area are shown in detail on plate 2.

The horseshoe-shaped anomaly at Hutchinson reflects a folded magnetic unit. Possibly it is a northward-plunging syncline, for the magnetic profiles are slightly steeper on the outer margin of the anomaly than on the inner margin. The maximum thickness of the magnetic unit probably does not exceed a few hundred feet. The anomaly resembles anomalies recorded above the folded iron-formations in the Cuyuna Range, 100 miles to the north, but has a somewhat lesser magnetic attraction. A simple depth calculation indicates that the source on the east limb lies at a depth of about 900 ± 350 feet. The only well in the region on which information is available was drilled to a depth of 200 feet in glacial drift.

The remainder of the block in the northwestern part of the county (pl. 2) is dominated by scattered subcircular or lens-shaped anomalies of moderate intensity in a neutral magnetic background. The anomalies appear to be alined roughly along east-west axes, but this apparent alinement may be fortuitous. They resemble in shape and size many of the anomalies above

intrusive rocks of intermediate and mafic composition in northern Minnesota; many examples can be found on the aeromagnetic maps of northern Minnesota published by the U. S. Geological Survey. The country rock that forms the matrix for the inferred intrusive bodies is possibly slate or schist, essentially nonmagnetic rocks.

The age of the rocks underlying the northwestern part of the county is not known, but from the regional geologic relationships known to the north in the St. Cloud area, and the magnetic data, the rocks can reasonably be inferred to be Animikian (Middle Precambrian) in age, intruded by bodies of Penokean age. The anomalies over the inferred intrusive rocks in McLeod County resemble those over known Penokean intrusive rocks to the north; further, the neutral magnetic background of the intervening areas indicates rocks similar in magnetization to the schists and slates to the north. The fold represented by the horseshoe-shaped anomaly at Hutchinson resembles the folds in the argillites and slates of the Thomson Formation to the north as well as those in the iron-formations and associated argillites of the Cuyuna Range, described by Schmidt (1959).

The pronounced west-northwestward trend of the magnetic contours in the southern part of the county, southwest of Brownton (pl. 1), contrasts markedly with the pattern to the north. This pattern probably reflects a layered succession of metamorphic rocks with a moderate magnetic susceptibility and a west-northwest trend. The succession may be folded along approximately east-west axes. Possibly the bedrock underlying this part of the area is equivalent to the ancient Precambrian metamorphic rocks exposed in the Minnesota River valley in the Morton-Granite Falls-Montevideo area (Lund, 1956; Goldich and others, 1961). These rocks consist dominantly of a layered sequence folded along east-west axes; the limbs of the folds trend approximately east-west. The large fold exposed in the vicinity of Granite Falls, currently (1963) being mapped in detail by Glen Himmelberg for the Minnesota Geological Survey, would project into southern McLeod County. Some rocks in this sequence have been dated by the zircon isotope method (Catanzaro, 1963) as about 3.2 billion years old.

According to the interpretation presented above, the 3 structural blocks recognized in McLeod County may represent rocks of 3 distinct ages, separated from one another by major unconformities. Possibly, older Precambrian rocks of the southern part of the county are overlapped in the vicinity of Brownton by rocks of Animikie age; these in turn are overlapped in the eastern part of the county by Keweenawan volcanic and sedimentary rocks.

ECONOMIC CONSIDERATIONS

Although the Hutchinson anomaly does not definitely reflect an iron-formation, the possibility of its being Cuyuna-type iron-formation is sufficiently promising to warrant further investigation and, possibly, exploration. The major target, to judge from the magnetic data, would be the eastern limb of the anomaly, in the vicinity of Hook Lake and Lake Emily, in sections 4 and 9, T.117N., R.29W.

The magnetic anomaly has regional as well as local significance. Should the anomaly prove to be an iron-formation, particularly of the Cuyuna type, this would materially extend the known areas underlain by iron-formations, and would open additional ground favorable for geologic exploration. Prospecting would be warranted in the entire area between McLeod County and the Cuyuna Range.

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