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Scale 1:250,000

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LINEAMENT MAP, HIBBING SHEET, MINNESOTA
1982

INTRODUCTION

All of the lineaments in the area of the Hibbing sheet in northern Minnesota (Fig. 1) are in one way or another related to glacial and postglacial processes that occurred in Pleistocene and Holocene time. The bedrock crops out extensively only in the northeastern and central parts of the sheet (Fig. 2), where mapping by successive generations of geologists has provided the basis for many classical studies in Precambrian and economic geology.

Despite numerous man-years of mapping, considerable interpretation and extrapolation are required to give continuity to the bedrock geology, even in areas where bedrock exposures are relatively abundant. Consequently much of the present geologic map (Fig. 3) is interpreted from geophysical data supplemented by subsurface information in the few places possible. The combined use of geophysical and geological data has greatly enhanced our understanding of the spatial distribution of various rock types, but in areas of poor outcrop the geophysical data provide only minimal structural information except where strongly contrasting rock types are juxtaposed. Several recent studies in northeastern Minnesota (Cooper, 1978; Cooper and others, 1981), however, have shown that interpretation of lineament data is a useful supplement in structural mapping.

PROCEDURES

The lineaments shown on this map are alignments of topographic features, such as hills, ridge lines, streams, and valleys, or some combination of these features, that are visible on high-altitude, blue-line aerial photographs flown in 1969 by Mark Hurd Aerial Surveys, Inc. for the State of Minnesota. Procedures for identifying the topographic lineaments shown on this map were similar to those developed by Cooper (1978) and used by Morey (1981a) for the Two Harbors sheet. In addition, this map also makes use of tonal lineaments which are associated with vegetational differences where Holocene bogs and peatlands are prominently developed.

All of the aerial photographs were interpreted at their original scale of 1:24,000. The interpretive maps were then photographically reduced and replotted at the final scale of 1:250,000. Although reduction tends to obscure many small lineaments, it does not detract materially from the validity of the lineament patterns portrayed.

GEOLOGIC SETTING

Most of the Hibbing sheet is underlain by Precambrian rock units of Archean and Proterozoic age (Fig. 3). Although the geology is complex, four major Precambrian lithotectonic segments can be recognized. These include: (1) complexly deformed, east-trending belts of Archean metavolcanic and metasedimentary rocks between (2) flanking batholiths of Archean granitic and locally migmatitic rocks, including the Giants Range batholith, the Vermilion Granitic Complex and several other unnamed plutons, in the southern half of the sheet, the Archean rocks are overlain unconformably by (3) relatively undeformed lower Proterozoic metasedimentary rocks of the Animikie Group, which in turn are intruded by (4) middle Proterozoic rocks of the Duluth Complex.

All of the Precambrian rocks are broken by major northwest-trending faults, many of which appear to be reactivated Archean structures. Several of the fault zones, especially those in the Archean terrane, are occupied by lower and middle Proterozoic dikes of gabbroic composition; these dikes are too thin and discontinuous to be shown at the scale of Figure 3. A thin veneer of Cretaceous nonmarine to marine strata unconformably overlies the lower Proterozoic rocks in the south-central part of the sheet.

Northern Minnesota was glaciated repeatedly during the Pleistocene Epoch (Wright, 1972a), as several 'old' drift units (Winter, 1971) have been exposed in open-pit mines on the Mesabi range in the areas of unit m on Figure 4. However the oldest Wisconsinan drift having extensive surface exposures in the Hibbing sheet area was deposited by the Hewitt phase of the Wadena ice lobe which advanced from the north and deposited till rich in Precambrian rock fragments, possibly during early Wisconsinan time.

Subsequently in late Wisconsinan time, much of the Hibbing sheet, including most of the Wadena lobe deposits, was covered by drift of the St. Croix advance of the Rainy lobe. This phase of glaciation also produced the Toimi drumlin field along the eastern edge of the sheet. Subsequently the Rainy lobe retreated northward only to readvance during the Automba phase across the northeastern quarter of the sheet, forming the Vermilion moraine complex, an arcuate belt of terminal and recessional moraines. The ice of this advance overrode the northern edge of the Toimi drumlin field and left a thin, discontinuous sheet of bouldery till rich in Precambrian rock fragments over much of the northern part of the sheet. At about the same time, the Superior lobe advanced southwestward, crossing the southeastern corner of the Hibbing sheet. Till and associated outwash deposits of the Highland moraine, which mark the edge of this ice lobe, sharply overlap the southern edge of the Toimi drumlin field.

The last major ice lobe, the St. Louis sublobe of the Des Moines lobe, advanced from the northwest and west across much of the Hibbing sheet during the Alborn-Nickerson phase (Wright, 1972a) and deposited drift rich in light-colored Paleozoic rock fragments. This drift forms a thin veneer that partly covers the Toimi drumlin field in the eastern part of the sheet, but elsewhere it occurs as thick deposits that deeply bury older drifts. As the St. Louis sublobe wasted away, sand, silt, and clay were deposited in two major glacial lakes—Glacial Lake Agassiz in the northern part of the sheet and Glacial Lake Upham in the south-central part. Most of the area that was occupied by these glacial lakes is now flat-lying poorly drained wetlands characterized by extensive peat deposits of Holocene age.

DISCUSSION

Comparison of Figures 2 and 4 indicates that the great majority of bedrock exposures occur in areas of drift associated with the Rainy lobe. The southern arm of the Vermilion moraine complex divides this area into two distinctly different physiographic areas (Wright, 1972b). North of the moraine complex is the Border Lakes area (Fig. 5), where glacial activity was largely erosional, producing topographic depressions and ridges that closely reflect lithologic and structural differences in the bedrock. Many bedrock units in this area can thus be distinguished by their associated lineament patterns; similar correlations between known geology and topographic lineaments have been described in some detail by Cooper and others (1981) and Morey and Hautmaker (1982). In contrast, south of the moraine complex, in the Chisholm-Embarrass physiographic area (Fig. 5), glacial activity was largely depositional, although sporadic bedrock outcrops suggest that the drift deposits are relatively thin. The terrain is characterized by low, east-trending moraines separated by outwash plains, and most of the lineaments trend toward the north and correspond to numerous small stream valleys incised into the drift deposits.

The Giants Range physiographic area (Fig. 5) crosses the southern part of the Chisholm-Embarrass area. It is a highland which rises from 50 to 120 meters above plains both to the north and south, and extends from west of Hibbing east-northeastward across the edge of the sheet. It is underlain predominantly by Archean rocks, but is flanked on the south by Proterozoic rocks of the Animikie Group. The Archean rocks of the Giants Range, like those of the Border Lakes area, are characterized by lineaments trending north-northeast and east-northeast that correspond to layering in the supracrustal rocks and small-scale internal structures in the granitic rocks. Some northeast-trending lineaments and all northwest-trending lineaments correspond to joints and faults in both the supracrustal and granitic rocks. Thus the lineament patterns in this area can be used to distinguish major bedrock units. Proterozoic rocks of the Animikie Group on the south side of the Giants Range display a few lineaments that parallel bedding or faults and joints in the Biwabik Iron Formation, but most of the natural topographic features are obscured by open-pit iron mines, large tailings basins, and huge piles of mine waste.

The western third of the Hibbing sheet is a heavily forested, lake-dotted till plain that Wright (1972b) subdivided into the Bemidji and Sugar Hills-Mille Lacs physiographic areas (Fig. 5). Glacial landforms in the Bemidji area north and west of Grand Rapids relate both to the movement of the Wadena lobe and to subsequent invasion by the Des Moines lobe. Lineaments typically trend to the north or north-northwest, and for the most part are drumlins and tunnel valleys of Pleistocene age, and lakes and drainageways of Holocene age. Although the drift deposits are relatively thick, the lineaments are more or less parallel to bedrock faults, which are transverse to the bedrock grain, and therefore the bedrock structure may have influenced ice movement throughout the glacial history of the area. Southwest of Grand Rapids the Sugar Hills-Mille Lacs area includes several moraines related to both the Wadena and Des Moines lobes. Lineaments here are related to glacial and postglacial landforms, but unlike the lineaments of the Bemidji area, they do not correspond to underlying bedrock structures. Most likely this difference reflects the easily erodible nature of the area's lower Proterozoic and Cretaceous bedrock.

Prominent northeast-trending lineaments along the eastern edge of the Hibbing sheet and south of the Vermilion moraine complex reflect drumlins and long gravelly plains of meltwater sediment that wind among the drumlins of the Toimi drumlin field (Fig. 5). Many of the gravelly plains contain linear drainageways and elongate swamps and small lakes. In contrast, the southeastern corner of the Hibbing sheet is characterized by northwest-trending lineaments that reflect linear drift accumulations formed as the Superior lobe overrode the Toimi drumlin field from the southeast. Scattered northwest-trending lineaments in the Toimi drumlin field itself also are related to the Superior lobe, for some of the drumlins have transverse flutes and a veneer of Superior lobe till (Wright and Watts, 1969). The western edge of the Toimi drumlin field and its veneer of Superior lobe till are overlain by clay-rich till deposited by the Des Moines lobe which advanced from the southwest and west. Where the clay-rich till occurs as a thin veneer, many of the underlying drumlins are still visible as northeast-trending lineaments. Consequently the lineament patterns are of little value in distinguishing the eastern edge of Des Moines lobe deposits in the Hibbing sheet.

Glacial lake plains associated with the Beltrami arm of Glacial Lake Agassiz in the northwestern part of the Hibbing sheet and with Glacial Lake Upham in the south-central part of the sheet (Fig. 5) are poorly drained peatlands consisting of raised bogs separated by fens. The raised bogs commonly have tonal lineaments that represent clusters or strings of trees, whereas the fens have lineaments that correspond to water tracks which run between the raised bogs. Many of the water tracks provide drainage from bog to stream, and thus are graded toward streams and rivers that drain toward the north in the former area of Glacial Lake Agassiz, and toward the south and southwest in the former area of Glacial Lake Upham.

SUMMARY

Lineaments in the Hibbing sheet are all in some way related to glacial or postglacial processes. Nonetheless there is a striking correspondence between topographic lineaments and bedrock structures where ice-scoured areas are covered by only a thin veneer of ground moraine. Further analysis of the lineaments in these areas in light of the high-resolution aeromagnetic data now available (Minnesota Geological Survey, 1980) should provide considerable new information regarding structural details in adjacent areas where the Pleistocene deposits are more continuous and the bedrock is only sporadically exposed. Topographic and tonal lineaments in areas of thick drift are of minimal value in bedrock interpretation, but they provide a means of delineating many of the glacial and postglacial deposits that occur in the Hibbing sheet.

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Figure 1. Index map showing location of study area.

Figure 2. Distribution of natural and man-made exposures of bedrock (modified from Morey, 1981b).

Figure 3. Generalized bedrock geologic map of the Hibbing sheet (modified from Morey and others, 1982).

Figure 4. Generalized surficial geologic map of the Hibbing sheet (modified from Hobbs and Goebel, 1982).

Figure 5. Physiographic areas of Wright (1972b) in the Hibbing sheet: 1, border lakes area; 2, Chisholm-Embarrass area; 3, Giants Range; 4, Bemidji area; 5, Sugar Hills-Mille Lacs area; 6, Toimi drumlin area; 7, Aurora-Alborn clay-till area; 8, Beltrami arm of Lake Agassiz; 9, Glacial Lakes Upham and Aitkin.