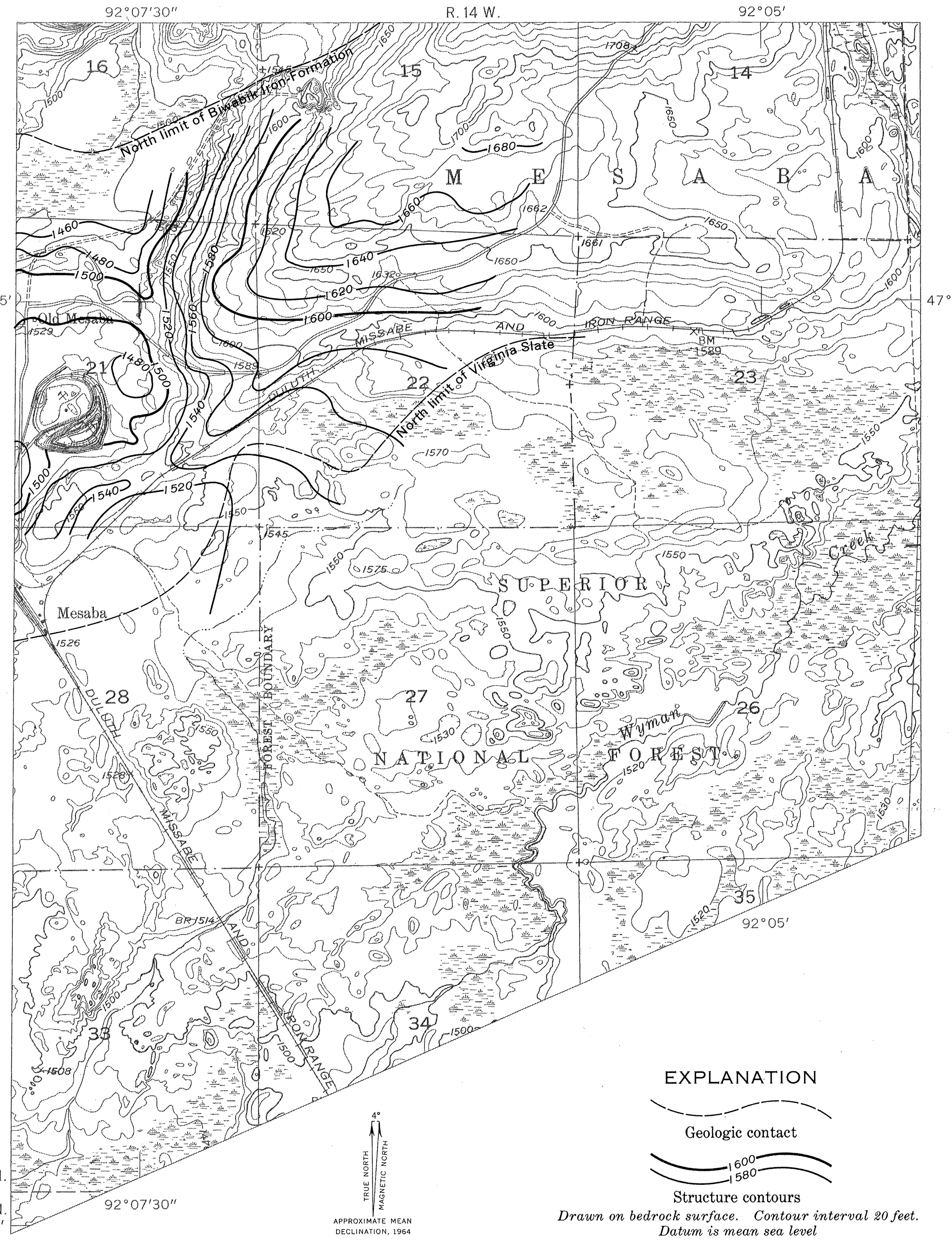
PREPARED IN COOPERATION WITH THE
DIVISION OF WATERS, MINNESOTA DEPARTMENT OF CONSERVATION
AND THE
DEPARTMENT OF IRON RANGE RESOURCES AND REHABILITATION



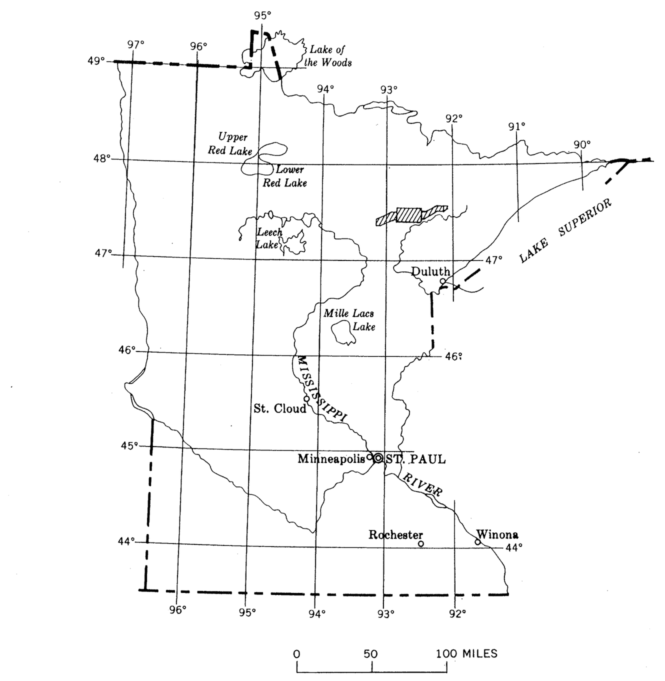
Base from U.S. Geological Survey topographic quadrangles: Allen and Aurora

Geology from Geological Society of America Guidebook Series, 1956, Precambrian of Northeastern Minnesota, plate 3

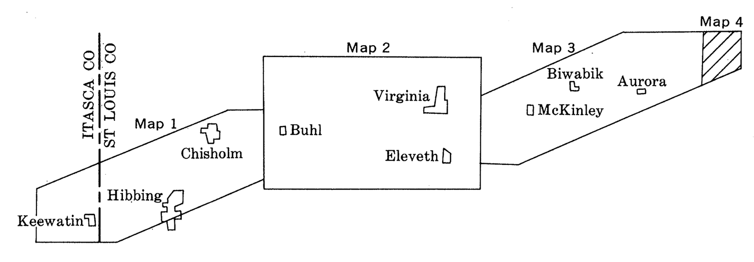
MAP 4

SCALE 1:24 000

CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL



INDEX MAP OF MINNESOTA SHOWING AREA COVERED



LOCATION DIAGRAM

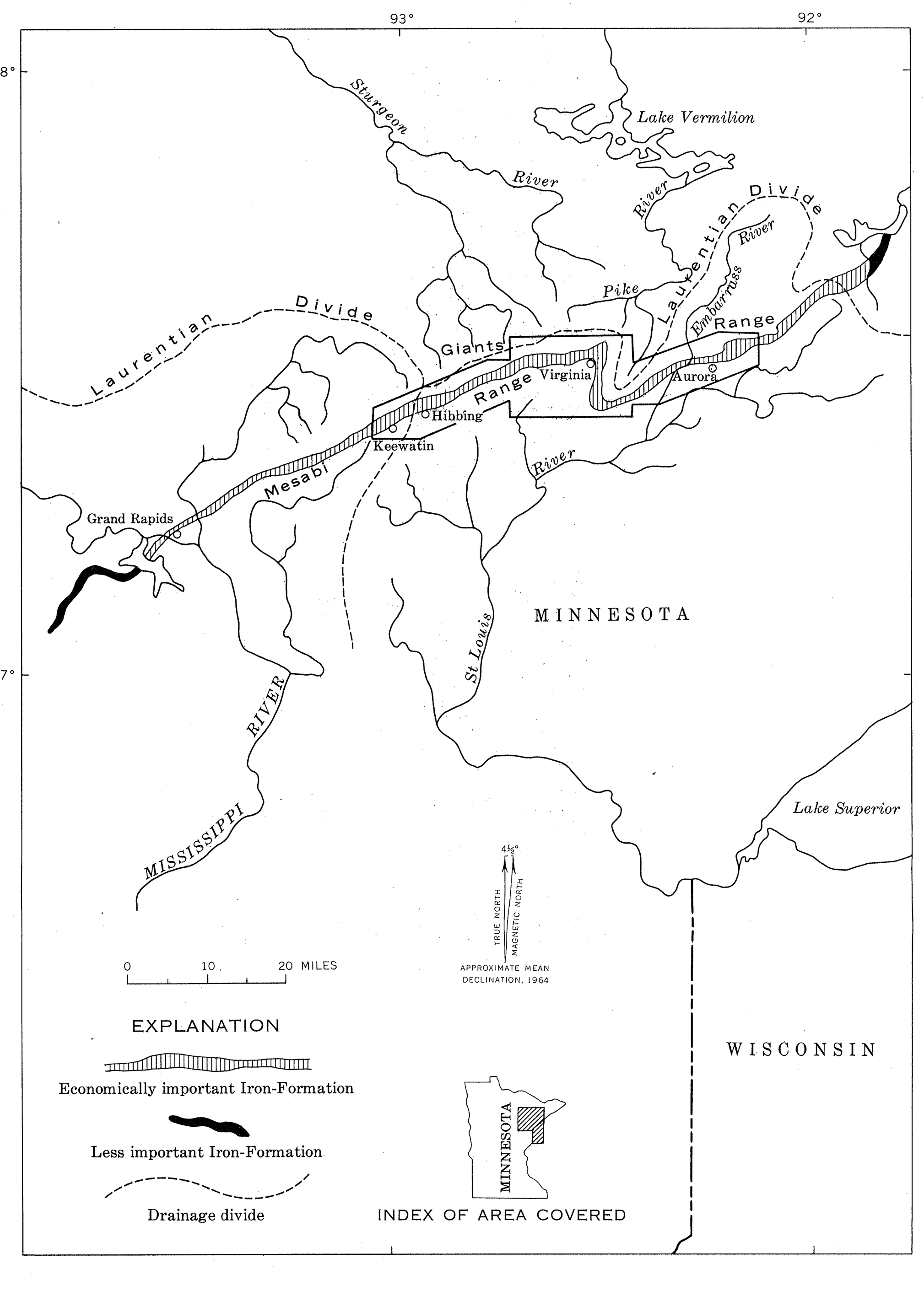


FIGURE 1. MAP OF NORTHEAST MINNESOTA SHOWING LOCATION OF THE MESABI RANGE AND MAJOR DRAINAGE FEATURES

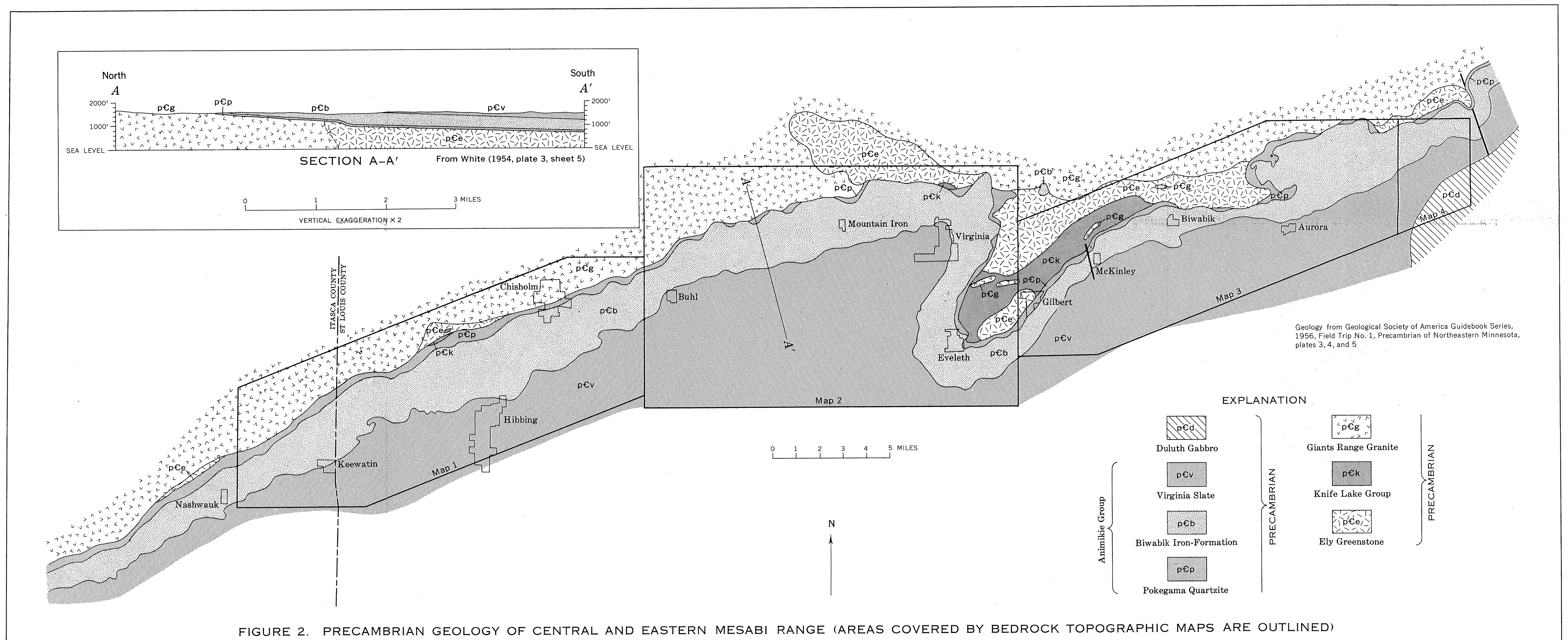


FIGURE 2. PRECAMBRIAN GEOLOGY OF CENTRAL AND EASTERN MESABI RANGE (AREAS COVERED BY BEDROCK TOPOGRAPHIC MAPS ARE OUTLINED)

INTRODUCTION

The Mesabi iron-mining district or range (fig. 1), is in northeastern Minnesota, 60 to 85 miles west of Lake Superior. The Mesabi Range, in this report, includes the iron-mining belt, ¼ of a mile to 3 miles wide, that extends for 120 miles in a northeasterly direction across Itasca and St. Louis Counties. It is the area of economically important iron-bearing formation and associated rocks, now mostly buried under glacial drift. (See fig. 2.)

The water resources of the Mesabi Range, northeastern Minnesota, are being studied by the U.S. Geological Survey, in cooperation with the Minnesota Department of Iron Range Resources and Rehabilitation. A preliminary step in the ground-water study was to make use of the available bedrock data to compile maps showing configuration of the buried bedrock surface. These maps can be used to determine areas of maximum thickness of glacial sediments, ground-water basins, and areas that probably have been favorable for the deposition of permeable glacial sediments.

Water is needed in large quantities for taconite processing and ore beneficiation, and for municipal supplies. In addition, chemical industries that utilize wood raw materials will locate in the area in the future. These industries also will need large water supplies and will have complex waste-disposal problems. Thus, the volume of water needed in the Mesabi area for industrial purposes is tremendous. For example, two major taconite plants were operating in the area in 1960. Processing taconite ore required about 95 billion gallons, or 200,000 gpm (gallons per minute). Of this amount, about 10 percent was consumed. The amount consumed is the equivalent of 6 inches of recharge—the maximum estimated available from precipitation in the area—over about 100 square miles of land.

Since 1872 numerous geologic investigations have been made in the Mesabi Range area, chiefly in relation to the occurrence of iron ore. Thiel (1947) was the first to describe the ground-water geology of northeastern Minnesota. The Geological Survey began its ground-water studies in 1952 in cooperation with the Lake Superior Industrial Bureau through the Division of Waters, Minnesota Department of Conservation.

The first cooperative project proposed was the construction of a bedrock topographic map of the Mesabi Range compiled from data furnished by the mining companies that comprised the Lake Superior Industrial Bureau.

In 1954 a cooperative ground-water program began with the Iron Range Resources and Rehabilitation Commission (now the Department of Iron Range Resources and Rehabilitation), an agency of the State of Minnesota. The Department replaced the Lake Superior Industrial Bureau cooperative program and continues to the present time.

The following mining companies, members of the Lake Superior Industrial Bureau, contributed some of the data from which the bedrock maps were compiled: The Cleveland-Cliffs Iron Co.; The M. A. Hanna Co.; Oliver Iron Mining Division, United States Steel Corp.; and Pickands Mather & Co. These contributions are gratefully acknowledged.

GEOGRAPHY

The climate of the central and eastern Mesabi Range is humid continental, characteristic of most of the Midwest. Average monthly temperatures range from a low of about 8°F in January to a high of about 68°F in July; the annual average is about 39°F. Precipitation averages about 26 inches annually, most of which falls as rain in midsummer and early autumn.

The principal topographic feature of the Mesabi Range area is the Giants Range, a northeasterly trending chain of low hills that parallels the Mesabi Range. The Mesabi Range occupies the south flank of the Giants Range. Near the east end of the Giants Range, north of Aurora in the section known as the Embarrass Mountains, altitudes are as high as 1,900 feet above sea level and about 400 feet above the surrounding countryside. To the west the altitude of the crest diminishes to 1,400 feet and is buried beneath glacial drift. West of Keewatin, the Giants Range is a subdued surface feature. North and south of the Giants Range crest, the land slopes into poorly drained lowlands marked by many lakes and swamps.

The central part of the Giants Range forms part of the Laurentian Divide, one of the principal drainage divides in northeast Minnesota. (See fig. 1.) The western part of the Mesabi Range drains into the Mississippi River; the central and eastern parts of the south flank drain into the St. Louis River, which flows into Lake Superior. The eastern part of the north flank is drained by the Embarrass River, which crosses the Giants Range and flows southward into the St. Louis River. The central part of the north flank of the Giants Range drains to the north by two routes: by way of tributaries of the Sturgeon River and by way of the Pike River, which flows into Lake Vermilion. Both of these rivers ultimately reach Hudson Bay via the Rainy River and Lake of the Woods. North of Hibbing, in sec. 26, T. 58 N., R. 21 W. (fig. 1), there is a three-way drainage divide where waters distribute to the Atlantic Ocean, Gulf of Mexico, and Hudson Bay.

The central and eastern Mesabi Range has an urban population of about 63,000 distributed among 16 communities. The largest cities are Hibbing (17,731), and Virginia (14,034).

Iron mining is the principal industry of the Mesabi Range. In 1959 the mines shipped 33,939,944 tons of ore (Wade and Alm, 1960, p. 247). This was 58 percent of the total United States production.

Minor industries include pulpwood harvesting, dairy and muckland farming, peat processing, and the seasonal resort trade.

Transportation to and within the area is available on U.S. Highways 2, 53, and 169, and State Highways 38, 65, 73, 135, 169, and 216. Rail service is provided by the Duluth, Missabe & Iron Range Railway Co., the Duluth, Winnipeg & Pacific Railway Co., and the Great Northern Railway Co. North Central Airlines furnishes scheduled service at the Hibbing Municipal Airport.

BEDROCK GEOLOGY

Although most of the bedrock geology of the Mesabi Range is obscured by a mantle of glacial drift, a great deal is known about the distribution of bedrock types owing to large open-pit workings and a wealth of drilling information. The following table shows the stratigraphic sequence in the Mesabi Range area.

The basement rocks of northeastern Minnesota are part of the southern exposed margin of the Canadian Shield and are Precambrian in age. The areal distribution of these rocks is shown in figure 2.

The Giants Range, which parallels the north boundary of the Mesabi Range, consists mainly of the Giants Range Granite. This granite intrudes the Ely Greenstone and Knife Lake Group, which crop out both north and south of the Giants Range.

CENOZOIC		PLEISTOCENE: Glacial drift (multiple till sheets, outwash) (0-300 ft.)
		Unconformity
MESOZOIC		CRETACEOUS: (Upper) Coleraine Formation of Stauffer (1933) (shale, conglomerate) (0-100 ft., Bergquist, 1944, p. 3)
		Unconformity
PRECAMBRIAN	Upper	KEWEENAWAN SERIES: Duluth Gabbro (thickness unknown)
		Unconformity
	Middle	Animikie Group (total thickness unknown, White, 1954, p. 22-27): Virginia Slate (argillite) (2,000+ ft.); Biwabik Iron-Formation (ferruginous chert) (340-800 ft.); Pokegama Quartzite (quartzite, argillite, conglomerate) (0-200 ft.)
		Unconformity
	Lower	ALGOMAN INTRUSIVES: Giants Range Granite
		Knife Lake Group (slate, graywacke, iron-formation, conglomerate, tuffs, flows, intrusives) (thickness unknown)
		Ely Greenstone (thickness unknown)

Unconformably overlying these older rocks is the Animikie Group which consists of three slightly metamorphosed sedimentary units: the Pokegama Quartzite, the Biwabik Iron-Formation, and the Virginia Slate. The Animikie Group has a regional dip of 5° to 15° SSE., with local variations. The southward extent, downdip, of the beds of the Animikie has not been determined. The north edge of the beds of the Animikie Group are truncated by erosion where they crop out against the Giants Range. At the east end of the Mesabi Range, the Animikie Group has been cut off by the intrusion of the Duluth Gabbro. The western extent has not been determined as the range is not economically important west of Grand Rapids (fig. 1) and few test holes have been drilled.

Lying with angular unconformity upon eroded beds of the Animikie are scattered thin outliers of shale and conglomerate of the Coleraine Formation of Stauffer (1933) which is Cretaceous in age. The formation has been positively identified only in a few open-pit mines and its areal extent has not been determined.

Bedrock geology of the Mesabi Range area has been described in detail by Leith (1903) and White (1954), and has been summarized by Leith, Lund, and Leith (1935), Marsden (1956), and Schwartz (1956). The most recent findings in the area have been published by the Minnesota Geological Survey utilizing revised stratigraphic terminology (Goldich and others, 1961, p. 168).

CONFIGURATION OF BEDROCK SURFACE

The structure contours on the bedrock topographic maps (Map 1, 2, 3, and 4) show the configuration of the pre-Quaternary surface cut on Precambrian, and possibly some Cretaceous rocks. These contours are limited to areas where test holes were drilled in areas of known or suspected iron-formation.

The holes that were utilized in compiling these maps were selected in a general grid pattern of 4 holes per 40 acres, or 64 holes per sqaure mile. Depths to bedrock in these holes were converted to altitudes above mean sea level, and 20-foot contour lines were drawn to the scale on the base maps furnished by one of the mining companies. The maps were then photographically reduced to 1:24,000 and the contour lines traced onto U.S. Geological Survey quadrangle maps of the same scale. The iron mines are blocked out and structure contours end at the edge of the mine workings. Most of the mines are shown as they were during the years 1947-50. Many have increased in size since that time.

SURFICIAL GEOLOGY

Bedrock is exposed along the Laurentian Divide, but elsewhere nearly all the Mesabi Range area is covered by deposits of glacial drift. Only the youngest three of several tills have been named and assigned ages (Wright, 1955, p. 411). These three tills were deposited during the Cary and Valders Stades of the Wisconsin Glaciation of the Pleistocene Epoch. The till sheet deposited during the Cary Stade contains numerous cobbles and boulders in a sandy, silty matrix. The overlying till sheets consist of a reddish-brown clayey till deposited by the Superior lobe and a brown silty till deposited by the St. Louis sublobe during the Valders Stade. The Cary and Valders tills are separated, in places, by associated stratified sand and gravel (outwash) and water-lain silt.

Cary drift blankets the entire area north and south of the Giants Range. The Valders drift is principally a thin ground moraine confined to the south flank of the Giants Range. Thicknesses of total drift cover vary considerably. The Giants Range is covered by as much as 20 feet of drift. To the south, in the Virginia-Mountain Iron area, the contact between the Biwabik Iron-Formation and the Virginia Slate is covered by 80 to 100 feet of drift. To the west about 30 miles, in the vicinity of Keewatin, the drift thickness increases to 200 feet.

Surficial geology of northeastern Minnesota has been described by Leverett (1932), Wright (1955, 1956a, 1956b), Zumberge and Wright (1956), and Arneman and Wright (1959).

GROUND WATER

Ground water is obtained from both bedrock and glacial drift formations. The largest supplies come from rocks of Quaternary age, but supplies adequate for domestic and limited industrial and public purposes are pumped from the older rocks also. The approximate distribution and extent of the bedrock formations are shown on the maps.

Nearly all domestic wells are finished in the glacial drift or Virginia Slate. In the area north of the range a few domestic wells are finished in the Giants Range Granite. The area underlain by the other bedrock types is almost wholly owned by the mining companies and few domestic wells have been drilled. Public and industrial supplies are obtained principally from wells in the Biwabik Iron-Formation and sorted outwash deposits.

The best bedrock aquifers are the fractured and leached zones of the Biwabik Iron-Formation. The Biwabik Iron-Formation yields public water supplies for 10 municipalities on the Mesabi Range (Cotter and Young, 1960, p. 5). The formation ranges in thickness from 340 to 800 feet (White, 1954, p. 22) but yields large quantities of water only from fractured leached zones associated with the ore deposits. Most of the known ore deposits have been mined out and the location of permeable zones is not known. The most suitable sites for testing are close to the open-pit mines where the ore extends beyond the mine face and the water table is at or above the mine floor. The city of Virginia obtains as much as 2,000 gpm from wells that penetrate abandoned drifts associated with open-pit mines.

The Virginia Slate yields water to many domestic wells and has produced 30 gpm (Cotter and Young, 1960, p. 52). However, it generally will yield little more than a domestic supply and is not an important source of water. The Ely Greenstone, Knife Lake Group, Giants Range Granite, and Pokegama Quartzite generally will not yield enough water for a domestic supply, though some wells may yield as much as 80 gpm from fractured zones. The Duluth Gabbro is not known to yield water to wells in the Mesabi Range.

The Coleraine Formation of Stauffer (1933) is known only from isolated exposures in pits. Although it has a maximum reported thickness of 100 feet its areal extent is not known. Probably it will not yield enough water for a domestic supply.

Pleistocene and Recent deposits are the most important source of water in the Mesabi Range area. The glacial drift overlies the bedrock nearly everywhere except the Giants Range. The drift is as much as 300 feet thick, but the thickness differs greatly in different areas. In general it is thickest in the bedrock valleys and thinnest along the Giants Range and other bedrock highs. The thickness of the drift at any point can be determined by subtracting the altitude of the bedrock at the point from the altitude of the land surface. (Maps 1, 2, 3, and 4.)

Water occurs under both water-table and artesian conditions. Generally water at depth is confined by younger overlying till sheets. Recharge to the drift aquifers is from local precipitation and probably amounts to about 4 to 6 inches a year. The Giants Range forms a ground-water divide in the area. The hydraulic gradient is generally from the divide to the south edge of the mapped area and roughly parallels the slope of the bedrock surface. Local changes in the piezometric surface, and thus directions of ground-water movement, result from the large difference in permeability between the glacial drift and the bedrock. Probably much of the ground water moves in the preglacial channels shown on the maps. The sides of these buried valleys are, in effect, impermeable boundaries.

Ground water occurs in the several tills and the associated stratified deposits. The Cary Stade till yields water for many domestic supplies and in places yields are sufficient for small industrial supplies. The till consists mostly of sand, gravel, cobbles, and boulders and locally contains almost no silt or clay. The overlying Valders tills are not known to yield water to wells.

Stratified drift is usually an excellent source of water and yields municipal supplies to nine communities as well as most domestic wells. It occurs as outwash, ice-contact features, and valley-train deposits. Some major deposits of outwash are associated with preglacial bedrock valleys. The major valleys are indicated on the maps. They are particularly prominent where they show as notches in the crest of the Giants Range and are continuous down the south flank of the range. These valleys are now filled with saturated glacial deposits and are an important potential source of ground water. Probably the valleys contain large deposits of highly permeable outwash interbedded with low permeability tills. Where outwash is penetrated, large capacity wells adequate for municipalities or major industries could probably be developed. Wells yielding as much as 1,300 gpm have been developed.

Generally the chemical quality of the ground water from all sources is satisfactory for most purposes, although some supplies from the drift contain excessive iron.

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BEDROCK TOPOGRAPHY OF THE EASTERN AND CENTRAL MESABI RANGE, NORTHEASTERN MINNESOTA (Sheet 4)

By
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1964

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