GEOLOGY AND GROUND WATER

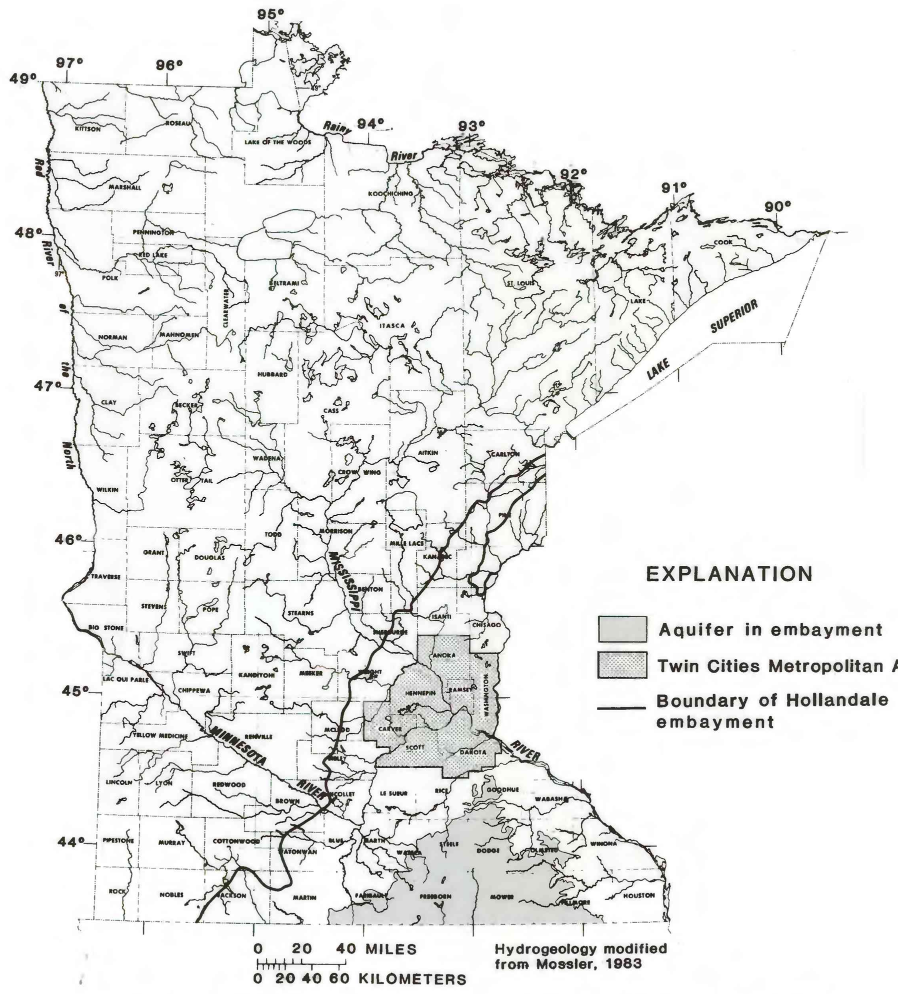

Figure 1.--Areal extent of aquifer and area of Hollandale embayment in southeast Minnesota

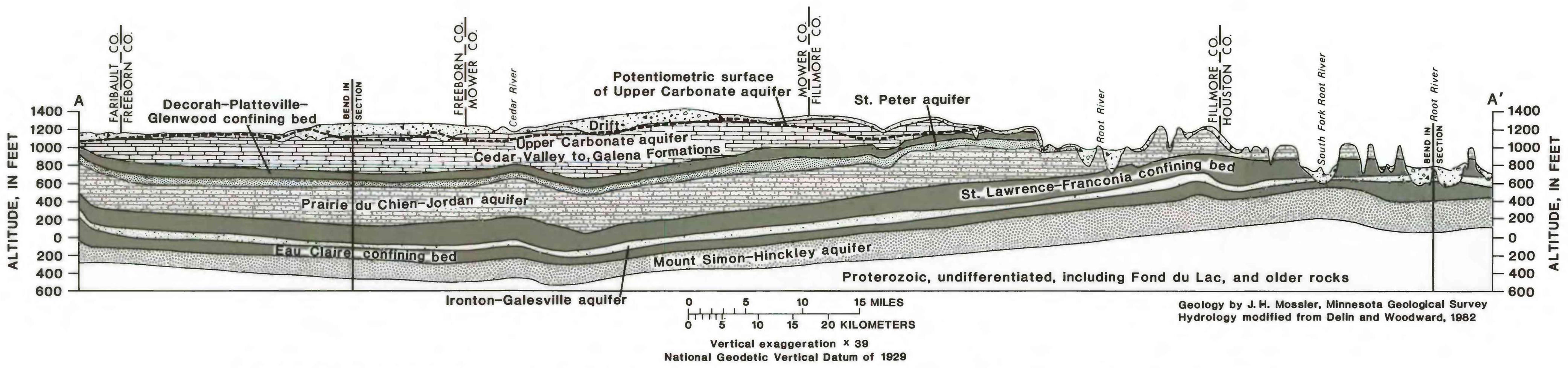

Figure 3.--Generalized section of major hydrogeologic units in the bedrock sequence of southeast Minnesota

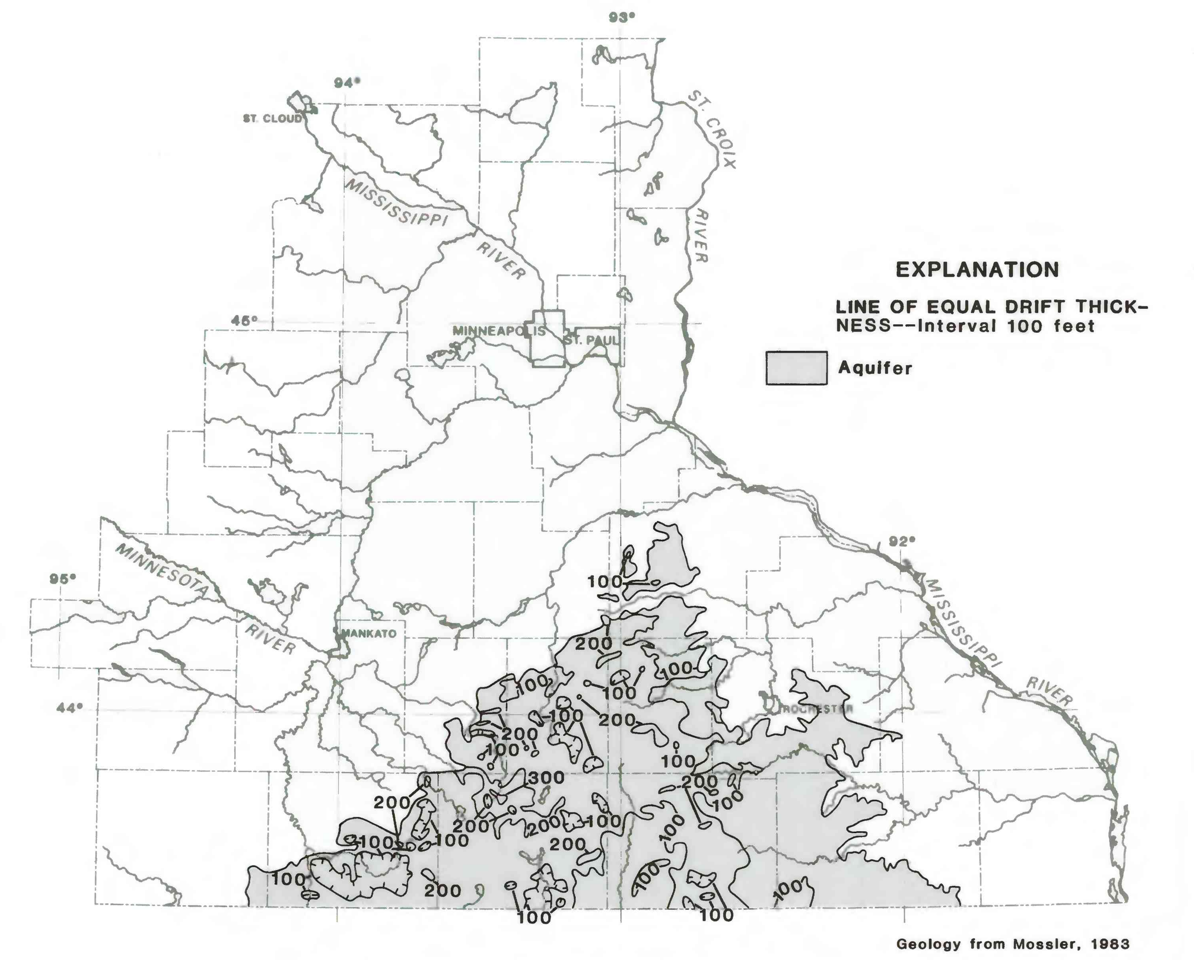

Figure 6.--Thickness of drift deposits overlying the aquifer

ABSTRACT

The Upper Carbonate aquifer is part of a sequence of sedimentary bedrock units deposited in Paleozoic seas that occupied a depression known as the Hollandale embayment. The aquifer is comprised of four formations, which, in ascending order, are the Galena Dolomite, Dubuque Formation, Maquoketa Shale, and Cedar Valley Limestone. Total thickness of the aquifer is as much as 650 feet. Yields from wells in the aquifer range from about 100 to 500 gallons per minute. Water flows mostly through fractures and solution channels toward the periphery of the aquifer and, locally, toward river and bedrock valleys.

The quality of water in the Upper Carbonate aquifer is suitable for most uses. However, the water is susceptible to contamination in karst areas because sinkholes and disappearing streams provide direct passageways for entry of contaminants into the aquifer. Calcium magnesium bicarbonate type waters are most common. Concentrations of dissolved solids and some major ions, specifically magnesium, sodium, bicarbonate, and sulfate, are generally highest in the southwestern part of the study area.

INTRODUCTION

The U.S. Geological Survey began a study in 1980 of the quality of water in the 14 principal aquifers in Minnesota. The U.S. Environmental Protection Agency funded the study as part of the Underground Injection Control Program, which deals with disposal of liquid wastes beneath land surface. The initial report designated the 14 aquifers and provided general information about their geologic, hydrologic, and water-quality characteristics (Adolphson and others, 1981). This report, one in a series that describes individual aquifers in more detail, concerns the Upper Carbonate aquifer.

HYDROGEOLOGIC DESCRIPTION

The Upper Carbonate aquifer is part of a sequence of sedimentary rocks that are predominantly sandstone, limestone, dolomite, and shale. Deposition of these rocks began in Proterozoic time and continued to the Devonian Period of the Paleozoic Era (table 1). These rocks were deposited in seas that occupied the Hollandale embayment, a shallow depression that extended northward from Iowa into southeast Minnesota (Austin, 1972). Figure 1 shows the areal extent of the aquifer and the embayment.

The Paleozoic sedimentary rocks and the underlying Proterozoic Hinckley Sandstone in southeast Minnesota comprise five bedrock aquifers and four major confining beds (Lindholm and Norvitch, 1976; Delin and Woodward, 1982). Table 1 shows this aquifer classification scheme and the relative stratigraphic positions of these hydrologic units, including Cretaceous deposits and drift. Kanivetsky and Walton (1979) and Adolphson and others (1981) have proposed classifications that are slightly different because they include the Franconia Formation as part of the Ironton-Galesville aquifer and the Fond du Lac Formation as part of the Mount Simon-Hinckley aquifer. Figure 2 shows the areal extent of the aquifers and confining beds listed in table 1 for southeast Minnesota. Figure 3 is a generalized section of the hydrogeologic units along an east-west line through southeastern Minnesota.

Geologic Features

The Upper Carbonate aquifer, which overlies the other bedrock units in southeastern Minnesota (table 1), comprises four formations, which, in ascending order, are the Galena Dolomite, Dubuque Formation, Maquoketa Shale, and Cedar Valley Limestone. These formations consist of grayish-yellow or olive-gray limestone, dolomite, and dolomitic limestone (Kanivetsky and Walton, 1979). Representative thicknesses of the Galena Dolomite, the combination of the Maquoketa Shale and Dubuque Formation, and Cedar Valley Limestone are 200, 100, and 300 feet, respectively (Farrell and others, 1975). Individual beds within these formations are only a few inches to several feet in thickness (Kanivetsky and Walton, 1979).

The aquifer thickens to as much as 650 feet in extreme southern Minnesota, where subsidence of the Hollandale embayment was greatest (fig. 4). The altitude of the top of the aquifer gradually increases in a broad undulating manner from west to east (fig. 5). Drift overlies nearly all the aquifer and generally ranges from about 50 to 200 feet in thickness. The drift generally is thinner in the eastern part of the study area (fig. 6). Cretaceous sedimentary rocks overlie a very small part of the aquifer in the southwest (fig. 2). Karst features, such as sinkholes, caves, disappearing streams, and springs, are common in the eastern part of the study area where the drift is thin.

Hydrologic Characteristics

Regional ground-water movement is toward the periphery of the aquifer and, locally, toward rivers and bedrock valleys (fig. 7). Flow toward rivers is particularly pronounced in the eastern and southern parts of the study area where mounds on the potentiometric surface are present (Delin and Woodward, 1982).

Precipitation on upland areas recharges the aquifer (Farrell and others, 1975). Water generally enters the aquifer by infiltration through drift, but water also enters directly through sinkholes and disappearing streams in karst areas. Shale beds, particularly those in the Dubuque Formation and the Decorah Shale, restrict vertical flow. Ground water in the Upper Carbonate aquifer discharges to streams directly and indirectly through springs and seeps where the potentiometric surface intersects valley walls. Although discharge from the aquifer responds to seasonal changes in precipitation, it generally sustains streamflow during dry periods (Delin and Woodward, 1982).

Permeability of the aquifer is due principally to fractures and solution cavities. Yields to municipal wells typically range from 200 to 500 gal/min (Anderson and others, 1975; Farrell and others, 1975), and hydraulic conductivities for the aquifer vary from 3 to 40 ft/d (Kanivetsky and Walton, 1979).

WATER USE

The aquifer supplies adequate quantities of water for most municipal, industrial, and domestic uses. However, the aquifer may yield insufficient amounts of water in some areas where fractures are sparse (Farrell and others, 1975). Hardness and susceptibility of water to contamination limit use in some areas (Farrell and others, 1975). A regulation of the Minnesota Department of Health prohibits the drinking of water from wells in fractured or cavernous carbonate rocks if drift overlying the rocks is less than 50 feet thick (Delin and Woodward, 1982). This regulation restricts use of water from the Upper Carbonate aquifer in the eastern part of the study area (fig. 6).

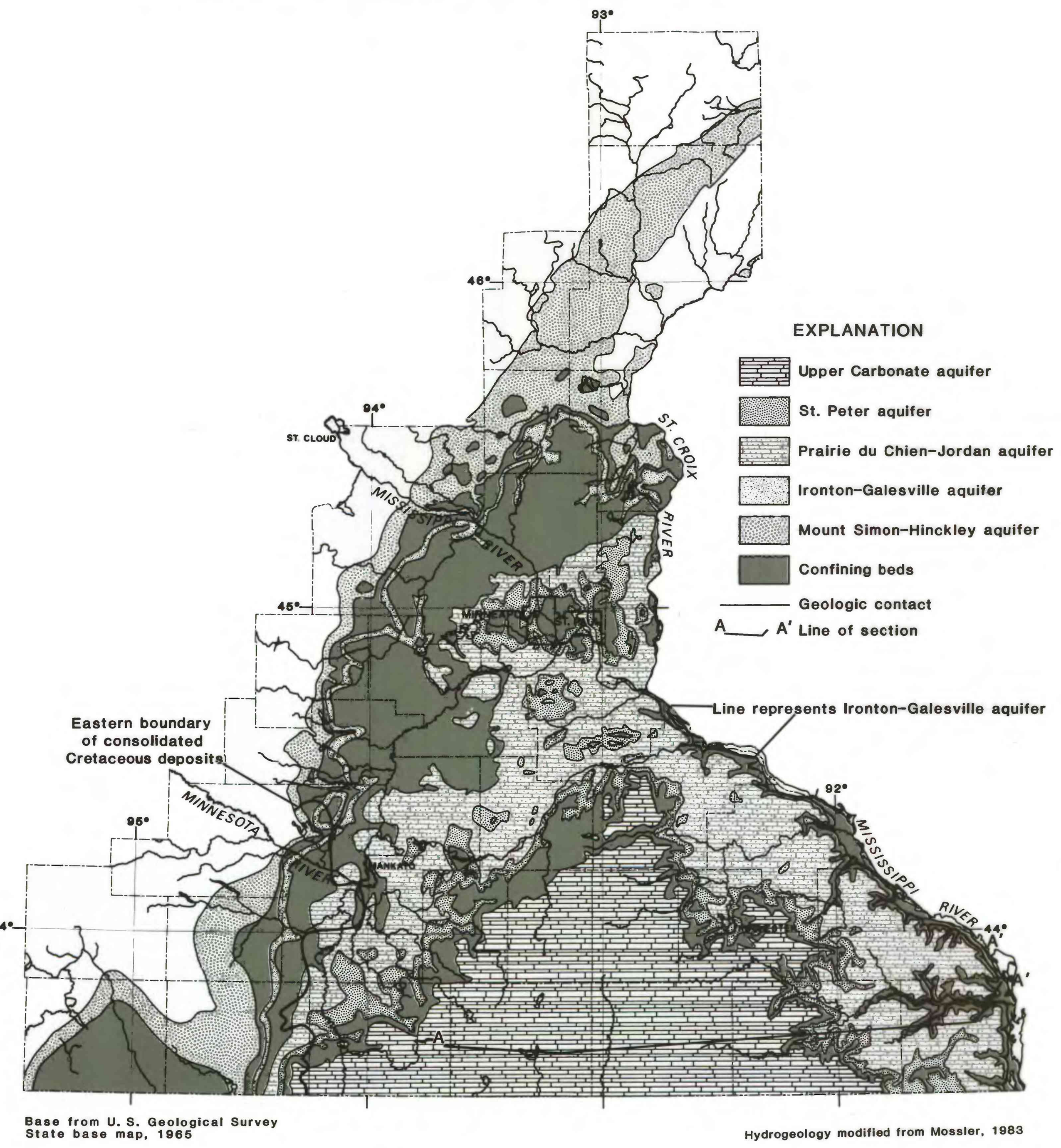

Figure 2.--Bedrock hydrogeology in southeast Minnesota

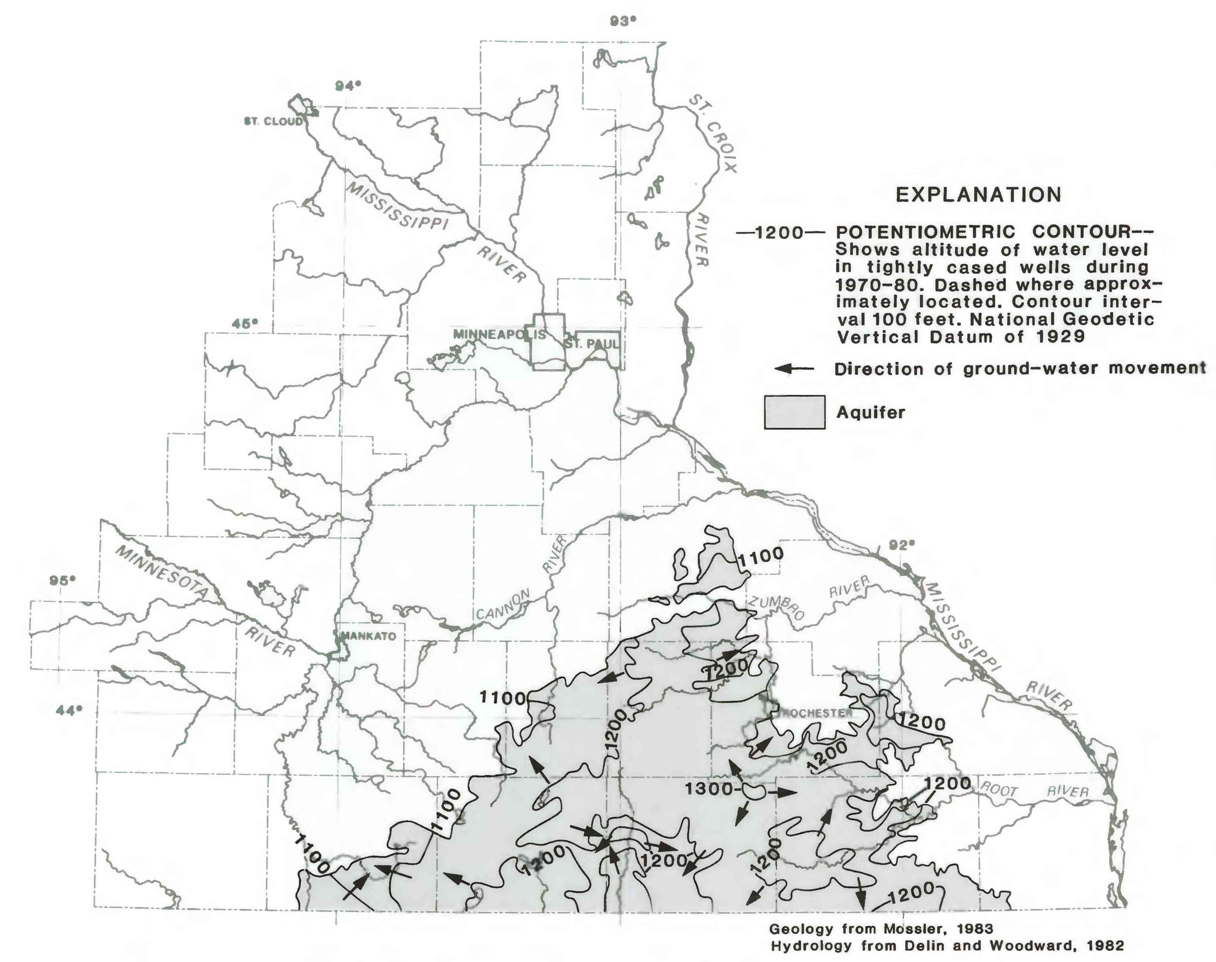

Figure 7.--Flow directions and potentiometric surface of the aquifer, 1970-80

Table 1.--Stratigraphic nomenclature for southeast Minnesota and general descriptions of the corresponding aquifers and confining beds

Stratigraphic nomenclature			Hydrogeology	
Erathem	Period or system	Geologic unit (group, formation, or bed)	Hydrogeologic unit (aquifers or confining beds)	Water-bearing characteristics and dominant lithology
Cenozoic	Quaternary	Drift	Surficial sand and gravel aquifer	Largly outwash, but includes alluvium along major streams and local ice-contact deposits. Slightly used, with additional development of supplies possible. High potential for contamination because the water table is at or near land surface. Yields as much as 1,000 gal/min in places.
			Confining beds	Till and clay of low permeability. Not a source of water to wells.
			Buried sand and gravel aquifers	Outwash and ice-contact deposits confined by till of low permeability. Slightly to moderately developed for water supplies with potential for additional development, especially in buried valleys. Yields range from 100 to 1,000 gal/min.
Mesozoic	Cretaceous	Cretaceous beds	Cretaceous confining beds	Shale beds of low permeability. Not a source of water.
			Cretaceous aquifer	Sandstone lenses near base of predominantly shale section. Slightly developed, may yield additional small supplies. Typical yields to wells are 5 to 50 gal/min, but may be as much as 250 gal/min. Water is highly mineralized, particularly in the basal units along the western border of the State.
Paleozoic	Devonian	Cedar Valley Limestone	Upper Carbonate aquifer	Limestone, dolomite, and dolomitic limestone. Major aquifer in the south-central part of embayment. Wells generally yield 200 to 500 gal/min from solution channels, joints, and fissures.
	Ordovician	Maquoketa Shale		
		Dubuque Formation		
		Galena Dolomite		
		Decorah Shale	Confining bed	Relatively impermeable shale, dolomitic limestone, and limestone. Platteville yields about 25 gal/min from local fractures and solution channels.
		Platteville Limestone		
		Glenwood Shale		
		St. Peter Sandstone	St. Peter aquifer	White, fine- to medium-grained sandstone. A major aquifer, but seldom used for public supply because larger yields are available from wells in other aquifers. Typical yields range from 100 to 250 gal/min.
			St. Peter confining bed	Contains siltstone and shale that restrict vertical flow. Areal extent unknown. Not a source of water to wells.
		Prairie du Chien Group	Prairie du Chien-Jordan aquifer	Mainly dolomite and sandstone. The major aquifer in the area. Commonly yields 500 to 1,000 gal/min. Supplies 75 percent of water in Twin Cities metropolitan area. Karstic conditions are common in extreme southeast.
	Cambrian	Jordan Sandstone		
		St. Lawrence Formation	Confining bed	Silty, sandy dolomite interbedded with layers of fine-grained sandstone and siltstone. Generally a poor source of water to wells; however, yields from the Franconia in the northwest part of the area are adequate for domestic use.
		Franconia Formation		
		Ironton Sandstone	Ironton-Galesville aquifer	Very fine to coarse-grained sandstone interbedded with shale, siltstone, and dolomite; an important aquifer outside the limits of other major aquifers. Yields range from 250 to to 500 gal/min.
		Galesville Sandstone		
		Eau Claire Sandstone	Confining bed	Sandstone, siltstone and shale, gray to reddish brown. Normally not a source of water; however, sandstone beds may yield small quantities to wells in the south.
		Mount Simon Sandstone	Mount Simon-Hinckley aquifer	Thick sequence of sandstone, siltstone, and shale. The secondary aquifer in Twin Cities area and only bedrock aquifer used in the northern part of the Hollandale embayment. Little used for water supply in extreme southeast. Wells generally yield from 400 to 700 gal/min, but may be as much as 2,000 gal/min.
Precambrian	Proterozoic	Hinckley Sandstone		
		Fond du Lac Formation	Hydrologic properties little known	Fond du Lac Formation, in combination with Hinckley Sandstone, yields water north of the Twin Cities metropolitan area where the Mount Simon is absent. Elsewhere, the Fond du Lac is deeply buried and undeveloped as a source of water supply.
		Sedimentary, metamorphic, and igneous rocks	Hydrologic properties unknown	Lack of detailed subsurface information precludes evaluation of hydraulic characteristics.

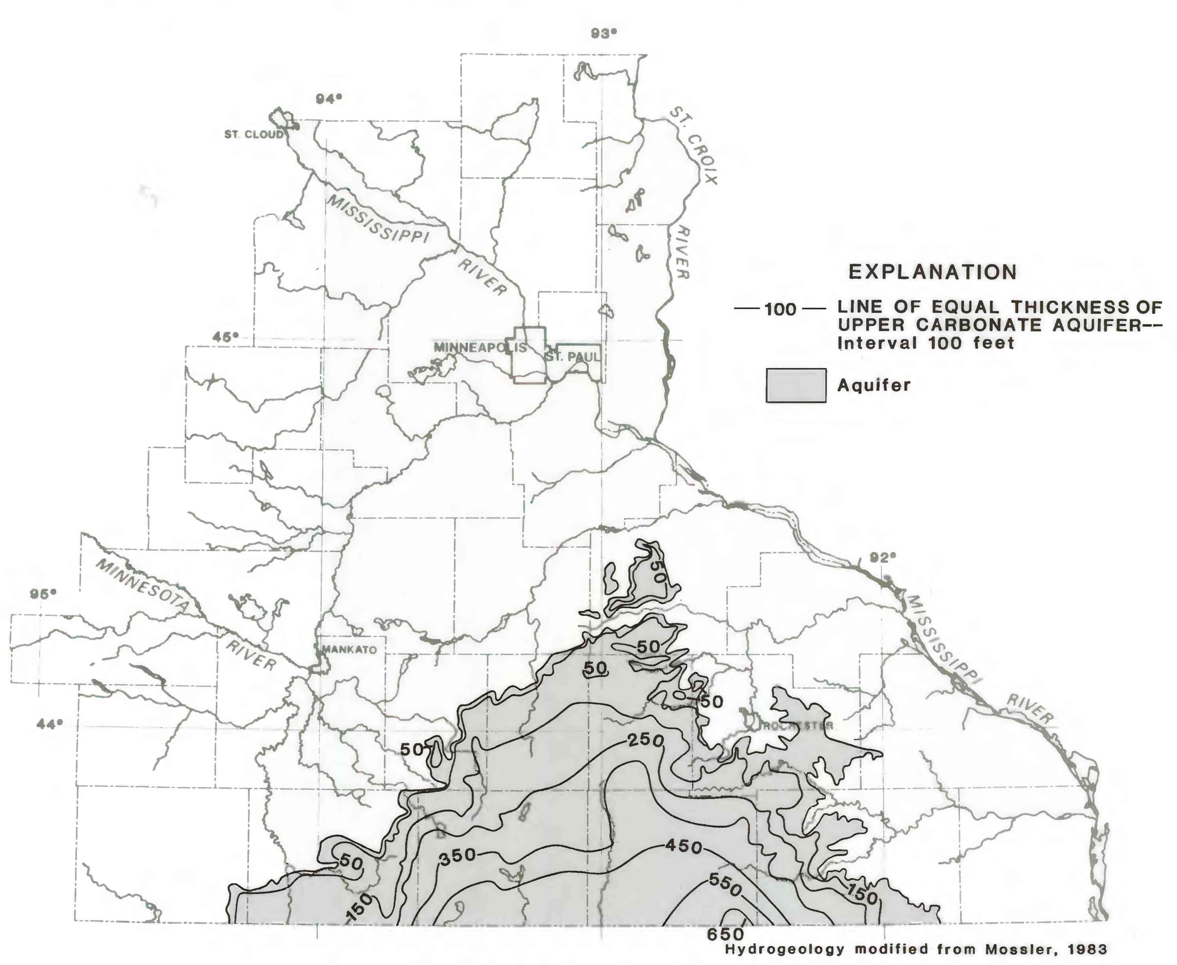

Figure 4.--Thickness of the aquifer

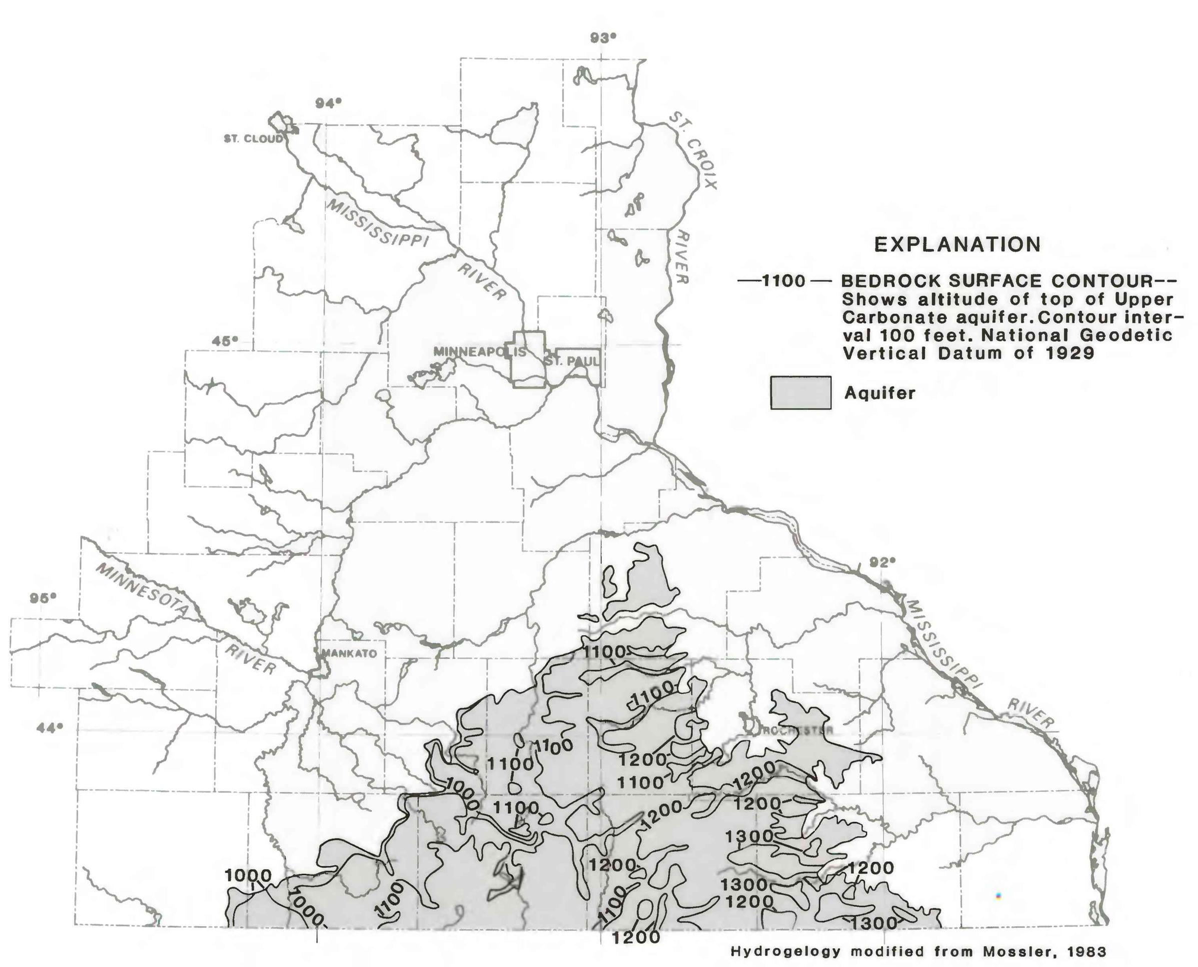

Figure 5.--Contours of the top of the aquifer

HYDROGEOLOGIC AND WATER-QUALITY CHARACTERISTICS OF THE UPPER CARBONATE AQUIFER IN MINNESOTA

BY
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