UNIVERSITY OF MINNESOTA
MINNESOTA GEOLOGICAL SURVEY
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COUNTY ATLAS SERIES
ATLAS C-15, PART A
Plate 4—Quaternary Stratigraphy

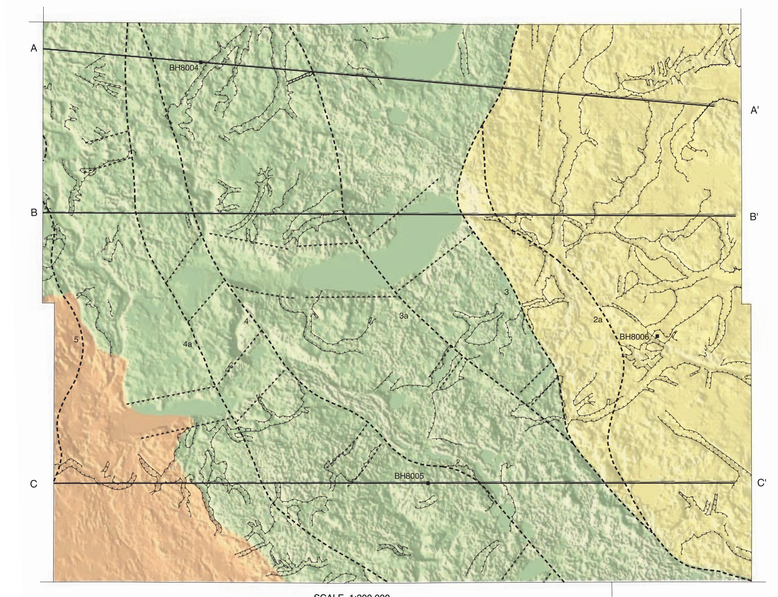
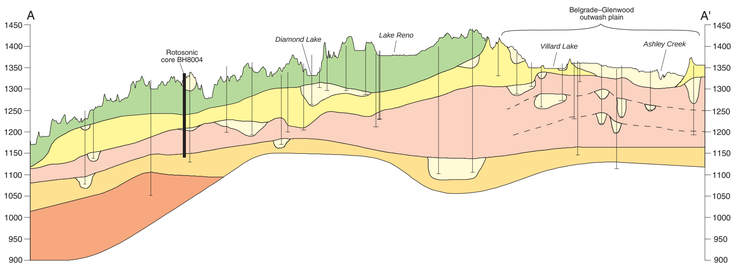
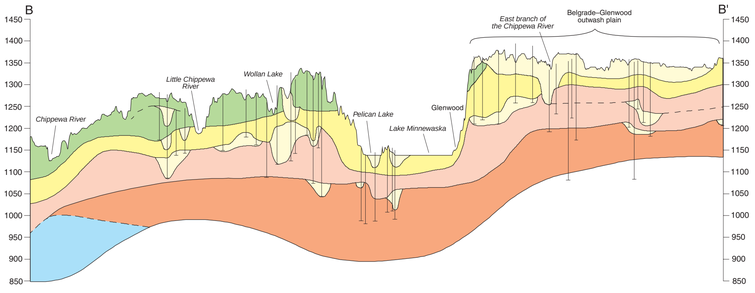


Figure 1. Digital elevation model of Pope County. Colors show areas of surface exposure of lithostratigraphic units and the area influenced by Glacial Lake Benson. Line symbols show location of cross sections, ice margins, tunnel valleys, and palimpsest drainage. The green and yellow colors in the map are keyed to the lithologic units shown in Figures 2 and 3 and Table 1.





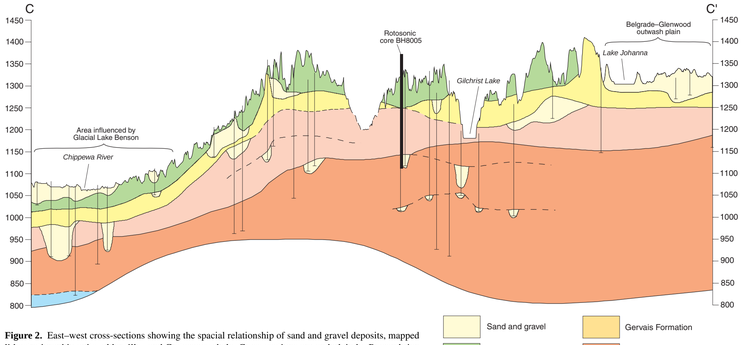


Figure 2. East–west cross-sections showing the spacial relationship of sand and gravel deposits, mapped lithostratigraphic units, older tills, and Cretaceous shale. Cross-sections are underlain by Precambrian rocks. The Cretaceous shale boundary is estimated. Dashed lines indicate uncertain boundaries. Light vertical lines indicate the locations of water wells used to construct the cross-sections. Heavy vertical lines indicate the locations of rotosonic core holes. Cross-sections are based on interpretations of water-well logs. Colors in the cross-section panels are keyed to the lithologic units shown in Figures 1 and 3 and Table 1. Vertical exaggeration is about 200. Horizontal scale is the same as Figure 1.

QUATERNARY STRATIGRAPHY

By

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2003

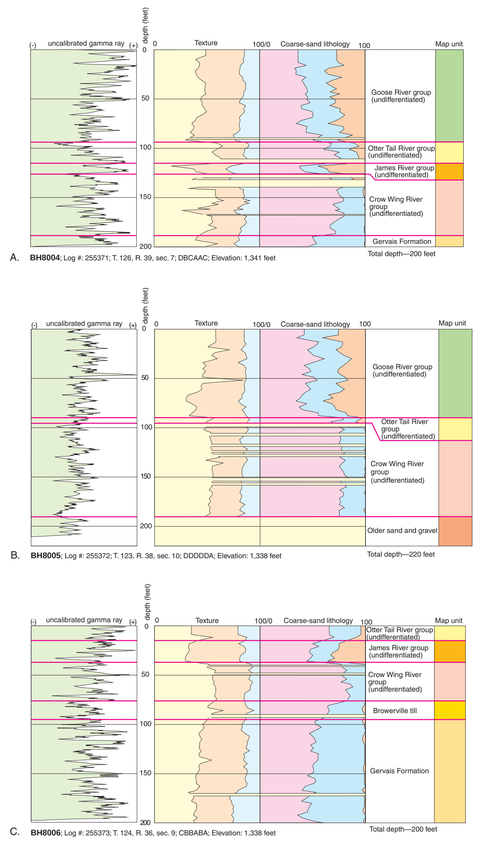

Figure 3. Graphic representations of the Pope County rotosonic core holes BH8004, BH8005, and BH8006 showing natural gamma ray, texture, coarse-sand lithology logs, and detailed stratigraphic interpretation. Sample logs from rotosonic core show more detailed stratigraphy than the water-well logs used to construct Figure 2. Colored panels are keyed to the lithologic units shown in Figures 1 and 2 and Table 1.

Stratigraphic unit	Southern Red River Valley (Harris, 1995)	Pope County
Goose River group	St. Hilaire 27-42-31 43-32-25 Dahlen Formation 30-41-29 27-18-55 Heiberg till 36-39-25 35-23-42	Lake Benson Goose River group (undifferentiated) 39-38-23 42-28-30
Otter Tail River group	RRV #10 38-38-24 54-43-23 RRV #11 44-39-17 66-33-01 RRV #12 46-35-19 50-31-19	Otter Tail River group (undifferentiated) 50-32-18 62-27-11
James River group	RRV #5 47-35-18 44-23-33	James River group 44-37-19 49-25-26
Lake Tewaukon group	RRV #13 30-43-27 16-11-73 RRV #14 20-42-38 14-12-74	
Unnamed unit	RRV #15 32-35-33 61-36-03	
Crow Wing River group	RRV #16 56-34-10 86-13-01 Marcoux Formation 57-29-14 74-25-01	Crow Wing River group (undifferentiated) 54-31-15 78-22-00
Sheyenne River group	RRV #18 30-39-31 49-36-15	
Browerville till		Browerville till 54-34-12 64-34-02
Gervais Formation	Gervais Formation 27-45-28 49-46-05	Gervais Formation 41-41-18 50-49-01

Table 1. Correlation of stratigraphic units reported in this study with stratigraphic units reported in the Red River Valley Regional Assessment (Harris, 1995). The upper set of numbers represents texture (sd-sl-cl); the lower set represents coarse-sand lithology (xt-co-sh). Texture abbreviations: sd, percent sand; sl, percent silt; cl, percent clay. Coarse-sand lithology (1 to 2 millimeter rock fragments) abbreviations: xt, percent igneous and metamorphic; co, percent carbonate; sh, percent shale.

DESCRIPTION OF STRATIGRAPHIC UNITS

The stratigraphic nomenclature used here is a combination of formal (Formation/Group) and informal terms (formation/group/till). Outcrops, drill cuttings, auger samples, water-well logs, and cores were used to interpret the Quaternary stratigraphy of Pope County. References are given for all terms used. Lobe names are informal working terms. "RRV" numbers correspond to those described in Harris (1995). An overview of upper Midwest glacial geology and glacial stratigraphy can be found in Wright (1972), Moran and others (1976), and Clayton and Moran (1982). Patterson and Wright (1998) provided a summary of more recent work in Minnesota.

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Lake Benson sediment (undifferentiated)—The southwest corner of Pope County was influenced by Glacial Lake Benson. This area consists of sediment deposited in three depositional settings: sand, silt, and gravel ridges that were deposited along the shoreline on wave-eroded glacial sediment; sand, silt, and clay deposited in a shallow-water nearshore environment; and river-transported sand, silt, and gravel deposited in a deltaic environment as the Glacial Chippewa River entered Glacial Lake Benson. Sediment deposited in these three settings are grouped and shown on Figure 1 as the area influenced by Glacial Lake Benson.

Goose River group (undifferentiated)—Glacial sediment of the Goose River group is present at the surface in the western two-thirds of Pope County and in the Red River lowland to the west (Figs. 1, 2, 3a, 3b; Table 1). It was deposited by unnamed phases of the Des Moines (Red River) lobe as glacial ice advanced to the south and receded to the north. The sediment was derived from a northwestern source area (the Riding Mountain area of western Manitoba). Sand and gravel were deposited in outwash plains by coalescing, braided meltwater rivers and in meltwater rivers on older stratigraphic units. These deposits are generally collapsed (pitted) due to melting of buried ice blocks.

Goose River sediment in Pope County can be characterized as a pebbly loam to pebbly clay-loam with igneous and metamorphic rock types slightly more common than carbonate rock types, and moderate to abundant shale pebbles (see Table 1). The Goose River group sediment present in Pope County is not differentiated because it consists of a complex mixture of the following stratigraphic units reported in studies to the north and northwest.

Upper Goose River group

St. Hilaire Formation [RRV #7]—Pebble-loam; clayey; light yellowish-brown (2.5Y 6/4) to very dark gray (2.5Y 3/3). Unsorted; unbedded; massive; friable; and calcareous. Clasts are angular to rounded. They contain abundant igneous and metamorphic rock fragments, moderate carbonate rock fragments, and moderate shale rock fragments; pebble- to cobble-sized stones; and may contain lignite fragments. Columnar structure or weak vertical jointing is common in outcrop. Overall unit averages: texture, 27-42-31 (clay-loam); lithology, 43-32-25; (Harris, 1973, 1975, 1995; Harris and others, 1974, 1996, 1999; Moran and others, 1976; Arndt, 1977).

Lower Goose River group

Heiberg till [RRV #9]—Pebble-loam; light olive-brown (2.5Y 5/4) to very dark gray (2.5Y 3/3). Unbedded; unsorted; massive; friable; and calcareous. Clasts are angular to rounded. They contain abundant igneous and metamorphic rock fragments, moderate carbonate rock fragments, and abundant shale rock fragments; pebble- to cobble-sized stones; and may contain lignite fragments. Overall unit averages: texture, 36-39-25 (loam); lithology, 35-23-42; (Harris, 1995; Harris and others, 1996, 1999).

Otter Tail River group (undifferentiated)—Glacial sediment of the Otter Tail River group is present at the surface in the eastern third of Pope County, it underlies the Goose River group in the western two-thirds of the county (Figs. 1, 2, 3; Table 1). It was deposited by unnamed phases of the Des Moines (Red River) lobe as glacial ice advanced to the south and receded to the north. The sediment was derived from a northern source area (eastern Manitoba and western Ontario). Sand and gravel were deposited in outwash plains by coalescing, braided meltwater rivers and in meltwater channels on older stratigraphic units.

Otter Tail River group sediment in Pope County can be characterized as a pebbly loam to pebbly sandy loam with roughly twice as many igneous and metamorphic rock types as carbonate rock types, and low to moderate amounts of shale pebbles (Table 1). The following subdivisions of the Otter Tail River group have been reported in regional studies to the north and northwest. Individual members of the group were not mapped in this study due to limited subsurface control, but Otter Tail River group sediment in Pope County consists mainly of RRV #12.

New York Mills till [RRV #11]—Pebble-loam; very dark grayish-brown (2.5Y 3/2). Unbedded; unsorted; massive; friable; and calcareous. Clasts are angular to rounded and moderately stony. They contain abundant igneous and metamorphic rock fragments, moderate carbonate rock fragments, and few shale rock fragments; pebble- to cobble-sized stones; and lignite pebbles. Rotosonic core BH8006 (Fig. 3c) unit averages: texture, 45-38-17 (loam); lithology, 68-25-07; (Anderson, 1976; Perkins, 1977; Harris, 1995; Harris and others, 1996, 1999).

[RRV #12]—Pebble-loam; sandy; grayish-brown (2.5Y 5/4) to very dark grayish-brown (2.5Y 3/2). Unbedded; unsorted; massive; friable to compact; and calcareous. Clasts are angular to rounded and moderately stony. They contain abundant igneous and metamorphic rock fragments, moderate carbonate rock fragments, and moderate shale rock fragments; and pebble- to cobble-sized stones. Rotosonic core BH8005 (Fig. 3b) unit averages: texture, 53-32-15 (sandy loam); lithology, 49-29-22; (Harris, 1995; Harris and others, 1996, 1999).

James River group—Glacial sediment interpreted as the James River group is present in the subsurface of Pope County, it underlies the Otter Tail River group or younger units (Figs. 2, 3a, 3c; Table 1). It was deposited by unnamed phases of the Des Moines (Red River) lobe as glacial ice advanced to the south and receded to the north. This subsurface unit can only be identified from samples recovered during test drilling. It is not identifiable from water-well logs and is therefore not shown on the cross-sections (Fig. 2). No surface outwash deposits are associated with the James River group. All buried outwash deposits are associated with and mapped as part of the underlying stratigraphic unit in Figure 2.

James River group sediment in Pope County can be characterized as a pebbly loam with roughly twice as many igneous and metamorphic rock types as carbonate rock types, and moderate amounts of shale pebbles (Table 1). Glacial sediment of the James River group has a similar texture to the Otter Tail River group, but contains more shale. Glacial sediment of the James River group has a similar lithology to the Goose River group, but contains more sand and much less clay (Table 1). This unit was derived from a northwestern source area (the Riding Mountain area of western Manitoba) and has been reported in regional studies to the northwest.

James River till [RRV #5]—Pebble-loam; very dark grayish-brown (2.5Y 3/2). Unsorted; unbedded; massive; friable; and calcareous. Clasts are angular to rounded. They contain abundant igneous and metamorphic rock fragments, moderate carbonate rock fragments, and moderate shale rock fragments; and pebble-sized stones. Rotosonic core BH8006 (Fig. 3c) unit averages: texture, 40-42-18 (loam); lithology, 47-21-32; (Biek, 1994; Harris, 1995; Harris and others, 1996, 1999).

Crow Wing River group (undifferentiated)—Glacial sediment of the Crow Wing River group is present in the subsurface of Pope County, it underlies the James River group and younger units (Figs. 2, 3; Table 1). These deposits have been reported in adjacent regional studies and in southeast North Dakota. Crow Wing River group sediment was deposited by glacial ice of the Rainy lobe that advanced into Minnesota from a northeastern source area (central Ontario). No surface outwash is associated with the Crow Wing River group in Pope County. All buried outwash deposits are associated with and mapped as part of the underlying stratigraphic unit in Figure 2.

The following members of the Crow Wing River group have been observed in Pope County sample data and reported in adjacent regional studies. Individual members of the Crow Wing River group were not mapped in this study due to limited subsurface control. Crow Wing River group sediment in Pope County consists mainly of the Marcoux Formation.

[RRV #16]—Pebble-loam; sandy; dark grayish-brown (2.5Y 4/2). Unbedded, unsorted; massive; compact; and calcareous. Clasts are angular to rounded. They contain abundant igneous and metamorphic rock fragments, moderate carbonate rock fragments, and very few shale rock fragments; pebble-sized stones; and may contain lignite fragments. Rotosonic core BH8006 (Fig. 3c) unit averages: texture, 56-34-10 (sandy loam); lithology, 81-19-00; (Harris, 1995; Harris and others, 1996, 1999).

Marcoux Formation [RRV #17]—Pebble-loam; sandy; dark grayish-brown (2.5Y 4/2). Unbedded; unsorted; massive; compact; and calcareous. Clasts are angular to rounded. They contain abundant igneous and metamorphic rock fragments, moderate carbonate rock fragments, and very few shale rock fragments; pebbles and cobbles; and may contain lignite fragments. Rotosonic core BH8004 (Fig. 3a) unit averages: texture, 60-27-13 (sandy loam); lithology, 70-21-09; rotosonic core BH8005 (Fig. 3b) unit averages: texture, 53-31-16 (sandy loam); lithology, 77-22-01; (Harris, 1973, 1975, 1995; Harris and others, 1974, 1996, 1999; Moran and others, 1976).

Browerville till—This unit is present in the subsurface of eastern Pope County and reported in northern, central, and southern Minnesota. The Browerville till underlies the Crow Wing River group (Fig. 3c; Table 1). The sediment deposited was derived from a northern source area (eastern Manitoba and western Ontario). No surface outwash is associated with the Browerville till.

Browerville till—Pebble-loam; sandy; light yellowish-brown (2.5Y 6/4) to very dark grayish-brown (2.5Y 3/2). Unbedded; unsorted; massive; compact; and calcareous. Clasts are angular to rounded. They contain abundant igneous and metamorphic rock fragments, moderate carbonate rock fragments, and very few shale rock fragments; and pebble-sized stones. Rotosonic core BH8006 (Fig. 3c) unit averages: texture, 54-34-12 (sandy loam to loam); lithology, 64-34-02; (Meyer, 1995; Meyer and Knaeble, 1996).

Gervais Formation—This unit is present only in the subsurface of Pope County and adjacent Red River lowlands; it underlies the Browerville till or younger units (Figs. 2, 3a, 3c; Table 1). The Gervais Formation is found in surface outcrops in the northern Red River valley where it is strongly jointed and contains abundant wood chips (twigs and logs), fragments of mollusk shells, insects, carbon flakes, and moss. Carbon dating has determined the organic debris to be older than 46,900 years before present (Ashworth, 1980). The Gervais Formation was deposited by glacial ice. The deposited sediment was derived from a northern source area (the Winnipeg area). No surface outwash is associated with deposits of the Gervais Formation. All buried outwash deposits are associated with and mapped as part of the underlying stratigraphic unit in Figure 2.

Gervais Formation [RRV #19]—Pebble loam; dark grayish-brown (2.5Y 4/2) to very dark grayish-brown (2.5Y 3/2). Unbedded; unsorted; massive; compact to very compact; and calcareous. Clasts are angular to rounded. They contain abundant igneous and metamorphic rock fragments, abundant carbonate rock fragments, and very few shale rock fragments; and pebble- to cobble-sized stones. Regolith pebbles may be present, and yellow-orange limestone pebbles are common in the lower part of the unit. Rotosonic core BH8004 (Fig. 3a) unit averages: texture, 42-37-21 (loam); lithology, 51-49-00; rotosonic core BH8006 (Fig. 3c) unit averages: texture, 41-41-18 (loam); lithology, 50-49-01; (Harris, 1973, 1975, 1995; Harris and others, 1974, 1996, 1999; Moran and others, 1976).

Unnamed stratigraphic units—These are subsurface stratigraphic units identified from descriptive water-well logs provided by water-well drillers (well logs). Well logs are usually reliable sources of information for the surface location of the well, depth of units encountered (elevation), and the general lithology of units encountered (glacial sediment, sand and gravel, and bedrock). Not enough information is usually provided to assign these sediments to stratigraphic units. Our interpretations are based on the pattern of occurrence of buried glacial sediment, outwash deposits, and a general understanding of the stratigraphy gained from the study of surface and subsurface occurrence of identified stratigraphic units.

Older tills—Pebble-loam; identified from descriptive well logs.

Sand and gravel—Sand and gravel; identified from descriptive well logs; generally deposited in outwash plains and fluvial channels, later buried by glacial events.

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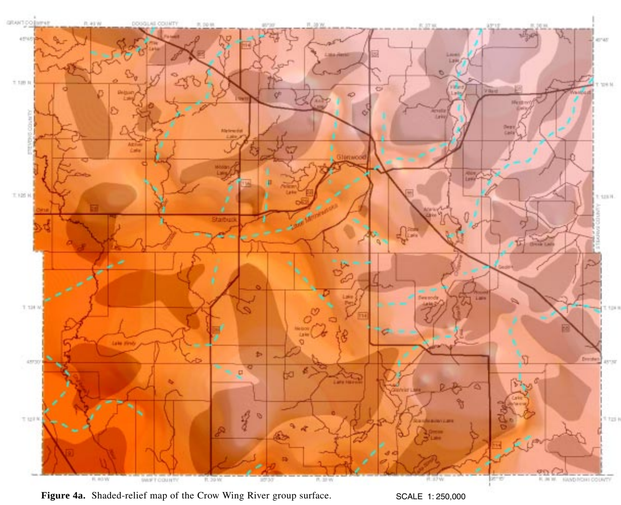

Figure 4a. Shaded-relief map of the Crow Wing River group surface.

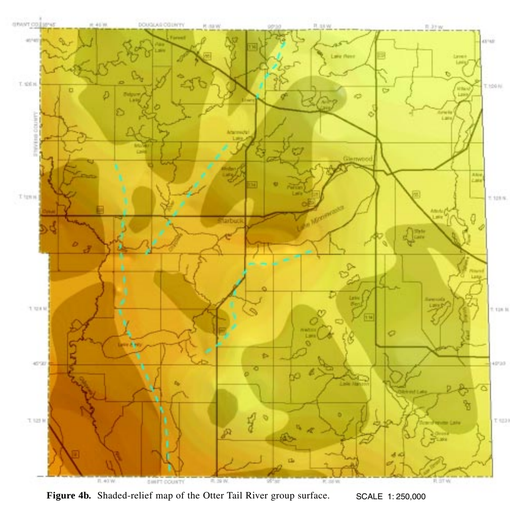

Figure 4b. Shaded-relief map of the Otter Tail River group surface.

SUBSURFACE SAND AND GRAVEL DEPOSITS IN POPE COUNTY

Buried sand and gravel layers are potential sources of water for domestic, industrial, and municipal use. Much of this sediment was deposited by meltwater from receding glaciers. Subsequent readvances of glacial ice eroded the sand and gravel in some places and buried them in others. The maps in Figure 4 show the approximate distribution of areas where sand and gravel associated with the Crow Wing River and Otter Tail River groups are present or thin to absent. Sand and gravel are likely to be present in all drainage areas. The first step in producing these maps was to create a network of cross-sections within the county that included the three rotosonic cores (Fig. 3). Stratigraphic information from cores, along with lithologic information from water-well logs, were used to estimate the elevation of the Crow Wing River and Otter Tail River groups within the county. These data were gridded and contoured to produce maps of the buried surfaces as they exist today. These surfaces have undergone collapse during deglaciation and erosion during reglaciation; they do not represent the topography at the time of glacial recession, but probably approximate that surface.

The ice advance that deposited the Crow Wing River group came from the northeast. As it receded, meltwater transported coarse-grained sediment to the west and southwest (Fig. 4a). In some areas, the surface expression of palimpsest channels were used to help define the paleodrainage patterns for the Crow Wing River group.

The ice advance that deposited the overlying Otter Tail River group came from the west and covered Pope County. As this ice receded, meltwater, confined by the elevated landscape to the east and the glacial ice to the west, transported coarse-grained sediment to the south–southeast (Fig. 4b).

The shaded areas on these maps indicate where sand and gravel deposits are thin or absent. Sand and gravel deposits (greater than 20 feet thick) are interpreted to be present in the unshaded areas. The total thickness of the sand and gravel in these areas is difficult to evaluate because water-well drillers will typically drill through only enough sand and gravel to produce the required water yield. Consequently, the total thickness of sand and gravel may not be penetrated. Therefore, much of the data between the shaded areas provide minimum values and a greater thickness of sand and gravel may be present. The dashed lines on these maps represent the locus of sand and gravel deposits that are greater than 20 feet (6 meters) thick. They are interpreted to represent the general paths followed by meltwater streams that were active on these surfaces.

Other more deeply buried sand and gravel units exist within the county but not enough data were available to map their distribution.

GEOLOGIC ATLAS OF POPE COUNTY, MINNESOTA

Computer graphics and cross-section compilation by James Berg (Minnesota Department of Natural Resources, Division of Waters) and R.S. Lively (Minnesota Geological Survey)
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