ANOKA SAND PLAIN REGIONAL HYDROGEOLOGIC ASSESSMENT

SURFICIAL GEOLOGY

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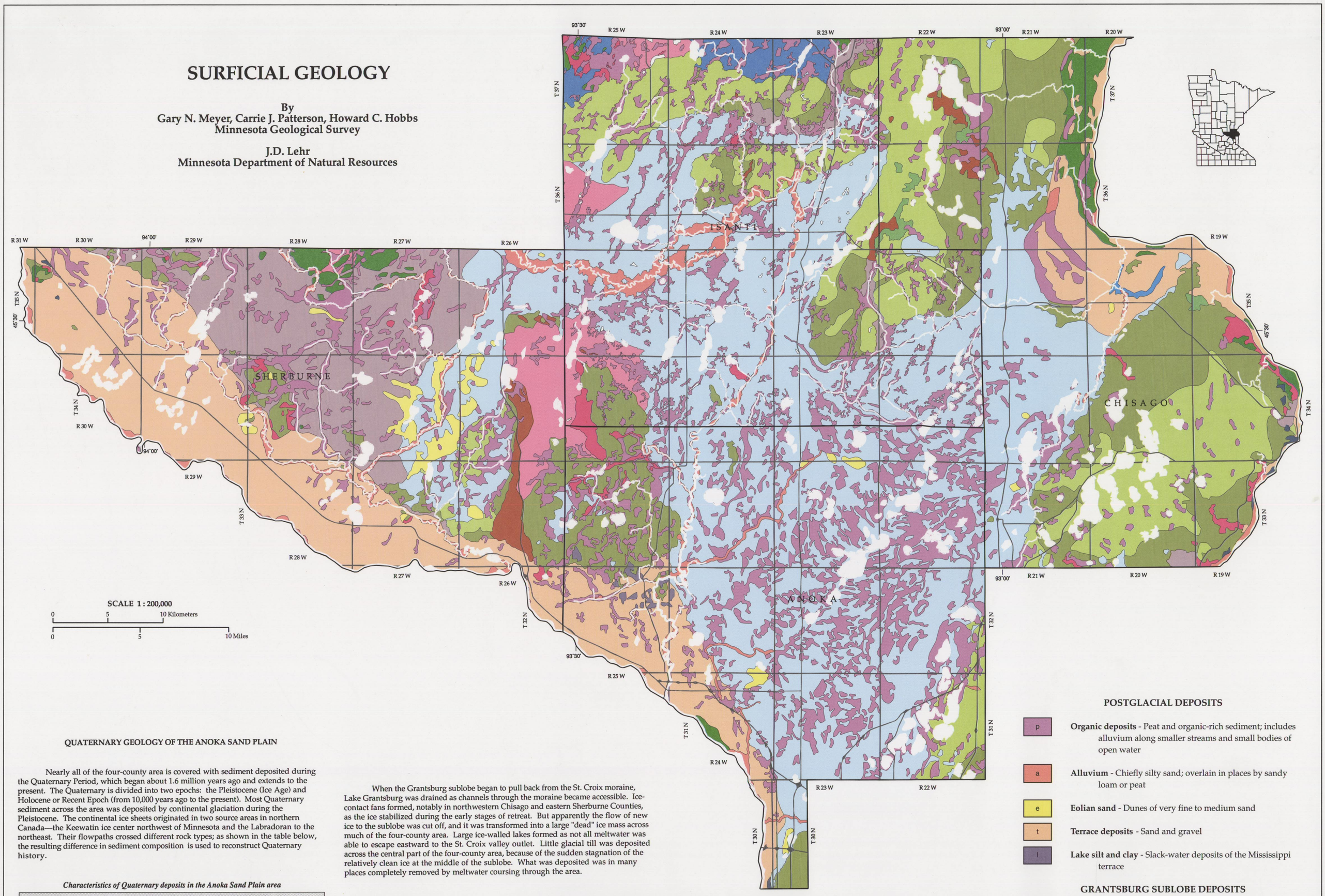


QUATERNARY GEOLOGY OF THE ANOKA SAND PLAIN

Nearly all of the four-county area is covered with sediment deposited during the Quaternary Period, which began about 1.6 million years ago and extends to the present. The Quaternary is divided into two epochs: the Pleistocene (Ice Age) and Holocene or Recent Epoch (from 10,000 years ago to the present). Most Quaternary sediment across the area was deposited by continental glaciation during the Pleistocene. The continental ice sheets originated in two source areas in northern Canada—the Keewatin ice center northwest of Minnesota and the Labradoran to the northeast. Their flowpaths crossed different rock types; as shown in the table below, the resulting difference in sediment composition is used to reconstruct Quaternary history.

Characteristics of Quaternary deposits in the Anoka Sand Plain area

Characteristic	Keewatin source	Labradoran source
Till texture	loamy	sandy
Color		
oxidized	yellow brown to olive brown	brown to reddish brown
unoxidized	gray to dark gray	reddish gray
Pebble type		
Paleozoic carbonate	common to abundant	rare to common
dark gray to gray-green rocks	uncommon to common	common to abundant
red felsite and sandstone	rare to common	common
Cretaceous shale	absent to abundant	absent

The uppermost sediment across the area was laid down during or after the last glaciation, the late Wisconsinan, which lasted from about 35,000 to 10,000 years ago. Sediment deposited during earlier glaciations, except for a few exposures in deep gullies adjacent to the St. Croix River, is found preserved only in the subsurface. Study of core from the area has yielded evidence for three pre-late Wisconsinan advances of Labradoran-source ice, and at least two earlier advances of Keewatin-source ice. However, these older deposits have only a patchy distribution in the subsurface of the four-county area, generally being found only where glacial deposits exceed 150 feet in thickness (Olsen and Mossler, 1982).

LATE WISCONSINAN GLACIAL EVENTS

The last advance of Labradoran-source ice, termed the Superior lobe, completely covered the four-county area. As the front of the Superior lobe became stabilized, it formed the St. Croix moraine, a linear series of high hills enclosing the four-county area to the west, south, and east (Hobbs and Goebel, 1982). During the eventual retreat of the ice front, meltwater issuing from the Superior lobe became channelized to escape through the moraine. Meltwater was ponded in lake basins dammed between the ice front and the stagnant ice-cored St. Croix moraine. Large fans of sand and gravel formed as the ice front periodically stabilized during its retreat. Prominent hills in central and eastern Sherburne, southwestern Isanti, northwestern and southernmost Anoka, and southeastern Chisago Counties are all cored by these Superior lobe ice-contact deposits and outwash.

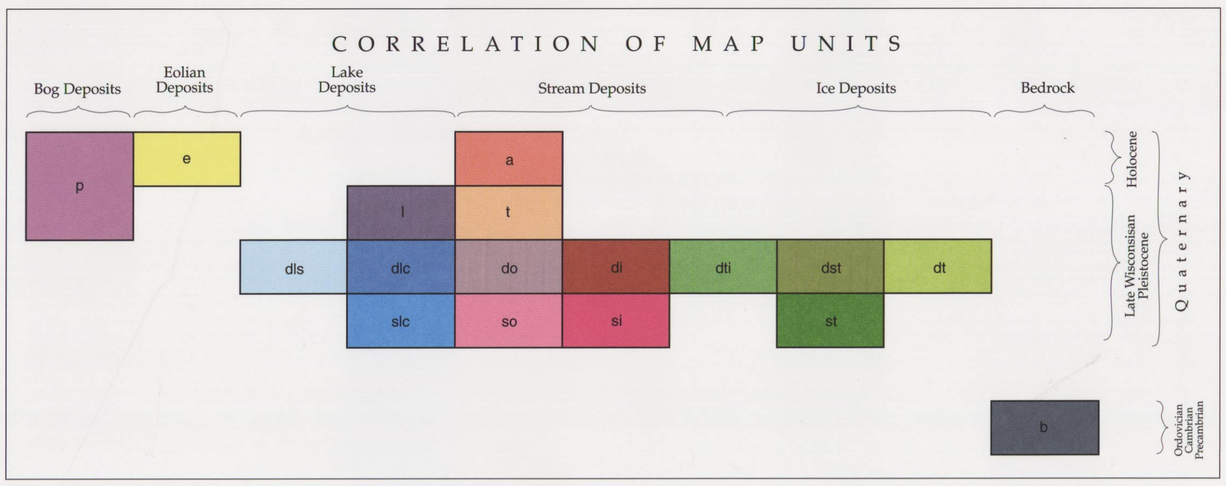
Eventually, as the Superior lobe retreated north over increasingly lower terrain, meltwater was no longer able to pass readily through the St. Croix moraine, and became ponded in a large lake which covered much of Anoka, southern Isanti, and central Chisago Counties. Exposures and core of varved silt and clay, believed to represent seasonal depositional cycles, indicate that the lake existed for many hundreds of years. A small area of this Superior lobe lake clay has been exposed by erosion of overlying material in central Chisago County. Exposures along the Sunrise River in Chisago County, together with core from Anoka County, indicate a readvance of Superior lobe ice into the lake basin at least as far as eastern Anoka County. This readvance over lake sediment left behind finer grained glacial till than is typically associated with the Superior lobe. Following final retreat of the Superior lobe, a second lake formed in the basin, which in turn was eventually drained prior to the last glacial advance into the area, the Grantsburg sublobe.

The Grantsburg sublobe was a northeast-flowing offshoot of the south-flowing Des Moines lobe. Unlike deposits of earlier Keewatin-source ice advances into central Minnesota, Des Moines lobe deposits are characterized by an abundance of Cretaceous shale fragments. Just as the stagnant ice-cored St. Croix moraine hindered escape of Superior lobe meltwater, the moraine also impeded the advance of Des Moines lobe ice into the low terrain of the Twin Cities area. After initially bulging onto the relatively higher ground of western Sherburne County, the flank of the Des Moines lobe was finally able to override the St. Croix moraine west of the Twin Cities, and extend its sublobe northeast as far as Grantsburg, Wisconsin. While the Grantsburg sublobe advanced across the four-county area, burying all but northernmost Isanti County and a small area in northern Sherburne County, ice was receding from western Sherburne County, leaving only a thin cover of deposits over Superior lobe sediment.

The maximum extent of the Grantsburg sublobe is marked by the Pine City moraine across northern Isanti County and just north of Chisago County. On the eastern and southern sides of the sublobe, however, no distinct moraine is discernible because the ice front rested against the St. Croix moraine. Here Grantsburg sublobe meltwater was able to escape via pre-existing channels through the St. Croix moraine. To the north, however, meltwater was dammed by the sublobe and formed Glacial lake Grantsburg, whose outlet may have been over the terminus of the ice itself (Cooper, 1935). Silt and clay deposited in the lake thin rapidly to the north away from the Pine City moraine.

When the Grantsburg sublobe began to pull back from the St. Croix moraine, Lake Grantsburg was drained as channels through the moraine became accessible. Ice-contact fans formed, notably in northwestern Chisago and eastern Sherburne Counties, as the ice stabilized during the early stages of retreat. But apparently the flow of new ice to the sublobe was cut off, and it was transformed into a large "dead" ice mass across much of the four-county area. Large ice-walled lakes formed as not all meltwater was able to escape eastward to the St. Croix valley outlet. Little glacial till was deposited across the central part of the four-county area, because of the sudden stagnation of the relatively clean ice at the middle of the sublobe. What was deposited was in many places completely removed by meltwater coursing through the area.

CORRELATION OF MAP UNITS



The St. Croix valley outlet was once again blocked to Grantsburg sublobe meltwater, but this time not by the glacier's own ice, but by an alluvial fan deposited by meltwater from the Superior lobe far to the north. This new dam formed a huge lake extending over much of Chisago, Isanti, and Anoka Counties, and into northeastern Sherburne County. Meltwater flowing from the stagnating Grantsburg sublobe, and along the margin of the Des Moines lobe across Sherburne County quickly began to fill the lake with mostly fine to medium sand. Much of the land surface both surrounding and beneath the lake was higher than at present due to buried stagnant ice, and thus the lake's boundaries are in places difficult to distinguish. In many places at this lake level the glacial till surface was only slightly modified by wave action and overlain by widely scattered, generally thin deposits of fine sand.

Geomorphic evidence in southeastern Chisago County indicates that a new outlet south of the blocking fan opened and allowed the catastrophic draining of the lake to the 940-foot level (Glacial Lake Hugo of Meyer and others, 1990). The lake at this level stabilized long enough for a recognizable plain to form across central and northeastern Chisago, southern Isanti, and all but northwestern Anoka Counties. The lake was lowered yet again to the 915-foot level (Glacial Lake Fridley of Meyer and others, 1990), being restricted primarily to central Chisago and eastern Anoka Counties. The lake was drained when a southern outlet finally became open at north Minneapolis (Meyer and Hobbs, 1989), establishing the present course of the Mississippi River above its confluence with the Minnesota River.

The course of the Mississippi and St. Croix Rivers varied widely across the flat outwash and lake plain of the Anoka Sand Plain, leaving behind a wide, high terrace across southwestern Sherburne and Anoka Counties and central Chisago County. During this period, fine sediment was deposited in slack water of the Mississippi River in Anoka County.

With the retreat of the Des Moines lobe north of the continental divide, Glacial Lake Agassiz formed in northern Minnesota and adjacent areas of North Dakota and Canada. Its southern outlet stream, Glacial River Warren, became the dominant stream draining across Minnesota, cutting the wide Mississippi valley below St. Paul, and what is now the Minnesota River valley. The Mississippi River above St. Paul, a tributary of River Warren at this time, became restricted in its floodplain as its upper terrace became incised to match the downcutting master stream. Ultimately its floodplain became controlled, as it is today, by St. Anthony Falls at Minneapolis. Terrace levels of the St. Croix River are more numerous and complex as the river continued to be lowered as River Warren lowered its valley, and as the St. Croix periodically served as the outlet to Glacial Lake Duluth of the Superior basin. Scoured Superior lobe till is at the surface in many places at the river's lower terrace levels.

RECENT EVENTS

When Glacial Lakes Agassiz and Duluth found lower outlets to the east less than 10,000 years ago, flow down the St. Croix decreased, and alluvium began to fill its valley. The low-lying portions of the glacial lake basin across southern Isanti, central Chisago, and Anoka Counties continue to fill with organic debris as do the numerous ice-block melt-out depressions and abandoned drainageways all across the four-county area. Beginning about 8,000 years ago, an extended dry period led to wind modification of the sand plain surface (Keen and Shane, 1990), with formation of sand dunes in some areas. Dunes are particularly well developed in east-central Sherburne and south-central Anoka Counties. Although the mid-Holocene dry period ended about 4,000 years ago, blowouts continue to occur on the sand plain during periodic droughts.

AKNOWLEDGEMENTS

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REFERENCES CITED

Cooper, W.S., 1935, The history of the upper Mississippi River in late Wisconsin and postglacial time: Minnesota Geological Survey Bulletin 26, 116 p.

Hobbs, H.C., and Goebel, J.E., 1982, Geologic map of Minnesota, Quaternary geology: Minnesota Geological Survey State Map Series S-1, scale 1:500,000.

Keen, K.L., and Shane, L.C.K., 1990, A continuous record of Holocene eolian activity and vegetation change at Lake Ann, east-central Minnesota: Geological Society of America Bulletin, v. 102, p. 1646-1657.

Meyer, G.N., Baker, R.W., and Patterson, C.J., 1990, Surficial geology, plate 3 *in* Swanson, L.M., and Meyer, G.N., eds., Geologic atlas of Washington County, Minnesota: Minnesota Geological Survey County Atlas Series C-5, scale 1:100,000.

Meyer, G.N., and Hobbs, H.C., 1989, Surficial geology, plate 3 *in* Balaban, N.H., ed., Geologic atlas of Hennepin County, Minnesota: Minnesota Geological Survey County Atlas Series C-4, scale 1:100,000.

Olsen, B.M., and Mossler, J.H., 1982, Geologic map of Minnesota, depth to bedrock: Minnesota Geological Survey State Map Series S-14, scale 1:1,000,000.

POSTGLACIAL DEPOSITS

- **p** — **Organic deposits** - Peat and organic-rich sediment; includes alluvium along smaller streams and small bodies of open water
- **a** — **Alluvium** - Chiefly silty sand; overlain in places by sandy loam or peat
- **e** — **Eolian sand** - Dunes of very fine to medium sand
- **t** — **Terrace deposits** - Sand and gravel
- **l** — **Lake silt and clay** - Slack-water deposits of the Mississippi terrace

GRANTSBURG SUBLOBE DEPOSITS

- **dls** — **Lake sand** - Very fine to medium sand; minor silt; includes some areas of fluvial sand at or near the surface
- **dlc** — **Lake silt and clay** - Deposited in Glacial Lake Grantsburg; on this map, only in extreme northwestern Isanti County
- **do** — **Outwash deposits** - Sand and gravel
- **di** — **Ice-contact deposits** - Sand and gravel; minor silt and till
- **dti** — **Till** - Complex of till and ice-contact sand and gravel
- **dt** — **Till** - Yellow-brown (oxidized) over gray (unoxidized); loam texture; thinly mantled in places by sand or silt
- **dst** — **Till of mixed composition** - Yellow-brown (oxidized) over red-brown loam to sandy loam texture; less than 20 feet thick over Superior lobe deposits

SUPERIOR LOBE DEPOSITS - MANTLED BY LESS THAN 10 FEET OF YOUNGER SEDIMENT

- **slc** — **Lake silt and clay** - varved
- **so** — **Outwash deposits** - Sand and gravel
- **si** — **Ice-contact deposits** - Sand and gravel; minor till and silt
- **st** — **Till** - Red brown; sandy loam texture

BEDROCK

- **b** — Ordovician, Cambrian, or Precambrian bedrock at or near the surface

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