UNIVERSITY OF MINNESOTA
MINNESOTA GEOLOGICAL SURVEY
Harvey Thorleifson, Director

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SURFICIAL GEOLOGY

By

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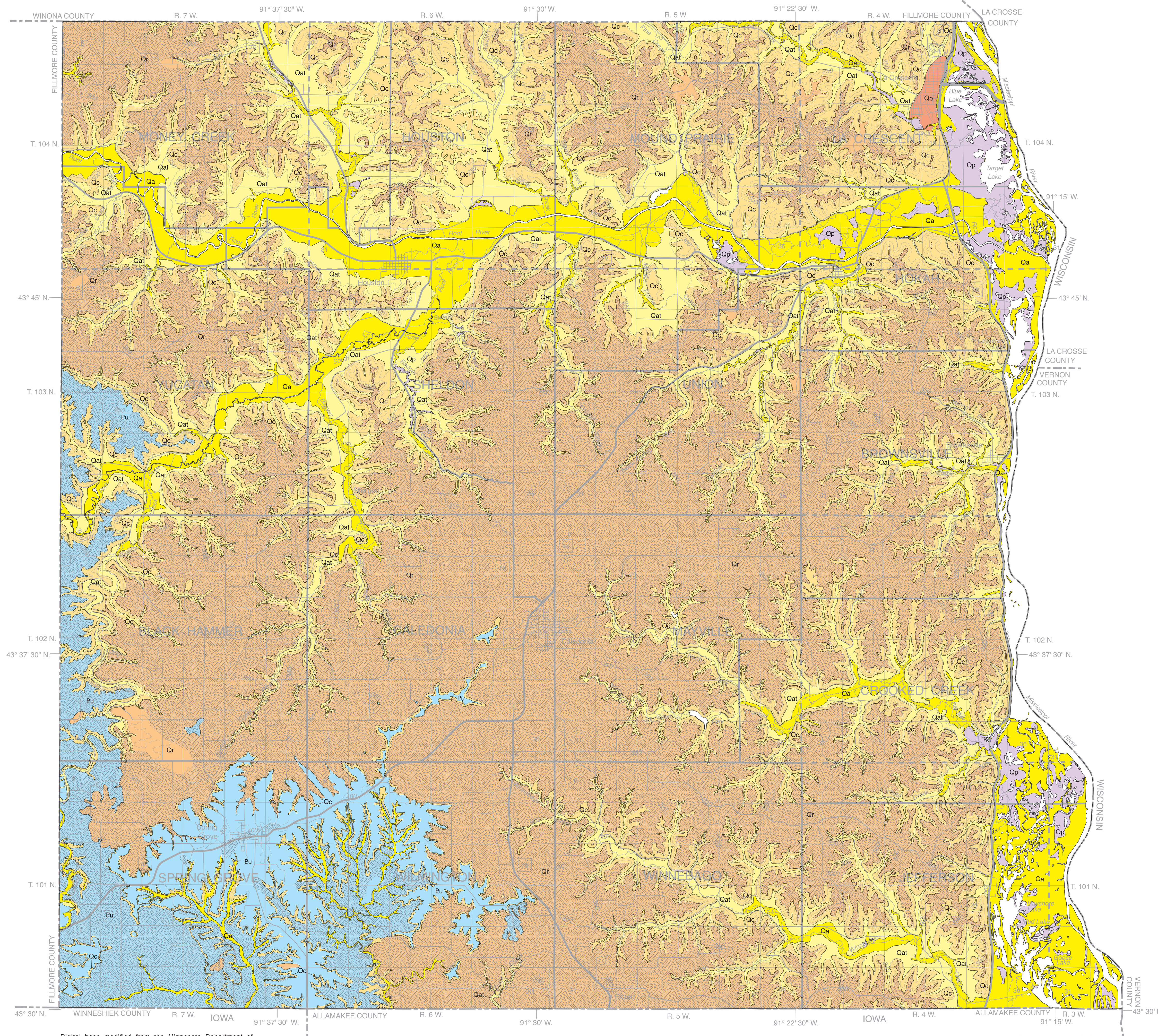
2014



Digital base modified from the Minnesota Department of Transportation BaseMap data; digital base annotation by the Minnesota Geological Survey.

Elevation contours were derived from the U.S. Geological Survey 30-meter Digital Elevation Model (DEM) by the Minnesota Geological Survey.

Universal Transverse Mercator Projection, grid zone 15
1983 North American Datum

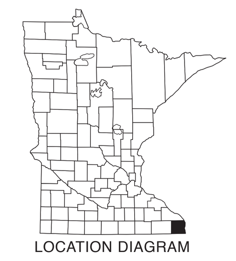
SCALE 1:100 000

1 0 1 2 3 4 5 MILES

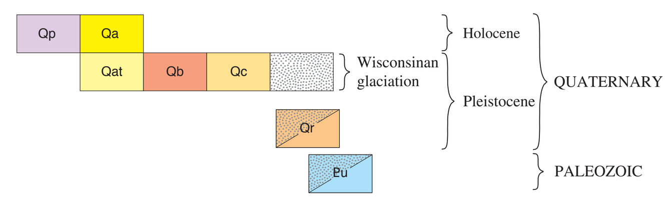
1 0 1 2 3 4 5 6 7 8 KILOMETERS

CONTOUR INTERVAL 50 METERS

GIS compilation by R.S. Lively
Edited by Lori Robinson



CORRELATION OF MAP UNITS



MAP SYMBOLS

Geologic contact—Approximately located.

Silt loam to loam, loess covering older sediment—May contain some fine-grained sand (Fig. 5). Shown where generally greater than 5 feet (1.5 meters) thick; elsewhere, thin loess (less than 5 feet [1.5 meters]) may be present. Thicknesses greater that 5 feet are shown on Figure 3. May include residuum at depth. May include two separate loess units—the Peoria Formation (upper; Johnson and others, in press) and the thin, patchy, Roxanna Silt (lower). In at least one location near Hokah, the lower loess lies atop what is interpreted to be a soil horizon of Sangamon age (Lively and others, 1987), marking the warm period between the Illinoian and Wisconsinan glacial stages. *Windblown sediment called loess.*

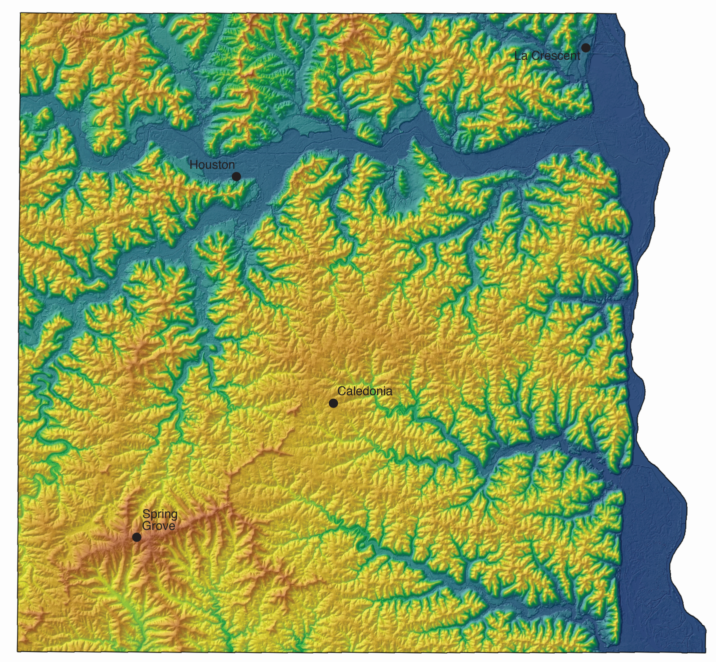


Figure 1. Physical relief of the land surface in Houston County (vertically exaggerated 3 times). Elevation is shown by color: red-orange (higher elevation) grading to blue (lower elevation). Elevation ranges from 1,335 to 617 feet (407 to 188 meters) above sea level. A false sun illumination at an elevation of 30° from the northwest (315°) provides contrast to accent landform details. This map was created using the U.S. Geological Survey's Digital Elevation Model with a 10-meter grid; scale 1:300,000.

INTRODUCTION

This map emphasizes the distribution and origin of surficial materials in Houston County. The map is based on a variety of data sources. The depiction of landform distribution and sediment character was initially drawn on 1:24,000 U.S. Geological Survey topographic maps that were overlain on a 10-meter digital elevation model that covered the area (Fig. 1). These interpretations were compared to a soil map for Houston County (Natural Resources Conservation Service, 2013), national wetlands inventory maps (U.S. Fish and Wildlife Service, 2013), and to well logs included in the Minnesota Geological Survey County Well Index. Fieldwork to verify and augment these interpretations was conducted from 2010 to 2012. Most described and sampled exposures consisted of excavations, including gravel pits, construction sites, and road cuts. These were supplemented with 62 auger borings drilled to a depth of about 13 feet (4 meters).

BEDROCK GEOLOGY

Bedrock near the land surface in Houston County consists of sedimentary rocks deposited in shallow seas during the Paleozoic Era from about 500 to 450 million years ago (Plate 2, *Bedrock Geology*). These rocks—exposed in bluffs, riverbanks, rock quarries, and road cuts—weather and were eroded differently. Rocks such as limestone and dolostone are the most resistant to weathering and generally form plateaus. The soft sandstone and shale are more easily eroded and occur within the walls of valleys.

Across the surface of these rocks is a layer of weathered material called residuum. Just as the different types of rock erode differently and occupy distinct positions on the landscape, the weathering products associated with each rock type are also distinct. Residuum above limestone and dolostone is generally red, clayey sediment, called terra rossa. Sandstone weathers to loose sand. Both may contain fragments of original rock near the unweathered bedrock surface.

GLACIAL GEOLOGY

The Pleistocene Epoch began about 2.5 million years ago. During this time, glaciers advanced and retreated across Minnesota several times. The glaciers advanced from many different directions, called provenances, leaving behind sediment of a particular color and containing distinct rock types indicative of the terrain over which they passed (Fig. 2; Table 1). The extreme southeastern corner of Minnesota is commonly referred to as the "driftless area," meaning lacking glacial deposits, or drift. This is not entirely correct. Although no exposures of glacial sediment were found during the course of this study, scattered glacial erratics, which are remnants of eroded glacial sediment, are present in places. Glacial sediment in this region is attributed to a pre-Illinoian age glaciation more than 300,000 years ago (Fig. 2A). Since then, glaciers have crossed other parts of Minnesota several times, but no evidence exists to indicate that they extended again into the southeastern corner of the state (Figs. 2B, C, D).

Before the onset of glaciation, the landscape in this region would have been relatively undissected. Deep erosion of the river valleys is thought to have started in the early Pleistocene Epoch and continued throughout the glacial period (Knox, 1985).

A layer of windblown silt, called loess, blankets much of the upland plateaus (Fig. 3). The silt (along with some fine-grained sand) was derived from sources to the west, across and including the Iowan Erosion Surface, which is an area of pre-Illinoian glacial sediment and bedrock that was subjected to periglacial climate conditions and wind erosion. This area is found mainly in Iowa, but extends into Minnesota and is exposed outside of the late Wisconsinan glacial margin (shown in blue on Fig. 2D; Mason and others, 1994). The bulk of the loess deposition occurred between 30,000 to 16,000 years ago (Ruhe and others, 1968; McKay, 1979 as reported in Johnson and others, in press).

Colluvium present along steep valley slopes is inferred to be the result of accelerated hillslope erosion due to intense freeze/thaw conditions and widespread permafrost during the late Wisconsinan age between 18,000 and 12,000 years ago (Mason and Knox, 1997). In addition, meltwater from the glaciers further north drained southward through what is now the Mississippi River valley. As the valley filled with glacial sediment, the tributary stream valleys also filled with sediment. Terraces of red (northeastern source) and gray (northwestern source) glacial lake sediment have been recognized along tributary streams as far as 5 miles (8 kilometers) upstream from the Mississippi River (Flock, 1983). When the climate warmed and the glaciers melted across the state, large glacial lakes that had been impounded by the ice drained southward through what is now the Mississippi River valley (Fig. 4). As the valley was incised, tributary streams also cut deeper into the landscape, thus reversing the aggradation, or build up, of sediment in the Mississippi River and its tributaries.

POSTGLACIAL GEOLOGY

The Holocene Epoch (11,700 years ago to present) marks the end of the ice age in Minnesota and the transition to the warm conditions we have today. This period has been characterized by relatively slow rates of erosion and the development of soils, alluvium, and organic deposits.

DESCRIPTION OF MAP UNITS

Holocene

Qp **Organic debris, clay, and silt**—Partially decomposed plant matter (peat) and fine-grained organic matter deposited in marshes and ponded water. Includes minor alluvial deposits along streams, as well as beach deposits. Modified from the Houston County web soil survey (Natural Resources Conservation Service, 2013) and national wetlands inventory maps (U.S. Fish and Wildlife Service, 2013). *Wetland sediment.*

Qa **Sand, sandy loam to silt loam**—Generally coarse-grained sediment (sand with some gravel) in the channels, and finer-grained sediment (fine-grained sand and silt) on floodplains; coarsens with depth. Capped by and/or interbedded with organic-rich layers locally. Low areas may be filled with thick silty to clayey sediment. Includes layers of colluvial sediment at the base of steep slopes. In the Mississippi River valley and lower parts of its tributary streams, alluvium is thick (80 to 100 feet [24 to 30 meters]) because the valley was deeply eroded by glacial River Warren (Fig. 4) and has been filling with alluvial sediments ever since. Deposited by modern streams and slope wash in channels and on floodplains. Not distinguished from older alluvium (unit Qat) in the upper reaches of the valleys. *Floodplain alluvium.*

Pleistocene

Wisconsinan age

Qb **Sand and gravelly sand**—Coarsens to cobbly gravel locally; capped in places by loamy fine-grained sand. Deposited as fluvial sediment from glacial River Warren and preserved as bars above the modern Mississippi River floodplain. *Fluvial sediment.*

Qc **Boulders to silt**—Angular rock fragments in a matrix of fine-grained sand to silt; overlain by silt with rock fragments. Deposited at the base of steep slopes. Bedrock is commonly exposed upslope. The occurrence of rocky talus with a silt overlay is consistent over much of the region and is the result of the repeated freeze/thaw conditions during which it was deposited (Mason and Knox, 1997). The overlying silt is derived from the loess on the uplands. *Colluvium.*

Qat **Sand and silt**—Predominantly locally derived; capped in places by loess and silty colluvium. Deposited as fluvial sediment along streams. Includes modern alluvial deposits (unit Qa) in stream channels in the upper reaches of streams that are too narrow to show at map scale. Contains gravel in places, especially along the Root River. *Alluvial terrace deposits.*

Pre-Illinoian age—The unit below tends to be patchy and discontinuous under a cover of loess. The unit is mapped based on the occurrence of materials where observed and sampled in outcrops, excavations, and drill holes (see Plate 1, *Data-Base Map*). Unit boundaries are extended based on the predicted occurrence of the sediment in a similar geologic setting. Thus, the extent of units mapped under loess should be considered a schematic depiction.

Qr **Clay to sand**—Residuum sediment that varies depending on the composition of the underlying bedrock. Residuum above limestone and dolostone is generally red, cherty clay (Fig. 5). Sandstone weathers to loose sand and clayey sand. Both may contain fragments of original rock near the unweathered bedrock surface. Crude bedding suggests that this sediment may have been mobilized and redeposited. Includes old, highly oxidized and leached glacial till. Generally less than 5 feet (1.5 meters) thick, although can be thicker in bedrock lows and sinkholes. Especially thin on steep slopes above the colluvium (where it is too thin to show). Best preserved on the level uplands between drainage divides. Loess cover is indicated by pattern. *Weathering residuum.*

Paleozoic

Pu **Bedrock undifferentiated**—Sandstone, shale, and carbonate deposited in shallow seas during the Paleozoic Era from about 500 to 450 million years ago. Includes formations in the Galena, Prairie du Chien, and Tunnel City Groups (see Plate 2, *Bedrock Geology*). May be overlain by residuum. Loess cover is indicated by pattern.

ACKNOWLEDGEMENTS

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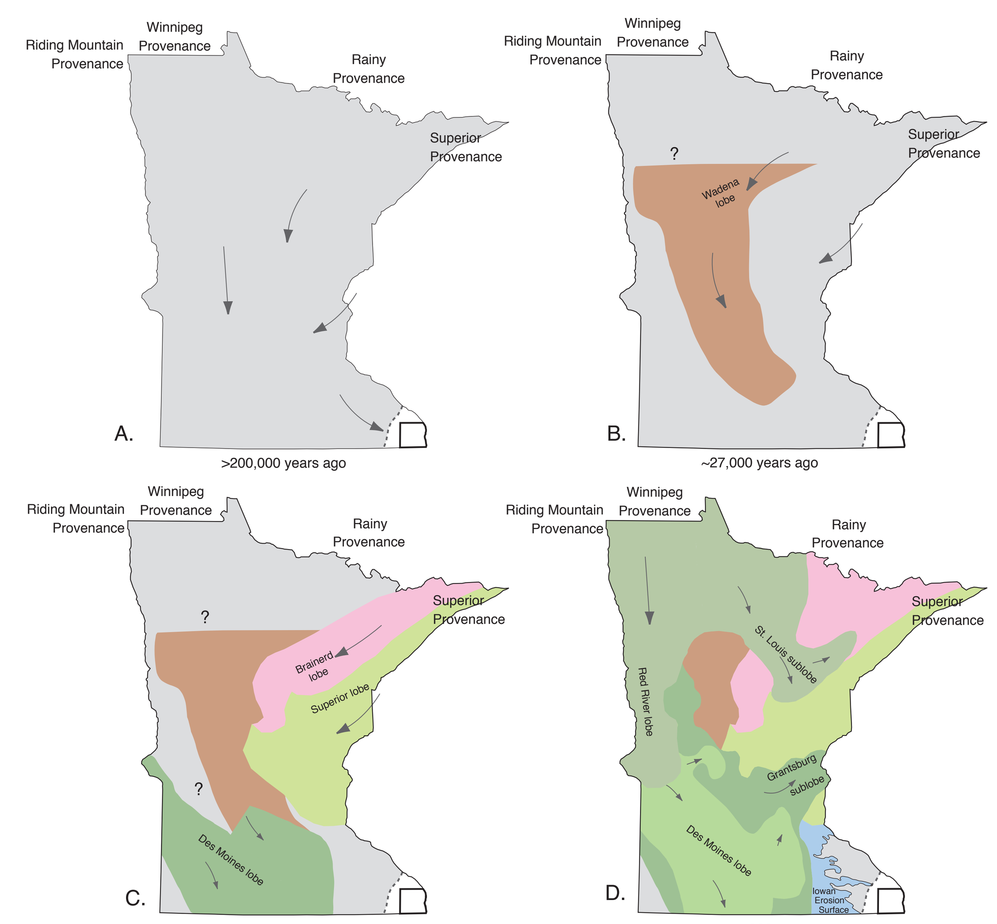

Figure 2. Location of Houston County in relation to the major provenances, or source regions, of glacial deposits. Associated glacial deposits, represented by the lobes that deposited them, are shown and stacked by relative age—oldest (A) to youngest (D). Deposits introduced together on the same diagram (such as D) are not necessarily contemporaneous and the specific timing of events may be uncertain, especially in separate areas of the state.

A. Glacial deposits greater than 200,000 years old (gray; undifferentiated). Glacial till in the Houston County area is interpreted to have been deposited over 300,000 years ago by ice that advanced from the north–northwest, or Winnipeg provenance. The approximate extent of clearly identifiable till is indicated by the dashed line. East of this line, any till deposits that exist are highly eroded, leaving little more than a few glacial erratics scattered in the loess and residuum.

B. Inferred extent of glacial sediment deposited by the Wadena ice lobe approximately 27,000 years ago. It is likely that other ice lobes were also advancing during this time but are not shown on this diagram.

C. Inferred extent of glacial sediments deposited by the Brainerd, Superior, and Des Moines ice lobes approximately 20,000 years ago.

D. Inferred extent of late Wisconsinan glacial sediments deposited by the Des Moines, Red River, and St. Louis ice lobes approximately 14,000 years ago. The Iowan Erosion Surface in southeastern Minnesota is blue (Johnson and others, in press).

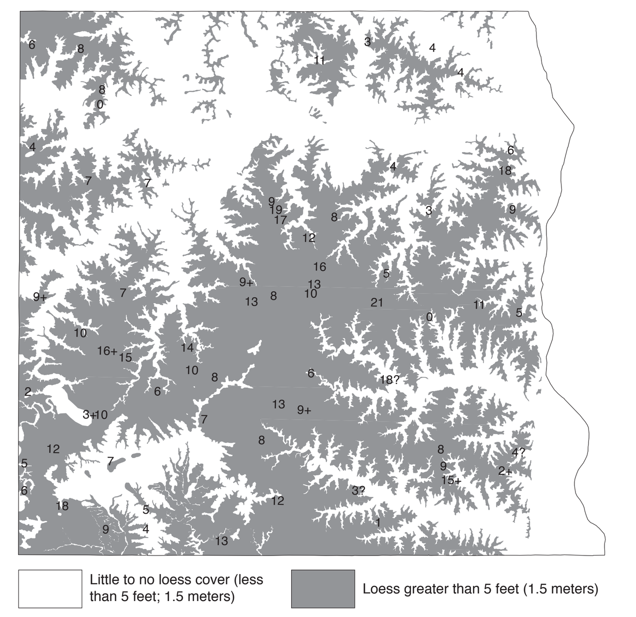

Figure 3. Map of Houston County indicating the occurrence of loess greater than 5 feet (1.5 meters) thick. Loess generally thins eastward (Mason and others, 1994). Thin loess is present on older alluvium and terraces in the upper reaches of stream valleys. Numbers indicate the thickness (in feet) as observed in auger drill holes. Not all drill locations are shown; locations are approximate.

Figure 4. Major glacial lakes during the Wisconsinan age (not necessarily contemporaneous) that drained through what is now the Mississippi River valley (modified from Lusardi, 1997).

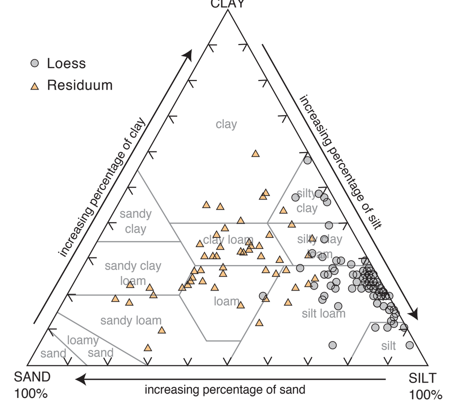

Figure 5. Ternary diagram showing the matrix texture of loess and residuum samples in Houston County. Loess is predominantly silt loam. Residuum tends to be clayey or sandy depending on the bedrock on which it formed. Several residuum samples in Houston County contain abundant silt. It is possible that some of the samples identified as residuum may actually include loess, residual till, or even older loess units. Similarly, loess samples that are more clayey in texture may include some residuum.

Table 1. Physical characteristics of glacial deposits in Minnesota. Only Winnipeg provenance sediments (bold) are found in Houston County, although fluvial sand and gravel bars in the Mississippi River valley (unit Qb) contain sediment interpreted to be eroded from Superior provenance deposits.

SOURCE AREA PROVENANCE	NORTHWEST RIDING MOUNTAIN	**NORTH–NORTHWEST WINNIPEG**	NORTH–NORTHEAST RAINY	NORTHEAST SUPERIOR
LOBE	Des Moines/Red River/St. Louis	**Wadena**	Wadena/Brainerd	Superior
TILL TEXTURE	Sandy loam to clay loam	**Loam to silt loam to clay loam**	Sandy loam to loamy sand	Sandy loam to loamy sand
TILL COLOR				
Oxidized	Light olive-brown	**Light olive-brown**	Yellow-brown to brown	Brown to red-brown
Unoxidized	Gray to dark gray	**Gray to dark gray**	Gray to brown-gray	Gray to red-gray
PEBBLE TYPE				
Carbonate	Common	**Common to abundant**	Rare to common	Rare to common
Gray-green rock	Uncommon to common	**Uncommon to common**	Uncommon to common	Common to abundant
Red felsite	Absent to rare	**Absent to uncommon**	Rare to uncommon	Common to abundant
Gray shale	Uncommon to common	**Absent to uncommon**	Absent	Absent
Clear quartz	Common	**Common to abundant**	Abundant to common	Uncommon to common