UNIVERSITY OF MINNESOTA
MINNESOTA GEOLOGICAL SURVEY
Harvey Thorleifson, Director

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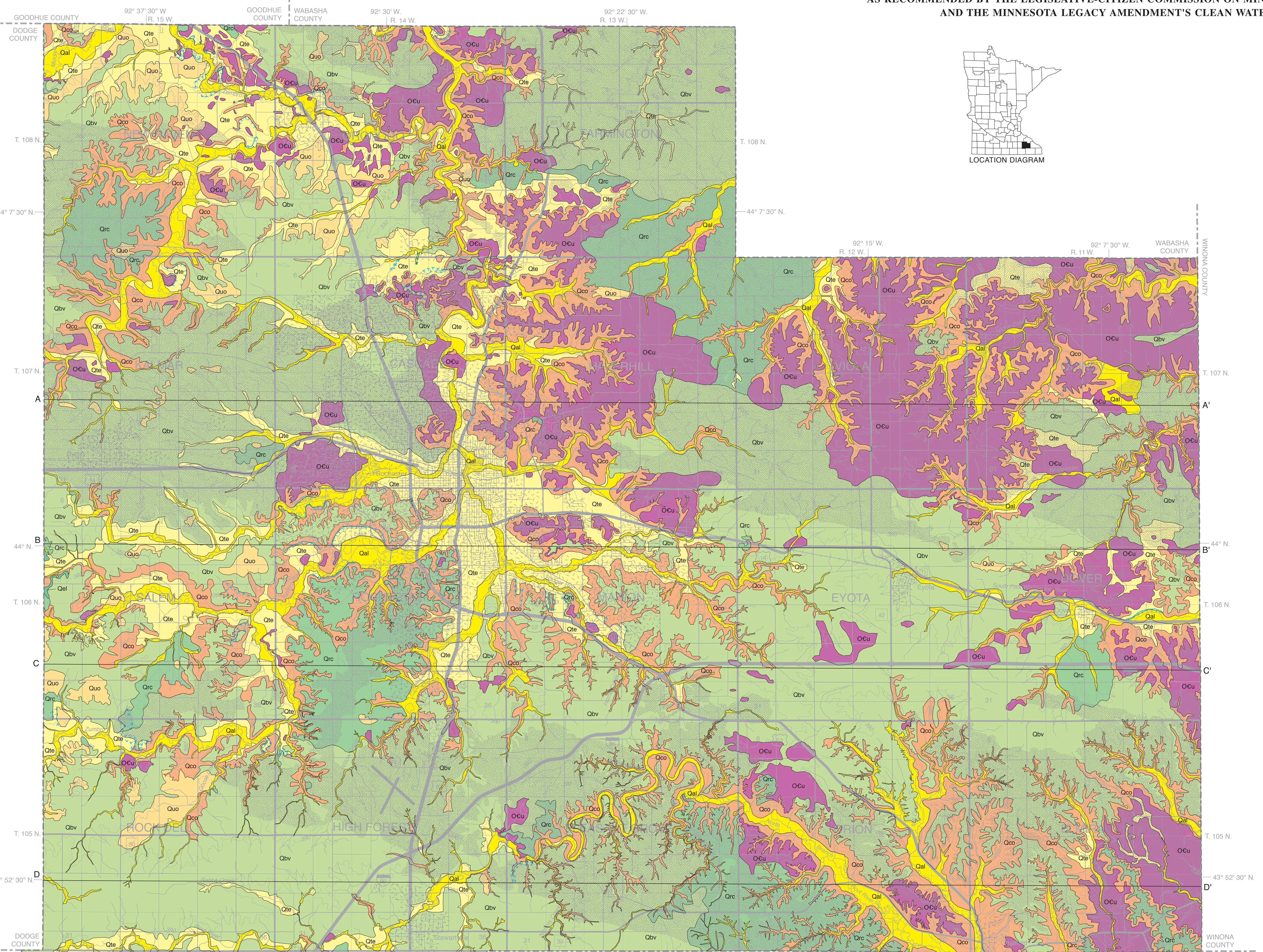


GIS compilation by R.S. Lively
Edited by Lori Robinson

Digital base modified from the Minnesota Department of Transportation BaseMap data; digital base annotation by Corey J. Betchwars.
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
5 MILES
8 KILOMETERS
CONTOUR INTERVAL 30 METERS

LOCATION DIAGRAM

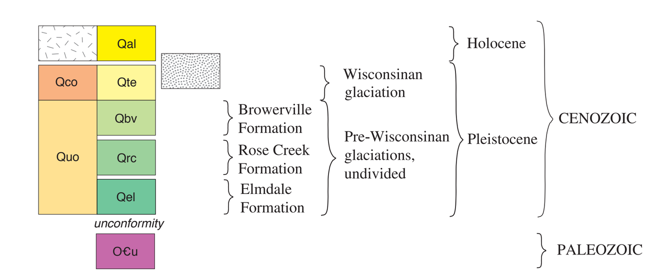
SURFICIAL GEOLOGY

By

Katherine J. Marshall and Jennifer M. McDonald

2020

CORRELATION OF MAP UNITS



MAP SYMBOLS

Geologic contact—Approximately located.

Stream-cut scarp—Erosional scarp formed by glacial and modern fluvial processes. Found within modern river channels. Hachures point down scarp.

Meander scar—Hachures point downslope. Formed by earlier phases of the stream, at a higher level within the same valley.

INTRODUCTION

This map displays the surface distribution of Quaternary sediments and areas where these sediments are thin or absent in Olmsted County. The depiction of landform distribution was based on 3-foot (1-meter) resolution lidar elevation imagery collected in 2008 (available from the Minnesota Geospatial Commons <https://gisdata.mn.gov>). The surficial geology map was compiled from descriptions and samples collected from natural exposures, gravel pits, road cuts, water-well cuttings, four rotary-sonic cores, and over 160 auger borings. Auger borings were drilled to an average depth of about 15 feet (4.5 meters) during the 2016 field season. Over 700 samples were analyzed for texture and lithology. Data from previous mapping in and adjacent to Olmsted County (see Mapping Index) were used to interpret map units. This was supplemented by the soil map of Olmsted County (Natural Resources Conservation Service, 2012), well logs from the County Well Index (CWI), and the Minnesota Geological Survey Quaternary Data Index (QDI), an internal working database that includes logs of Minnesota Department of Transportation bridge borings.

Map units are distinguished from each other by texture, very coarse-grained sand (1-2 millimeters) lithology, stratigraphic position, and landscape position. Most of the Quaternary deposits are assigned to the lithostratigraphic units defined in Johnson and others (2016).

GLACIAL HISTORY

Sediments deposited during the Quaternary Period dominate the surficial geology of Olmsted County. This period, which began about 2.6 million years ago and extends to the present, is characterized by repeated advances of the Laurentide Ice Sheet into Minnesota. During these glacial advances, ice flowed into the state from four different source areas: the central-northwest Winnipeg provenance, the northwest Riding Mountain provenance, the central-northeast Rainy provenance, and the northeast Superior provenance (Fig. 1). As ice advanced from these source areas, it incorporated different types of rocks and deposited glacial sediments with distinct lithologic compositions, which are indicative of the provenance from where the ice originated. However, by the time it reached southeastern Minnesota, ice from the four source areas had flowed along similar paths for hundreds of miles. As the ice flowed, it incorporated additional rocks that diluted the distinct lithologic composition of the provenance from where it originated (Fig. 2). Therefore, glacial deposits in southeastern Minnesota tend to have less diagnostic lithologic compositions than deposits in central or northern Minnesota (Meyer, 2000).

The most recent glacial event in Minnesota was the Wisconsinan glacial episode, which lasted from 75,000 years ago to the start of the Holocene Epoch, 11,700 years ago. During this time, glaciers deposited thick layers of sediment across much of Minnesota. However, these glaciers did not reach the southwest and southeast corners of the state (Fig. 1). As a result in Olmsted County, glacial sediment deposited prior to the Wisconsinan glacial episode, referred to as pre-Wisconsinan, occurs across the county at the land surface. These sediments are relatively thick in the western part of the county, but are thin and patchy in the eastern portion of the county, where bedrock commonly occurs at or near the land surface.

Pre-Wisconsinan glaciation (Illinoian and Pre-Illinoian Episodes, undivided)

The oldest glacial material preserved at the land surface in Olmsted County is the Elmdale Formation till (unit Qel) of Winnipeg provenance (Fig. 1). This unit is at lower elevations along a valley in western Olmsted County, where the overlying Rose Creek and Browerville Formations have been eroded. Till of the Elmdale Formation is texturally similar to that of the Browerville Formation, but generally has fewer Paleozoic carbonate clasts (see Plate 4, Table 1). The Rose Creek Formation (unit Qrc), also exposed in Olmsted County through erosion, is interpreted to have been deposited by Rainy-provenance ice as it advanced from the northeast (Fig. 2). Rose Creek Formation till is distinguished by an absence of Cretaceous material within the very coarse-grained sand (1-2 millimeters) fraction, and the matrix is typically more silt-rich than other tills in Olmsted County (Table 1). Age dating of the Browerville Formation (see discussion below) indicates that it was deposited during a pre-Wisconsinan glaciation, probably the Illinoian glaciation (Knaeble and Meyer, 2007), which began about 190,000 years ago (Martinson and others, 1987). Detrital remanent magnetism samples collected from Rose Creek Formation till exhibit normal polarity (Meyer, 2000). This implies that the Rose Creek Formation was deposited during the Middle Pleistocene Epoch (125,000 to 780,000 years ago; Jennings and others, 2006), probably prior to the Illinoian glaciation.

Following deposition of the Rose Creek Formation, ice retreated from Olmsted County. In the absence of ice cover, a boreal forest developed (Meyer, 2000). Eventually, Winnipeg-provenance ice buried this forest, and in places, the soil in which it formed was preserved as part of the Bennington Member of the Rose Creek Formation (not differentiated here). The Bennington Member also includes silty sediments interpreted to be loess, remobilized by the wind, and ponded sediment that was reworked by cryoturbation and permafrost (Meyer and Knaeble, 1998; Meyer, 2000).

Winnipeg-provenance ice deposited the Browerville Formation. Although this formation is present across much of Minnesota, in most areas it is buried beneath younger, Wisconsinan-age glacial sediments. Till from this formation contains Cretaceous limestone, *Inoceramus sp.* shell fragments, and trace amounts of gray and speckled shale within the 1-2 millimeter sand fraction (Table 1). In Olmsted County, Browerville Formation till (unit Qbv) is the most widespread surficial unit. Glacial landforms of the Browerville Formation have been subdued by periglacial activity during the Wisconsinan glaciation. As a result, the Browerville Formation forms a relatively low relief landscape across Olmsted County.

Radiocarbon and uranium/thorium dating have been used to determine the age of the Browerville Formation. Wood collected from Browerville Formation till at a gravel pit in Stearns County was older than about 48,000 calendar years before present (cal YBP; Table 2; Meyer and Knaeble, 1996; Johnson and others, 2016). Two calcite samples were collected from marl deposits in lacustrine sediment on top of Browerville Formation till in a rotary-sonic core drilled in central Minnesota. These samples had a uranium/thorium disequilibrium minimum date of 200,000 YBP (Knaeble and Meyer, 2007) and imply that the Browerville Formation is pre-Wisconsinan, and probably Illinoian, in age.

In places, the Browerville and Rose Creek Formations are overlain by highly leached and oxidized deposits of sand and gravel (unit Quo; Table 2). The sand and gravel clasts are typically coated by a thin layer of reddish clay and they break apart easily due to extensive chemical weathering. This unit was most likely deposited over an extended time period, following deposition of the Elmdale Formation, by either glacial meltwater or post-glacial rivers. Following deposition, the sand and gravel probably formed a continuous surface similar to that of floodplain alluvium (unit Qal). However, over time, these deposits have been eroded and now are preserved as scattered remnants across Olmsted County.

Wisconsinan glaciation

Glacial ice did not advance into Olmsted County during the Wisconsinan glacial episode. Instead, glacial meltwater, precipitation, and a harsh, cold climate continued to modify the landscape. While Des Moines-lobe ice constructed the Bemis moraine in eastern Steele County, glacial meltwater washed east across Olmsted County, forming the valleys of the modern South and Middle Forks of the Zumbro River. At the same time, non-glacial streams and meltwater streams from the Des Moines lobe deposited sand and gravel (unit Qte) across Olmsted County (Fig. 3).

Due to the harsh climate, this ice-free landscape remained sparsely vegetated and was exposed to the elements. As strong winds blew off the ice sheet from the northwest, they swept across the land surface, mobilizing and depositing fine-grained sediment from the Des Moines-lobe outwash and pre-Wisconsinan glacial deposits (Mason and others, 1994; Zanner, 1998). This formed a unit of fine-grained sand and silt called the Peoria Formation loess (stippled pattern; Table 2). The thickness of this loess is highly variable (Fig. 4). Basal radiocarbon ages from organic material buried by loess in east-central Iowa range from about 33,200 to about 23,000 cal YBP (Table 2; Ruhe and others, 1968). This indicates the beginning of loess deposition. Organics buried in the upper section of Peoria Formation loess range from about 17,900 to 17,300 cal YBP (Table 2), implying loess deposition ended around that time in Iowa (Ruhe and others, 1968).

Periglacial conditions, including permafrost, contributed to a major mass-wasting episode during the Wisconsinan glaciation. Materials from the uplands mixed with bedrock along steep slopes, forming a poorly sorted mix of sediment and angular bedrock clasts called colluvium (unit Qco; Table 2). Radiocarbon dating of organic matter collected from colluvium deposits in southeastern Minnesota indicates that deposition occurred around 19,900 to 13,900 cal YBP (Table 2; Mason and Knox, 1997).

Holocene Epoch

The Holocene Epoch began around 11,700 years ago and marks the end of the ice age in Minnesota. When the ice melted and the climate warmed, vegetation returned to the area. The reestablishment of vegetation halted significant wind erosion and stabilized slopes in southeastern Minnesota. Far to the northwest, drainage of glacially dammed lakes eroded and deepened the Mississippi River valley. This caused tributary streams in Olmsted County to downcut their valleys, dissecting and preserving older alluvium (unit Qte) as terraces above the newly established floodplains. Following drainage of the glacial lakes, sediment-carrying capacity waned and tributaries began to fill with floodplain alluvium (unit Qal; Hobbs, 1995). More recently, large-scale movement of sediment by industrial machinery created fill in urban areas and landfills.

ACKNOWLEDGEMENTS

Matthew Ettsen, Collin Giusti, Ryan Puzel, Anik Regan, and Zachary Van Orsdel, formerly of the Minnesota Geological Survey, assisted with fieldwork, including drilling auger holes. Thanks to all of the landowners and gravel pit operators who gave permission to examine exposures on their property. Alan Knaeble, Barbara Lusardi, and Gary Meyer of the Minnesota Geological Survey provided valuable guidance in the creation of this map.

DESCRIPTION OF MAP UNITS

HOLOCENE

Fill—Formed by large-scale movement of sediment by industrial machinery. Present in urban areas, gravel pits, quarries, and landfills. Materials used vary depending on land use. *Fill.*

Qal **Sand and gravel, sandy loam to silt loam**—Generally coarse-grained sediment (sand and gravel) in channels, and finer-grained sediment (fine-grained sand and silt) on floodplains; coarsens with depth. Locally capped and/or interbedded with organic-rich layers. Areas of low elevation are typically filled with thick silty to clayey sediment. Generally, sediment along smaller streams is finer-grained. Deposited by modern streams in channels and on floodplains. *Floodplain alluvium.*

PLEISTOCENE

Late Wisconsinan

Qco **Loam, locally includes silt to boulders**—Deposits associated with steep slopes. Derived from both bedrock and older Quaternary deposits. The unit is thin upslope and thickens downslope. Upslope, the unit is finer-grained and consists of reworked loess, soil, or diamicton. Downslope, the unit is generally poorly sorted and rocky, containing angular clasts of the local bedrock in a silty to sandy matrix. Unit is commonly found directly on top of bedrock, therefore bedrock exposures within this unit are common. *Colluvium.*

Peoria Formation—Sediment deposited predominantly by northwesterly wind during the late Wisconsinan glaciation (Johnson and others, 2016).

Silt loam—Silt mixed with some clay and fine-grained sand (Table 1). Present as loamy sand in places on the western edge of the county. Generally yellowish-brown (10YR 5/6) to light yellowish-brown (10YR 6/4) where oxidized, rarely unoxidized. The gravel component (Table 1) is due to mixing of this unit during sampling with an erosive gravel lag at its base. Thickness is highly variable. Deposit may have been removed by road building or construction in places where mapped. Shown as a stipple pattern where thicker than 3 feet (1 meter). Pattern is omitted where overlying colluvium. *Loess.*

Qte **Gravelly sand with minor silt and clay beds**—Generally coarsens to cobbly gravel locally and may be capped by loamy, fine-grained sand. Present as terraces above modern rivers, deposited during higher stages of flow. *Terrace alluvium.*

Pre-Wisconsinan (Illinois and Pre-Illinois Episodes, undivided)

Quo **Sand to gravelly sand with minor beds of silt and clay**—Weathered, oxidized, and leached, usually to depths of approximately 15 feet (5 meters). Clasts are typically coated by reddish clay in the upper part of the deposit. This unit is patchy and discontinuous throughout the county. Occupies an upland position above the elevation of modern floodplains. Unit was deposited by meltwater flowing away from a glacier, or deposited in a glaciolacustrine environment in contact with the active ice margin. *Undifferentiated outwash or alluvium.*

Browerville Formation—Sediment deposited by Winnipeg-provenance ice (Johnson and others, 2016).

Qbv ***Loamy diamicton***—Unsorted sediment, contains pebbles and scattered cobbles suspended in a loamy matrix. Generally yellowish-brown (10YR 5/6) where oxidized and dark olive-gray (5Y 3/2) where unoxidized. Sand lenses frequently occur in the upper 6 feet (2 meters) of the unit. Depth of carbonate leaching varies locally but is generally 10 feet (3 meters). Average composition of the very coarse-grained sand fraction is shown in Table 1. Contains Cretaceous limestone clasts and fragments of *Inoceramus* shells. *Glacial till.*

Rose Creek Formation—Sediment deposited by Rainy-provenance ice (Johnson and others, 2016).

Qrc ***Loam diamicton***—Unsorted sediment, contains pebbles and scattered cobbles suspended in a loamy matrix. Generally yellowish-brown (10YR 5/6) where oxidized and gray (5Y 6/1) where unoxidized. Depth of carbonate leaching varies. This unit is typically encountered beneath the Browerville Formation, but is exposed at the surface in areas where the land surface is highly dissected, implying erosion of the overlying Browerville Formation till. This unit contains fewer 1-2 millimeter carbonate grains than does Browerville Formation till, lacks Cretaceous limestone, and contains about 2 percent red volcanics of the Superior provenance. Average composition of the very coarse-grained sand fraction is shown in Table 1. *Glacial till.*

Elmdale Formation—Sediment deposited by Winnipeg-provenance ice (Johnson and others, 2016).

Qel ***Loam diamicton***—Unsorted sediment, contains pebbles and scattered cobbles suspended in a loam matrix. Ranges from brown (10YR 4/4) to yellow-brown (2.5Y 5/6) where oxidized and gray (5Y 4/1) to dark gray (5Y 3/1, 10YR 3/1) where unoxidized. Depth of carbonate leaching varies depending on how much of the deeply leached weathered horizon has been eroded. This unit is typically encountered beneath the Rose Creek Formation, but is exposed where the land surface is highly dissected, implying erosion of the overlying Rose Creek Formation glacial till. Generally has fewer Paleozoic carbonate clasts than the otherwise similar Browerville Formation glacial till.

ORDOVICIAN AND CAMBRIAN

O€u **Bedrock at or near the land surface**—Paleozoic bedrock exposed in outcrop and buried by less than 3 feet (1 meter) of Quaternary sediment. Outcrops occur locally outside of this map unit, primarily along stream valleys, but are typically too small to depict here. For all bedrock outcrop locations, refer to Plate 1, *Database Map*, and for a complete description of the bedrock geology units, see Plate 2, *Bedrock Geology*.

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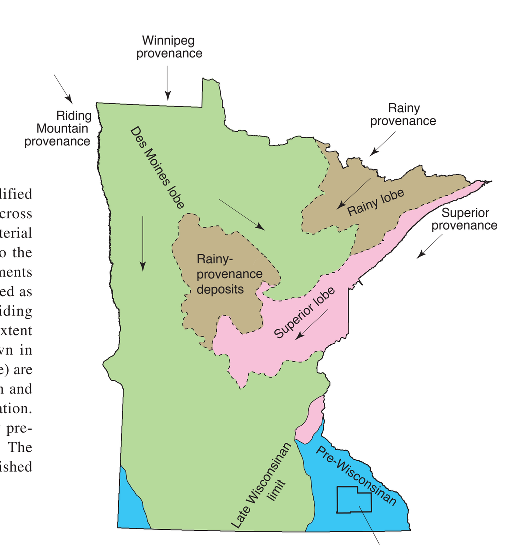


Figure 1. Location of major provenances and a simplified distribution of ice-lobe materials at the land surface across Minnesota. Glacial sediments derive their distinct material content from bedrock and sediment incorporated into the ice in these source areas (provenances). Glacial sediments deposited during the Wisconsinan glaciation are colored as follows: the extent of Des Moines-lobe deposits (Riding Mountain provenance) is shown in green; the surface extent of Rainy-lobe deposits (Rainy provenance) is shown in brown, and Superior-lobe deposits (Superior provenance) are shown in pink. Ice did not advance into southwestern and southeastern Minnesota during the Wisconsinan glaciation. In these regions, glacial sediments were deposited by pre-Wisconsinan glacial advances and are shown in blue. The provenances of these older sediments are not distinguished in this figure.

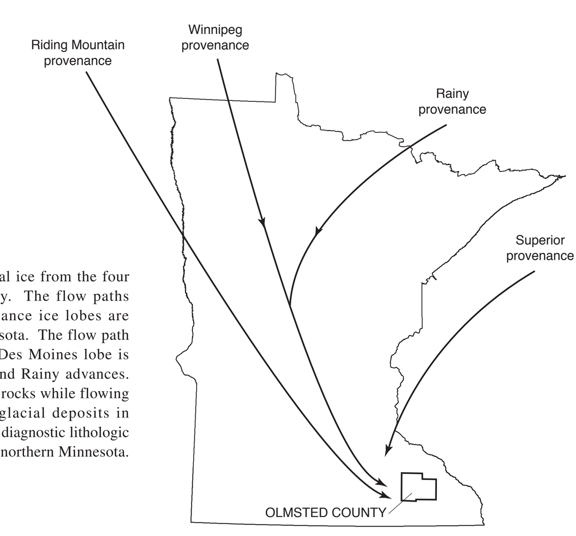


Figure 2. General flow paths of glacial ice from the four provenances towards Olmsted County. The flow paths for the Winnipeg- and Rainy-provenance ice lobes are nearly identical south of central Minnesota. The flow path for the Riding Mountain provenance Des Moines lobe is very similar to that of the Winnipeg and Rainy advances. Because the ice incorporated additional rocks while flowing along these similar flow paths, the glacial deposits in southeastern Minnesota tend to have less diagnostic lithologic compositions than deposits in central or northern Minnesota. Figure modified from Meyer (2000).

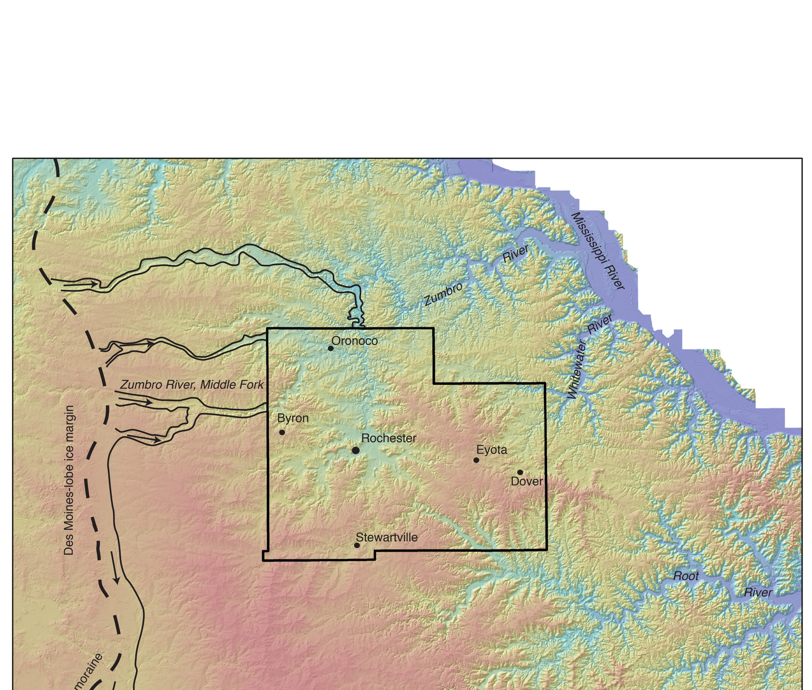


Figure 3. Physical relief of the land surface in southeast Minnesota (vertically exaggerated 2x) showing the extent of the Des Moines-lobe advance during the Moland phase (dashed line) and the eastern edge of the Bemis moraine. Meltwater flow paths are indicated by arrows. Olmsted County is outlined. Elevation is shown by color: red-orange (higher elevation) grading to purple (lower elevation). Elevation within Olmsted County ranges from 993 to 1,380 feet (303 to 421 meters) above sea level. A false sun illumination at an elevation of 30° above the horizon and from the northwest (315°) provides contrast to accent landforms. This map was created using the Minnesota Department of Natural Resources' digital elevation model with a 30-meter grid.

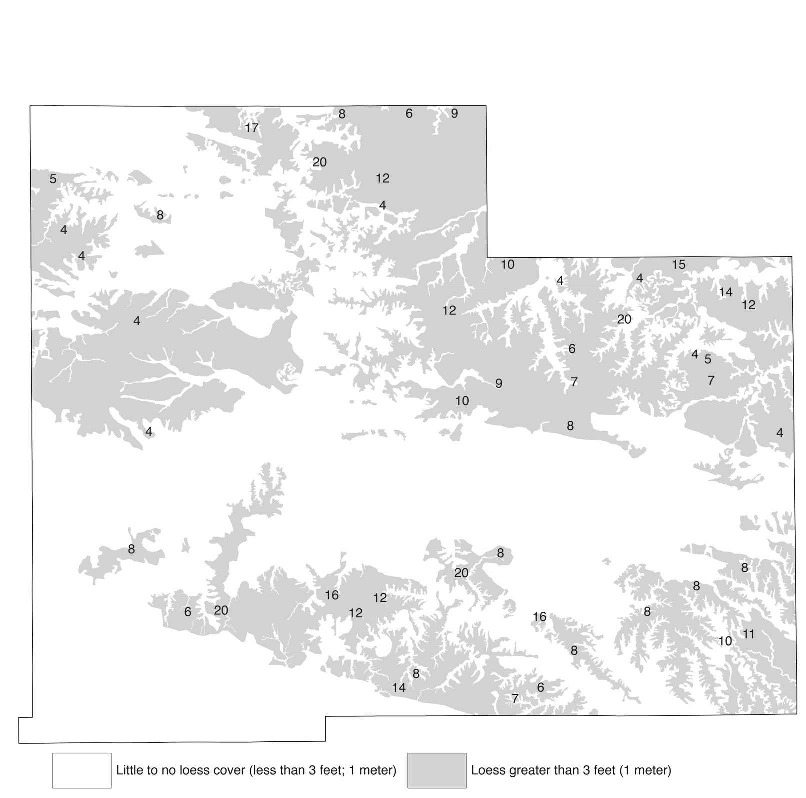
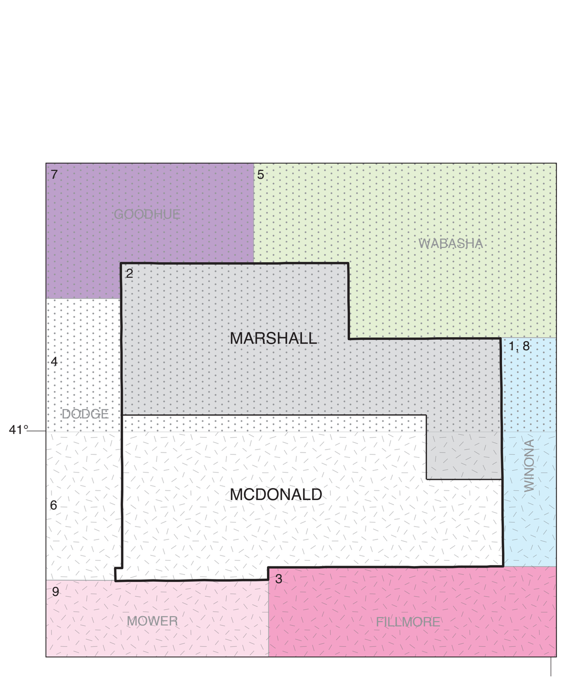


Figure 4. Map of the distribution of loess greater than 3 feet (1 meter) in Olmsted County. Numbers indicate the loess thickness (in feet) as observed in soil auger borings drilled for this atlas.



MAPPING INDEX

Marshall mapped the northern portion of the county (gray); McDonald mapped the southern portion (white). Numbers for previous mapping projects correspond with those listed in the references.

Table 1. Texture and grain-count averages for sediment mapped at the surface in Olmsted County. Averages are for samples collected from depths of 10 feet (3 meters) or less (averages for deeper samples are included on Plate 4, *Quaternary Stratigraphy*). Samples with less than two hundred 1-2 millimeter sand grains were not included in the averages.

Deposit description	MATRIX TEXTURE: Total number of samples	Gravel (percentage of total sample weight)	Percentage of the less than 2 millimeter fraction: Sand	Silt	Clay	CLAST TYPE: Percentage of total grains counted of the 1-2 millimeter fraction: Crystalline	Carbonate	Shale	Percentage of total crystalline grains counted: Light	Dark	Red	Percentage of total grains counted of the 1-2 millimeter fraction: Precambrian	Paleozoic	Cretaceous
Peoria Formation loess unleached, undifferentiated	107	0.2	7.2	75.4	17.4									
Browerville Formation till (unit Qbv),unleached	165	5.1	41.6	34.8	23.6	76.5	23.5	0	86.1	13.0	0.9	77.85	18.05	4.1
Rose Creek Formation till (unit Qrc), unleached	91	8.8	39.2	37.2	23.6	81.9	18	0.1	85.3	13	1.7	60.9	39	0.1
Outwash (unit Quo), unleached, undifferentiated	24	6.1	80.8	12.7	6.5	88.0	12.0	0	84.95	14.05	1.0	87.55	11.75	0.7

Table 2. Radiocarbon ages (^{14}C) from publications cited in the text were recalibrated using the radiocarbon calibration program Calib 7.1 (Stuiver and others, 2018). The recalibrated ages are the median probability age and are reported in calendar years before present (cal YBP). Recalibrated ages are used within the map text.

Sample name	^{14}C	±	cal YBP	Material dated	Unit	Source
AA-17777	12,053	111	13,900	Shell (AMS)	Colluvium	Mason and Knox (1997)
AA-17783	12,735	94	15,200	Shell (AMS)	Colluvium	Mason and Knox (1997)
AA-17780	13,308	98	16,000	Shell (AMS)	Colluvium	Mason and Knox (1997)
Beta-82839	13,580	60	16,400	Wood (AMS)	Colluvium	Mason and Knox (1997)
Beta-82840	14,090	60	17,200	Wood (AMS)	Colluvium	Mason and Knox (1997)
AA-17781	14,388	105	17,500	Shell	Colluvium	Mason and Knox (1997)
Beta-82841	14,650	210	17,800	Wood	Colluvium	Mason and Knox (1997)
AA-17784	15,737	225	19,100	Shell (AMS)	Colluvium	Mason and Knox (1997)
AA-17787	15,983	136	19,300	Shell (AMS)	Colluvium	Mason and Knox (1997)
AA-17779	16,511	125	19,900	Shell (AMS)	Colluvium	Mason and Knox (1997)
Beta-82571	> 45,000		> 48,000	Wood	Browerville Formation till	Meyer and Knaeble (1996)
I-1402	14,200	200	17,300	Spruce wood	Peoria Formation loess, top	Ruhe and others (1968)
W-512	14,470	400	17,600	Fir, hemlock, larch, spruce wood	Peoria Formation loess, top	Ruhe and others (1968)
W-153	14,700	400	17,900	Hemlock wood	Peoria Formation loess, top	Ruhe and others (1968)
W-879	19,050	300	23,000	Spruce wood	Peoria Formation loess, base	Ruhe and others (1968)
I-1022	20,290	1,000	24,400	Organic carbon from a paleosol	Peoria Formation loess, base	Ruhe and others (1968)
I-1403	23,900	1,100	28,100	Peat, conifer zone	Peoria Formation loess, base	Ruhe and others (1968)
I-1406	24,600	1,100	29,000	Organic carbon from a paleosol	Peoria Formation loess, base	Ruhe and others (1968)
I-1267	25,000	2,500	29,100	Organic carbon from a paleosol	Peoria Formation loess, base	Ruhe and others (1968)
I-1269	29,000	3,500	33,200	Organic carbon from a paleosol	Peoria Formation loess, base	Ruhe and others (1968)

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