INVESTIGATION OF PRE-WISCONSINAN GRAY TILL IN THE MANKATO AREA OF THE MINNESOTA RIVER VALLEY

by
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under the supervision of Professor Mark D. Johnson

ABSTRACT

Exposures of pre-Wisconsinan gray till in the Mankato area of the Minnesota River Valley show that this unit is a thick, somewhat continuous layer. The dark gray, dense, blocky, calcareous till correlates well with other pre-Wisconsinan gray tills that have been described in the Midwest, based upon lithological, textural, and other characteristics. The "old gray" till in Mankato may be the result of multiple glaciations, as has been proven for other similar tills in the Midwest, however, further research is necessary to verify this.

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INTRODUCTION

Many tills are present in the Pleistocene stratigraphy of the Midwest as a result of glaciations that occured during this epoch. Some of these till units have been formally named (or correlated to formally named units) and attributed to the advances of particular glaciers. In Mankato the only unit that has been formally named is the New Ulm Till from the Late Wisconsinan advance of the Des Moines Lobe (Wright, 1972). The Des Moines Lobe (Figure 1) was the most recent glacier to cover this area, with ice that reached its greatest volume about 14,000 years ago. As this lobe retreated, the Minnesota River Valley became the outlet for glacial Lake Agassiz and the river downcut to expose units older than the New Ulm Formation. These units include one that was likely deposited by the Early Wisconsinan Wadena Lobe (Figure 2a), one that was likely deposited by the Pre-Wisconsinan Superior Lobe (Figure 2b), and an older gray till which has been informally referred to as "old gray" till (Zumberge and Wright, 1956). This paper presents a description of the physical characteristics of the "old gray" till in the Mankato area, several hypotheses as to how and when it was deposited, and suggestions for further research that may help to more closely correlate it with formal till units in the Midwest, therefore contributing to the overall Pleistocene stratigraphy of this region.

Many exposures of gray till underlie Wisconsinan deposits in the Mankato area. Three main field sites were chosen based upon accessibility and quality of the exposures of gray till present. Two of these are located north of the Minnesota River and one is located south of it (Figure 3). The "old gray" till is most likely the oldest preserved glacial deposit in the study area. No Pleistocene deposits are visible below it at any known exposure, and a contact with bedrock is exposed at one site. County well indexes from the Minnesota Geological Survey support the fact that a gray Pleistocene till lies directly above the Paleozoic bedrock in some of the areas where the contact is not exposed.

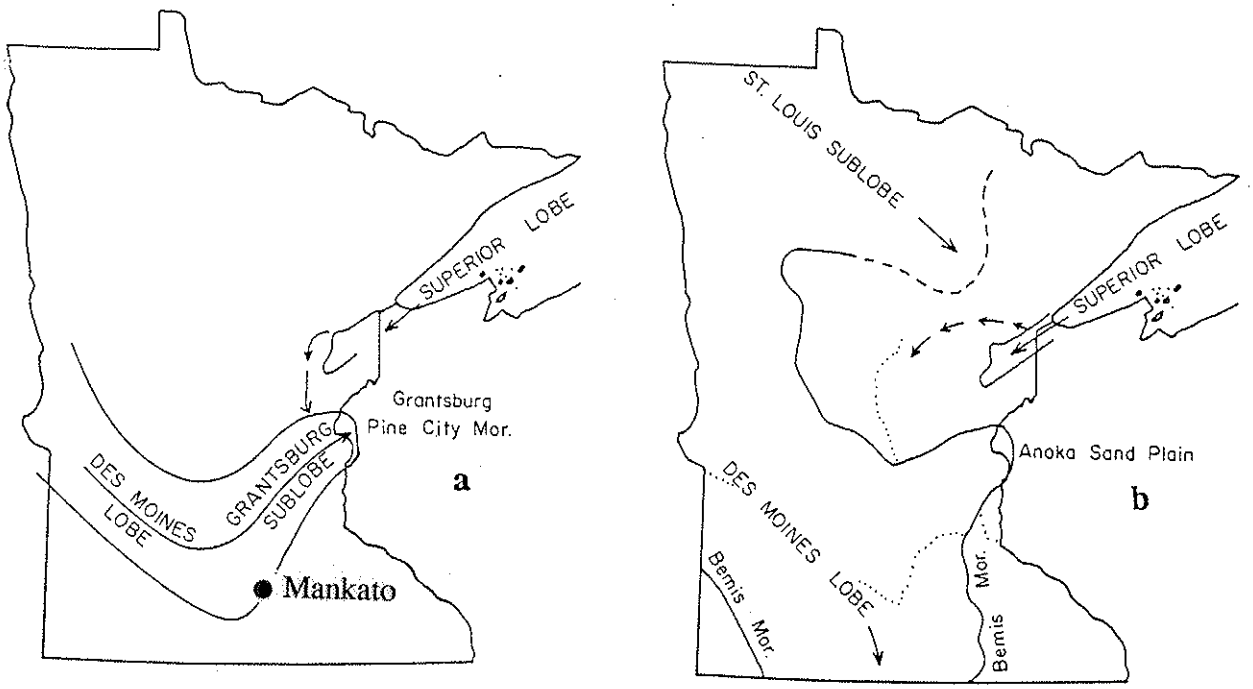


Figure 1. Phases of the Wisconsinan Des Moines Lobe (modified from Wright, 1972):
1a = the advance of the Grantsburg sublobe, approximately 16,000 YBP.
1b = the advance of the Des Moines Lobe that deposited the Bemis Moraine, approximately 12,000 YBP.

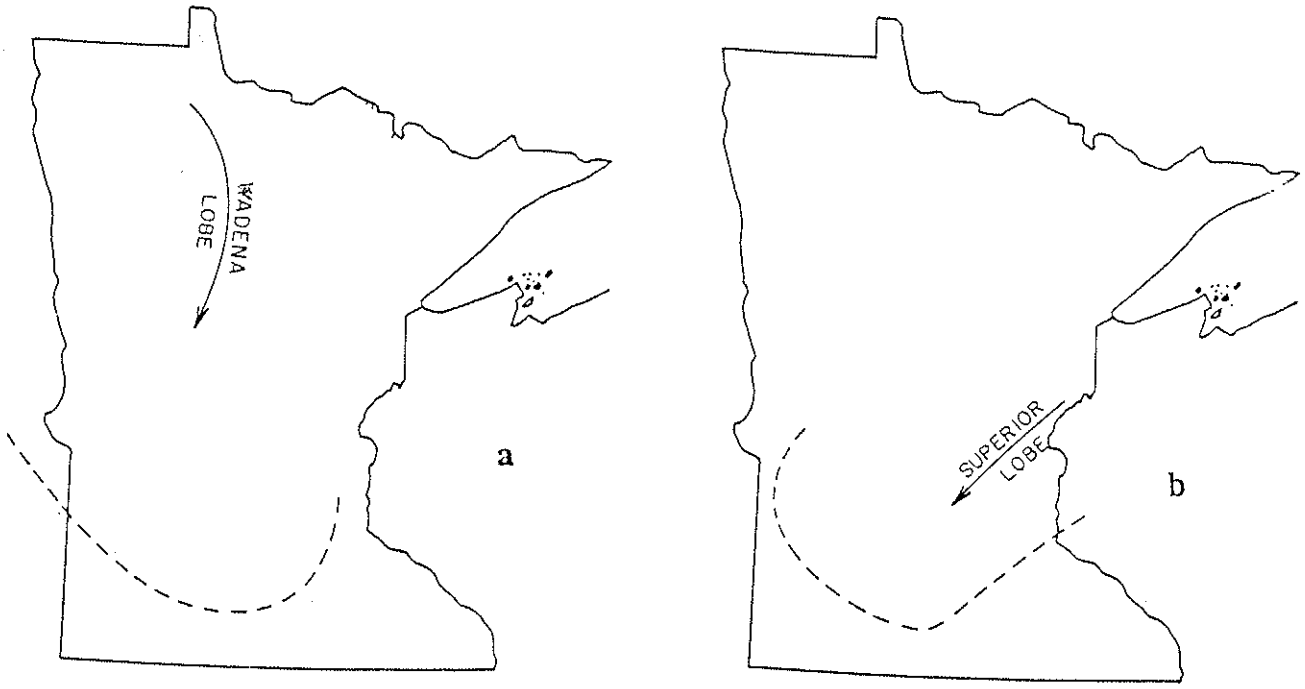


Figure 2. Pre- Des Moines Lobe glacial advances over southern Minnesota (modified from Wright, 1972):
2a = the advance of the Early Wisconsinan Wadena Lobe.
2b = the advance of the pre-Wisconsinan Superior Lobe.

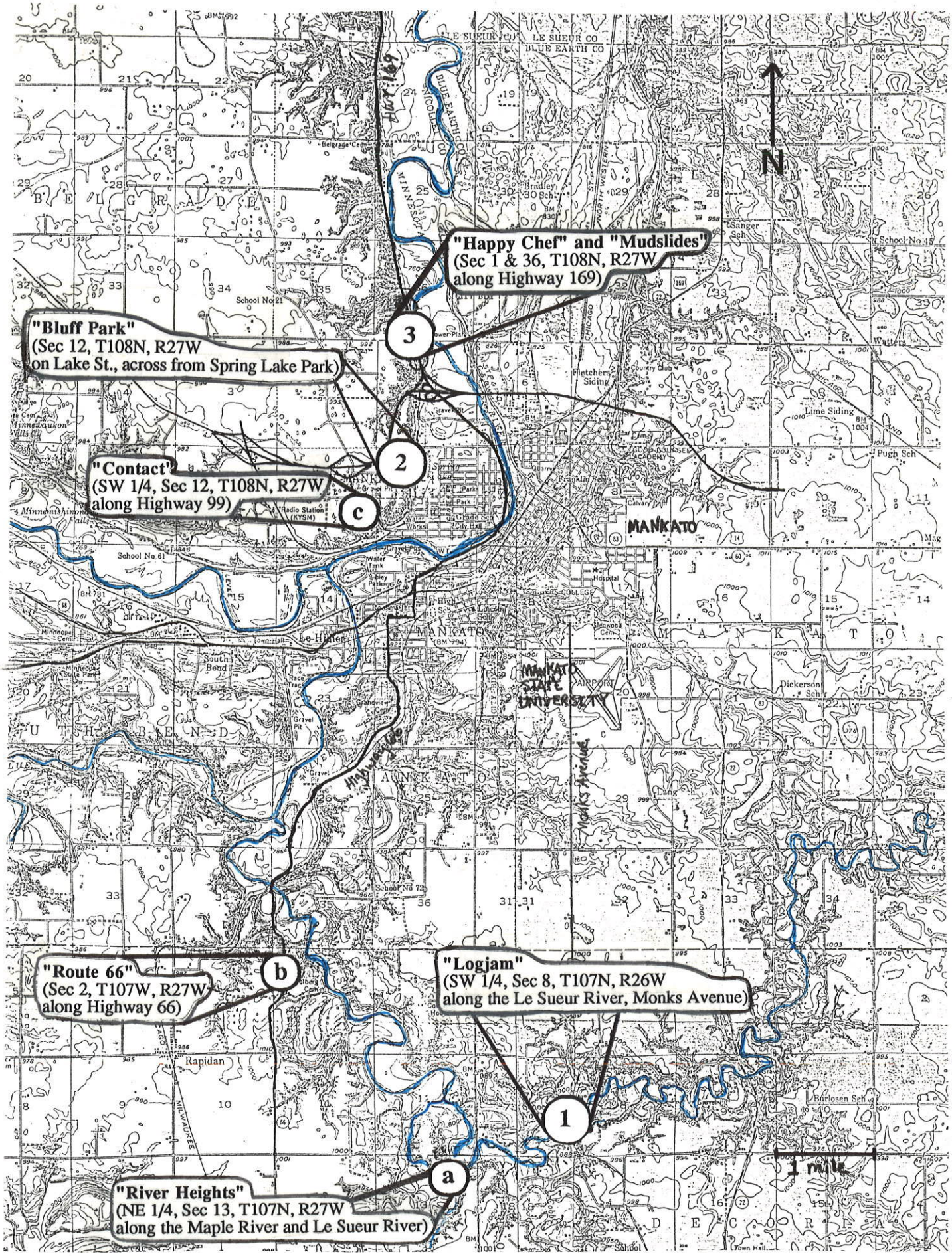


Figure 3. Locations of primary and secondary sites. Primary sites are numbered and secondary sites are designated with letters.

The Minnesota River flows along the path of a bedrock valley which contains some of the lowest bedrock surfaces in Minnesota (Figure 4). Bedrock elevations in this region of Minnesota often reflect the thickness of glacial sediment that has been preserved above them; bedrock surfaces with lower elevations are usually positioned below thicker glacial deposits than bedrock surfaces that are at higher elevations (Figure 5). The Minnesota River Valley is therefore an excellent location to study older glacial deposits that may not have been preserved or exposed as well, due to higher bedrock elevations or lack of significant glaciofluvial or fluvial processes, respectively.

Pre-Wisconsinan gray tills in the Midwest

Pre-Wisconsinan gray tills are generally recognized by their grayish color, calcareous nature, texture, and clay- and sand- fraction mineralogy, which are typical of glacial deposits in Minnesota and Iowa that have northwestern source areas (Ruhe and Gould, 1954; Matsch, 1972; Hallberg, 1980a, 1980b; Kemmis and others, 1981). The glacier or glaciers responsible for depositing the "old gray" till in Mankato may also have covered much of the Midwest during the same glaciation episode. Similar tills are stratigraphically positioned below Wisconsinan deposits in Minnesota (Meyer, 1986; Lusardi, 1996), Iowa (Hallberg, 1980a), Wisconsin (Attig and others, 1988), South Dakota (Gilbertson, 1990; Lineburg, 1993), Missouri (Rovey, 1996) and Nebraska (Boelstorff, 1979) (Figure 6). Following is a brief description of the research that has been done in these places. It is not representative of all of the formal research that has been completed to date, however, which is shown in Figure 6. An attempt to correlate the gray, pre-Wisconsinan till in Mankato to these other gray till localities will be made in later sections of this paper.

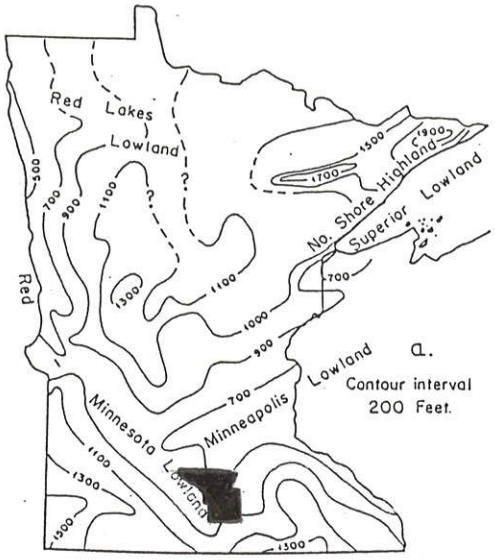


Figure 4. Bedrock topography of Minnesota (from Wright, 1972).

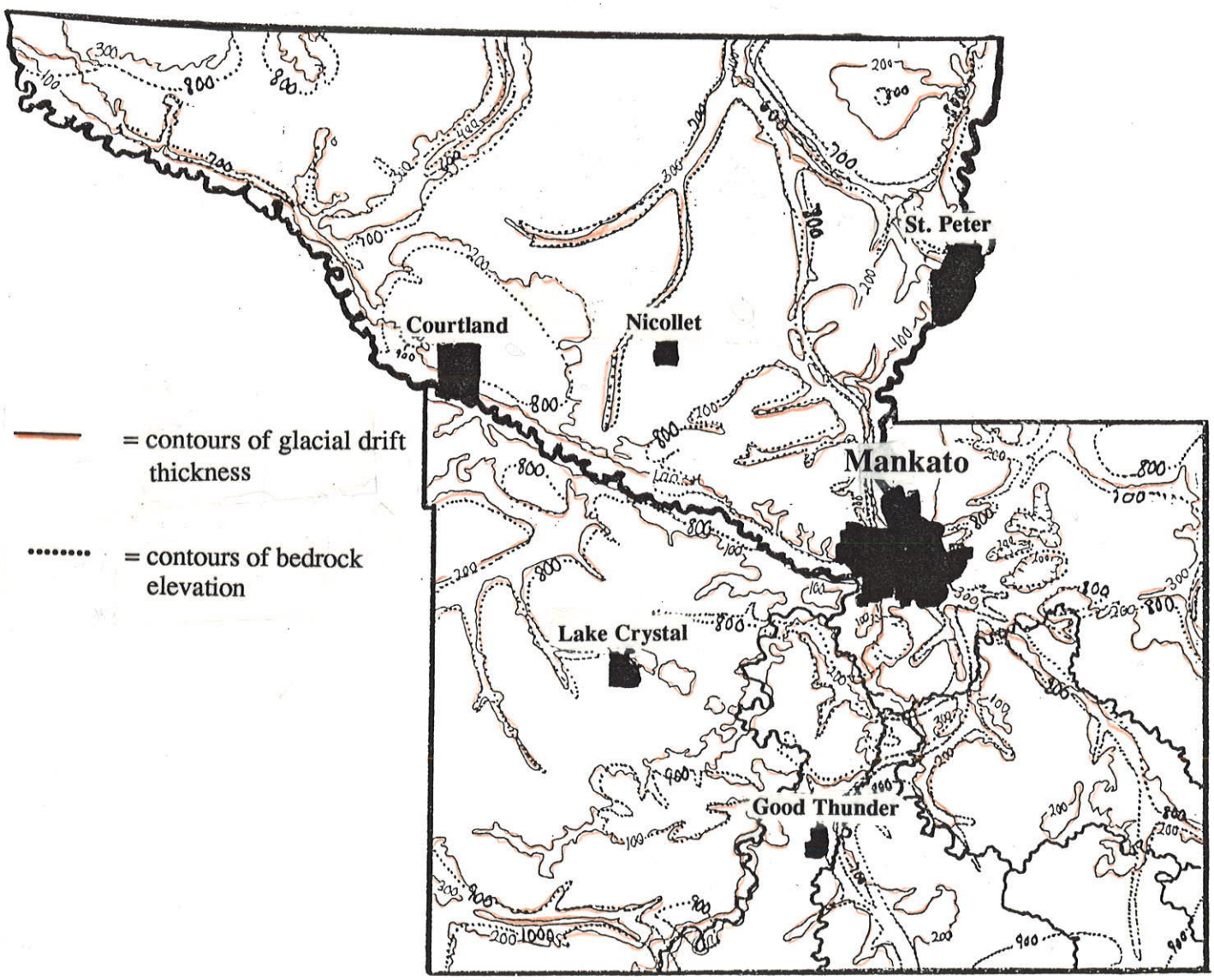
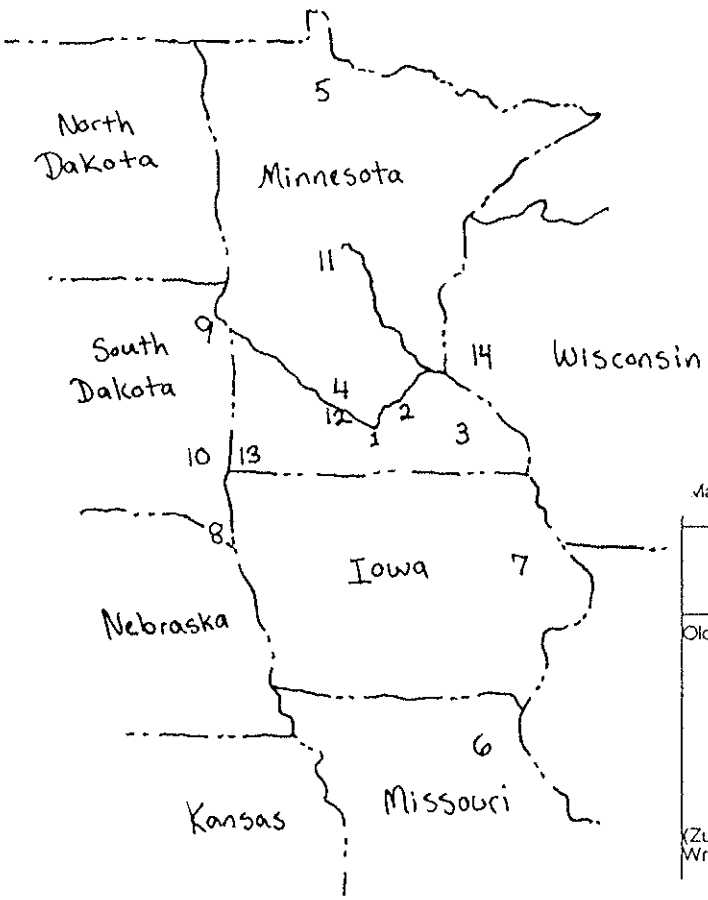


Figure 5. Bedrock topography of Mankato area with glacial drift thicknesses superimposed (modified from Hydrogeologic atlases).

Figure 6. Map of the Midwest and sites where pre-Wisconsinan gray till has been described.



Location	1 Mankato, MN	2 Henderson, MN	3 Rice County, MN	4 Kandiyohi County, MN	5 Grand Forks - Bemidji, MN
pre-Des Moines lobe till that overlies the older gray till		unit 2 55 31 14 83 16 01	red till 61 25 14 76 24 00	Wadena till 54 24 22	Marcoux Formation 47 31 22
Pre-Wisconsinan tills Pre-Wisconsinan tills (correlation possibilities unsure)	Oldest till	unit 1 05 43 22 43 52 05	old gray till 44 35 21 67 30 03	Kandiyohi till 24 39 27	Unit 2 37 32 29 Unit 1 17 46 36
(Following each member: %sand, silt, clay %crystalline, carbonate, shale *%expandables, kaolinite, illite) Source	(Zumberge and Wright, 1956)	(Lusardi, 1996)	(Patterson and Hobbs, 1995)	(Giencke et. al., 1983/1984)	(Sackreiter, 1975)

Location	6 N Missouri	7 East Central IA	8 NE Nebraska	9 Grant Cty, SD	10 Southeast SD	11 Todd Cty, MN	12 New Ulm, MN	13 SW corner, MN	14 Western WIS
pre-Des Moines lobe till that overlies the older gray till				Hawk Creek 55 29 16 84 14 02		Red Sandy/ Sandy/ Wadena 54 44 22 80 20 00	Hawk Creek 55 22 23 12-17% carbonate		River Falls Formation 60 15 25 30-40 20-30 15-20
Pre-Wisconsinan tills Pre-Wisconsinan tills (correlation possibilities unsure)	McCredie Formation: Macon 36 34 30 *49 30 21 Columbia 36 34 32 *53 27 20 Fulton 26 37 37 *58 21 21	Wolf Creek Formation: Hickory Hills 44 34 22 *63 20 17 Aurora 38 40 22 *62 21 18 Winthrop 34 41 25 *60 24 16	Type A Type A Type A	Yellow Bank 30 29 41 39 20 40 Whetstone 39 33 28 60 25 15 (South Fork?) 34 31 35 55 17 27	Crooks (DC 4) 28 30 42 64 21 16 Big Sioux 25 30 45 54 21 25 Brandon (DC 3) 25 39 36 49 27 24	Browerville 36 32 32 63 35 02 Green Meyer Lake Eagle Bend Elmdale	calcareous, gray till 29 27 44 55 30 05	TO 3 25 33 41 61 19 20 TO 4 19 29 51 43 26 31	Pierce Formation: Hersey 42 33 25 75 21 25 Woodville 45 31 24 *64 22 14
Pre-Wisconsinan tills (Following each member: %sand, silt, clay %crystalline, carbonate, shale *%expandables, kaolinite, illite) Source	Moberly Formation: undifferentiated 30 39 31 *39 29 32 Atlanta Formation: undivided 28 40 33 *00 43 57 (Rovey and Kean, 1996)	Alburnett Formation: undifferentiated 44 34 22 *43 32 25 (Hallberg, 1980)	Type A with reversed polarity Type B Type C (older than 2.2e6) (Boelstorff, 1978)	(Gilbertson, 1990)	(Lineburg, 1993)	(Meyer, 1986)	(Matsch, 1971, 1972)	(Patterson, 1995	(Baker et. al., 1983; Attig, Clayton and Mickelson, 1988)

South Dakota

Gilbertson (1990) found evidence for two pre-Wisconsin till units in west-central South Dakota. The Whetstone is the oldest deposit that he found. He characterized it as a massive, calcareous, pebble-poor loam to clay-loam that is typically gray when dry and very dark grayish brown when wet. He observed no oxidized or leached zones within this unit. A sharp, irregular, erosional lower contact separates it from some Gastropod silts, which have been dated to be at least 300,000 years in age. The other pre-Wisconsin gray till that Gilbertson observed is in a similar stratigraphic location with the Whetstone. This South Fork Till has very similar characteristics, but contains a greater percent of pebbles in its matrix, and also has a greater percentage of Pierre Shale, which suggests that it may have come from a slightly different source area. Gilbertson does not correlate these two tills, but suggests that they are both pre-Illinoian in age because of their stratigraphic positions.

Minnesota

Meyer (1986) found evidence for nine pre-Wisconsinan till units in Todd County, Minnesota (Figure 6), and was able to produce a sequence of glacial events based upon their characteristics (Figure 7). The tills (from a northwestern source, in order from oldest to youngest) include the Elmdale till, a very dark gray clay loam that is sandier in some areas and has the highest amount of Cretaceous rock fragments of the tills studied; the Green till, a pale-olive to dark greenish gray till with few Cretaceous fragments; the Eagle Bend till, the most clayey and carbonate-rich till in the area; the Meyer Lake till, a gray to greenish-gray loamy till with dark grayish-brown woody zones, a great amount of Cretaceous fragments, and more dark Precambrian grains than the other tills of a northwestern source area; the Green till, a pale-olive to dark greenish gray till with few Cretaceous fragments; and the Browerville till, a dense, dark-gray clay loam, with the

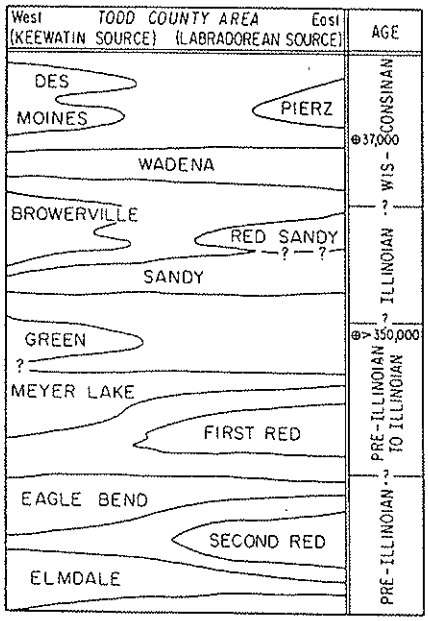


Figure 7. Time-distance diagram showing relative timing and extent of glacial events in the Todd County area. (Meyer 1986)

greatest amount of gray and speckled shale of all nine tills. Meyer noted that limestone makes up the greatest amount of the Cretaceous material that is found in these tills, but that it makes up a small part of the source area. This Cretaceous limestone exists only in the Greenhorn Limestone Formation, which consists of marlstone and calcareous shale in eastern North Dakota, and fossiliferous, calcareous shale in southeastern North Dakota. Some of these fossils include pelecypod fragments and dark brown fishbone fragments.

Iowa

Hallberg (1980a) describes several pre-Wisconsinan glacial deposits in east-central and northeast Iowa (Figure 6). His Wolf Creek and Alburnett Formations, pre-Illinoian in age, contain till that is similar to the "old gray" till. Hallberg subdivided the Wolf Creek formation into three formal till members; the Hickory Hills Till Member; the Aurora Till Member; and the Winthrop Till Memberbased upon clay mineralogy, particle-size distribution, and lithology of the very coarse sand fraction. In the most complete sections, the formation is bounded above by Yarmouth-Sangamon paleosols, and below by the top of the Westburg Paleosol. Paleosols also occur within the formation. The Dysart Paleosol, between the Hickory Hills and Aurora members, is strongly developed. Most of the other paleosols are characterized by a distinct A-horizon. Stratified glaciofluvial sediment is also often present just below the Hickory Hills Member. The Alburnett Formation, just below the Wolf Creek Formation, consists of undifferentiated tills and has reversed polarity.

Wisconsin

The Pierce Formation in west-central Wisconsin (Figure 6), contains two pre-Wisconsinan till units (Attigand others, 1988). These include the the Hersey Member,

which Baker (and others, 1983) described as a "gray, calcareous till and associated sand and gravel of northwestern origin", and the Woodville Member, which is similar to the Hersey Member, but with more sand, montmorillonite and kaolinite The Woodville Member may correlate with the Aurora Member of the Wolf Creek Formation in Iowa (Baker, 1988). The texture is quite consistent throughout the Pierce and St. Croix Counties. Baker (and others, 1983) noted that the Hersey Member lacks Cretaceous shale, which is a feature of pre-Illinoian tills in eastern Iowa (Hallberg, 1980a) and pre-Wisconsinan tills of central Minnesota (Matsch, 1972). Because of this, and because of till-fabric data, Baker concluded that the glacier that deposited the Hersey Member must have taken a more easterly path than the others.

Missouri

Rovey and Kean (1996) found a series of five tills in northern Missouri that may correlate with those of the Wolf Creek Formation and the underlying Albernett Formation in Iowa (Figure 6). The three youngest tills in each sequence have similar lithologic characteristics and normal remanent polarities. The fourth till in each was deposited during a time of reversed polarity. The five tills in the sequence in Missouri consist of the McRedie Formation, containing the Macon member and the Columbia member, which are separated by the underlying Fulton member by a paleosol; the Moberly Formation, an undifferentiated unit underlying the McCredie and seperated from it by a layer of sand and gravel; and the Atlanta formation, also undifferentiated, containing no expandable clay minerals, and with an uncertain remanent polarity.

Western Iowa/ Nebraska

Boelstorff (1978a, 1978b) distinguished six tills in western Iowa and eastern Nebraska which he attributed to pre-Illinoian glaciations. The four youngest tills, which he labeled "A type" tills, may correlate with the Wolf Creek Formation, the McCredie Formation and the Moberly Formation. The underlying "B type" is present at few sites, and contains 60 to 80% sedimentary pebbles. The oldest "C type" till has been attributed to one glaciation (Richmond and Fullerton, 1986), is more common than the "B type" till, and contains 90% sedimentary grains.

METHODS

Prior to field work, a literature search was completed to determine the types of field observations and lab work that have been previously undertaken in the research of pre-Wisconsinan gray tills in the Midwest. The literature search provided valuable information about possible correlations that could be made when this project was completed, and about methods that would be most beneficial to this research project.

Field Methods

All field sites for this project include exposures of the "old gray" till that were found by driving, canoeing and walking to areas that contained steep relief (and therefore a higher chance of exposed sediments) in the Mankato area. County well indexes from the Minnesota Geological Survey were the only type of subsurface data used, and were used only to confirm that a "gray Pleistocene till" lies directly above Paleozoic bedrock.

Detailed descriptions of the exposed stratigraphy were made at three main sites (Figure 3). Topographic maps were used to determine approximate surface elevations. All exposed sediments were described because a pre-Wisconsinan Pleistocene sequence of this area has yet to be constructed, and any information about the sediments surrounding the

"old gray" till prove beneficial to comprehending the environment in which it was deposited. Hand samples (used for lab analyses) were taken at intervals of aproximately two meters, and more frequently when abrupt lithological differences were encountered. Several large, gallon-sized samples were taken at each of these three main sites as well, for pebble lithology analyses. Four secondary sites were described in less detail, and only a few hand samples were taken from these.

Descriptions of the stratigraphy at the three main sites included an estimation of the thickness of units by taking Brunton measurements at eye-level increments, and observations of Munsell color, texture, and sedimentary structures. Descriptions of till/ diamictons included the aforementioned, as well as an estimation of the percent and type of lithologic fragments, measurements of clast orientations to be used in till-fabric analyses, and extraction of oriented samples for paleomagnetic studies.

Lab Methods

Methods used in the lab include textural analyses, sand-fraction analyses, plotting of till-fabrics, pebble counts, isothermal remanent magnetization measurements and x-ray diffractometer measurements of clay fractions. Some of these analyses were successful and very useful to this study. Others were not successful because of the researcher's lack of experience with them, particular characteristics of the analyzed sediments, and various other reasons. Both the successful and unsuccessful methods are described below, as those who wish to continue this research would benefit by understanding the best way to approach lab analyses of this till.

Successful Lab Methods

The method of textural analysis used in this project proved to be a very succesful procedure. Instructions in Folk's (1974) chapter, "Techniques of Grain Size Analysis",

were followed to seperate the less than 2 mm. fractions of the hand samples and to analyze them using sieving and pipetting techniques. As most studies on pre-Wisconsinan tills are concerned with only the sand, silt and clay fraction in the till, Folk's method of pipet analysis was abbreviated in this project to include measurements of only 4 phi (which accounts for the 4-7 phi silt fraction) and the 8 phi (which accounts for the 8-infinity phi clay fraction) fractions.

Sand-fraction analysis was also very successful in this project. The 1.0-2.0 mm. sand fraction (obtained during grain size analyses) were examined under a microscope. The sand was separated into approximately 50-grain fractions and exposed to 1M HCl, one fraction at a time. The grains in each fraction that reacted were separated into a "carbonate" pile: those that did not were separated into a "crystalline" pile, and shale grains were separated into a third pile. All of the grains were then counted and a percentage was obtained. Most samples contained from 100 to 300 grains.

Till fabric analyses were also very successful. Approximately twenty five clast orientations were taken for each till-fabric analysis. The results were plotted on a stereonet program, which produced a diagram that showed the strengths and orientations of the fabrics.

Pebble counts were another successful procedure. The gallon-sized till samples were placed in buckets of water with dispersant and allowed to disaggregate for approximately five days. The samples were then worked manually until they reached a near-complete disaggregated consistency and pebbles could easily be obtained. Pebbles were divided into groups of carbonate, shale, granite, quartz and fine-grained mafics.

Unsuccessful Lab Methods

Magnetostratigraphy is a characteristic that has been used to aid in correlation of pre-Wisconsinan gray tills with similar textures and lithologies as the "old gray" in

Mankato (Rovey and Kean, 1997). Isothermal remanent magnetization determination (to be used for magnetostratigraphic correlative techniques) was carried out at the IRM lab at the University of Minnesota. Before the original polarity of the samples (the polarity that they had when deposited) could be determined, effects of later magnetic signals had to be removed. Unfortunately, even after removal of these signals most of the samples still showed scattered polarities. This was most likely due to the fact that the samples had not been preserved very well after extraction (they had dried out), and some of them did not fill the collection containers (causing them to break, scatter and lose their orientations). However, because the scattered polarities may have been due to the fact that the grains were the wrong size (too large or small to preserve the magnetic signal during deposition) or the wrong lithologic composition (not enough of the right type of magnetic grains), the IRM lab tested one sample for these properties. The tests showed that the sample contained the right composition but that the grains were too large to preserve polarity. Unfortunately this sample happened to be a sample that was likely supraglacial flow till, with a coarser texture than the other samples. Therefore, it is unknown whether or not all of the other samples (all meltout till with finer textures) contained favorable textures. When future samples are taken for IRM analyses, it is important to remember to fill the sample containers during extraction, and to keep them moist before running them.

The clay mineralogy of tills can be used to aid in correlation over large distances (Baker and others, 1983), and does not vary as much as texture, so it is a valuable characteristic that can be used to describe tills. The clay mineral analysis in this project was another unsuccessful procedure. The main reason for this was inexperience and unfamiliarity with the equipment used. Carleton College's x-ray diffractometer was used for this analysis. This was the first time that this diffractometer had ever been used on a sample of till, which probably accounts for the lack of success. The computer program that was used to analyze the data obtained was set up for soil analysis, and no comparable

program for till was available. Because of unfamialiarity with the equipment, an appropriate program was not able to be set up. In future analyses of clay mineralogy, it is suggested that samples of the clay-fraction be sent to a lab, or be brought to the lab at a University that has much experience with this procedure.

PRIMARY SITE DESCRIPTIONS

Three main sites were chosen based upon quality and extent of exposed "old gray" till. "Old gray" till was located based upon the fact that it is gray in color, its lithology has a high percent of carbonate material and a low percent of shale, it is older than (and therefore positioned below) the shale-rich till of the New Ulm Formation that is relatively extensive and continuous in this part of southern Minnesota, and it is positioned above Paleozoic bedrock.

Logjam Site

Site 1 (T107N, R26W), the Logjam site (Figure 3), was discovered on a canoe trip down the Le Sueur River during the summer of 1996 as part of the REU program at Gustavus. Most research at this site was carried out as part of the REU program. The exposure is approximately 160 feet thick, of which 50 feet is pre-Wisconsinan gray till (Figure 8). The sequence of sediments here represents the advance of the glacier or glaciers that deposited the pre-Wisconsinan gray till, the successive development and filling of a lake, later fluvial action, and the advances of later, Wisconsinan glaciers.

Figure 9 shows all of the different sediments present at Logjam, along with brief descriptions of their compositions and textures. The "old gray" till is the loamy, massive unit present at the bottom of the sequence. It is a dark gray unit (2.5 Y 4/1), is very dense and blocky, and contains less than 5% lithic fragments in its matrix. Most of these fragments are small gravel-sized, and are sub-rounded to rounded. The majority of them

Figure 8. The Logjam site. The part of the exposure that contains the Wisconsinan New Ulm Till is just above the range of the photograph.

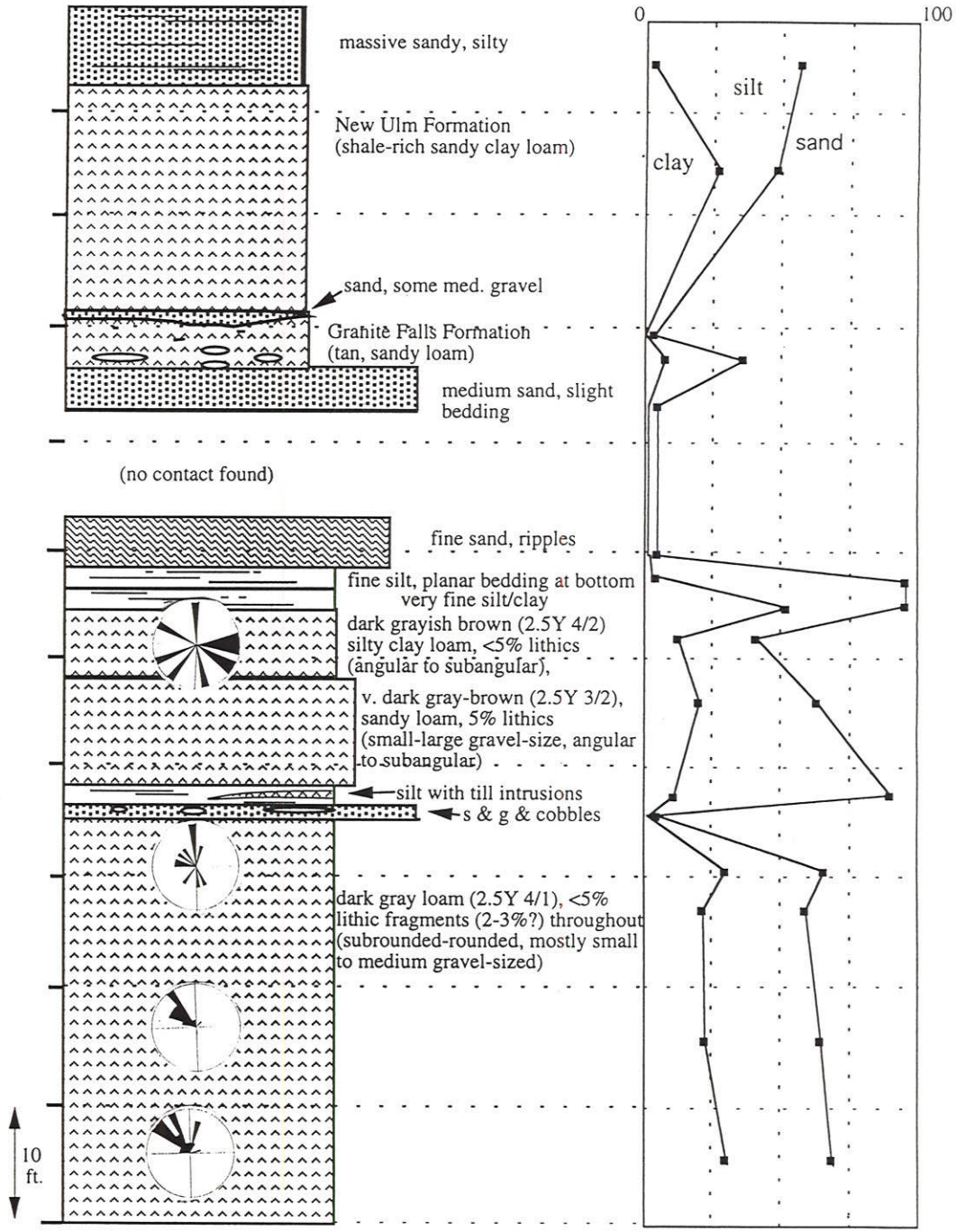


Figure 9. Stratigraphic section of Logjam, with till fabrics at four locations.

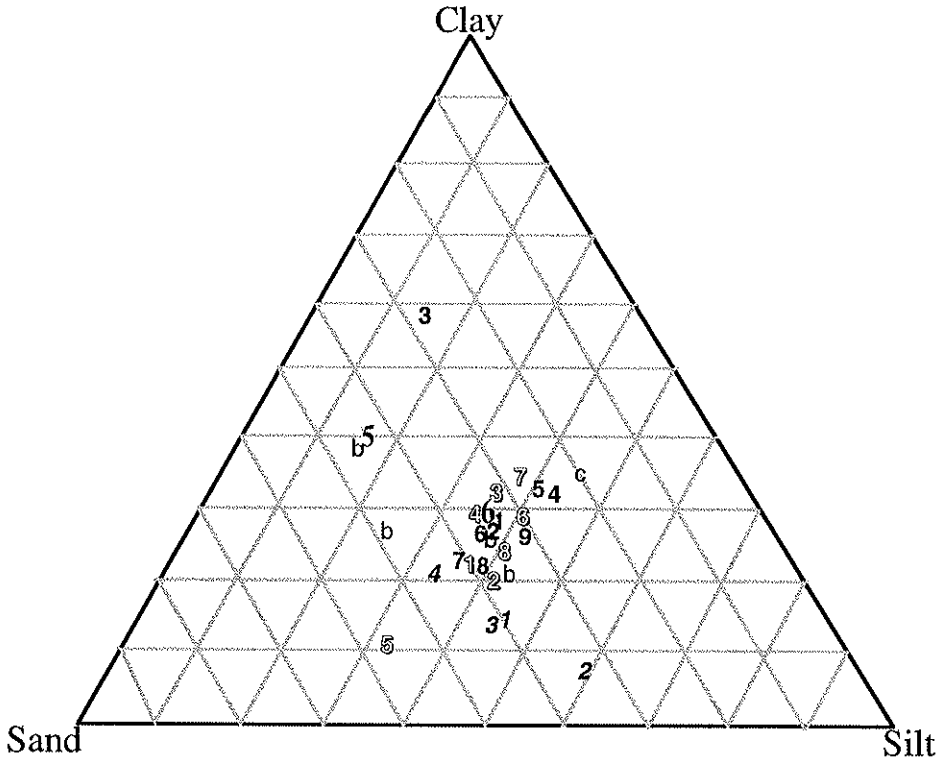


Figure 10. Textures of tills in this study.

primary sites	secondary sites
bold numbers = site 1, "Logjam"	b = site b, "Route 66"
shaded numbers = site 2, Bluff Park	c = site c, "Contact"
italicized numbers = site 3, from "Mudslides"	

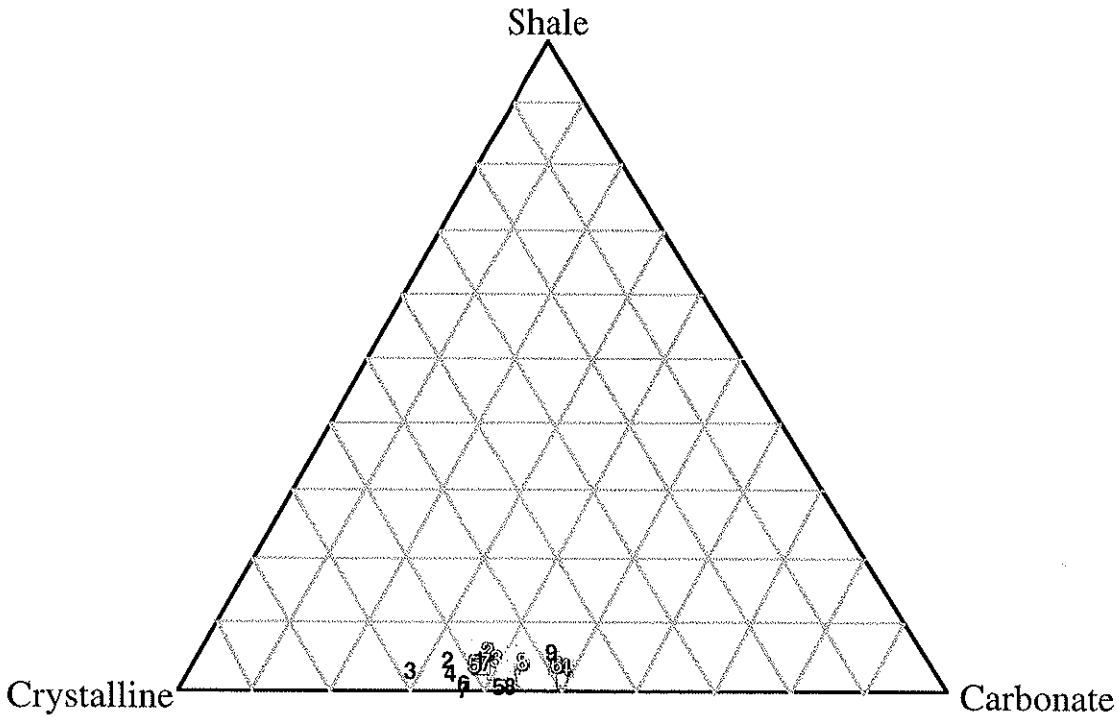


Figure 11. Sand-fraction lithologies at sites 1 and 2.

are carbonates, but small amounts (10-15%) include granite, fine-grained black rocks and quartz. This till has a loamy texture, as shown in Figure 10, and contains less than 10% shale throughout, as shown on figure 11. One strong till fabric (Figure 9) indicates flow from the northwest. A layer of sand, gravel and cobbles, and a layer of silt with till intrusions interrupts this "old gray" unit near the top, but till with similar characteristics (though darker in color/ 2.5Y 3/2, with a slightly larger percent of lithic fragments/ ~5%, which are also more angular) continues for approximately ten feet above this interruption until a sharp contact with a sandier loam till unit is reached. The sandier loam is similar to the lower unit in every way, except that it is sandier. This sandy loam is about five feet thick and grades into fine lake sediments, which continue for approximately ten feet before encountering coarser sand. Two units of till overlie this sand. The younger (upper) till is part of the New Ulm Formation, and the lower, sandy till likely correlates with the Granite Falls Till of the Wadena Lobe (Figure 2a).

The lithology of the pre-Wisconsinan gray till at Logjam suggests that it came from a northwestern source area. This is also supported by the one strong fabric. Other characteristics, including texture, color, and the blocky and dense consistency are similar to those of other pre-Wisconsinan gray tills described previously in this paper. There are no significant variations (paleosols, loess, sharp contacts, etc.) in the lowest part of the unit at Logjam, however, as there are in some other places. Therefore, the unit here may represent the advance of just one glacier. However, it is not possible to conclude this until further research has been done, including paleomagnetic studies and clay mineralogy. Paleomagnetic research on the overlying lake sediment would likely be very beneficial in determining the age of the underlying till.

Bluff Park Site

Site 2 (T108N, R27W), the Bluff Park site, is located along Lake Street in North Mankato, across from Spring Lake Park (Figure 3). This site was discovered in the fall of 1996. The exposure is approximately 115 feet thick, of which up to 60 feet may be pre-Wisconsinan gray till. Unfortunately, as suggested by the bedding, which is slightly angled in the middle and lower exposures (Figure 12), the lower part of this site may not be in place. However, layers of crossbedded sand are preserved within this lower exposure, suggesting that it underwent little deformation if displaced. Though some of the sediments at Bluff Park may have shifted since their original deposition, their sequence and characteristics can still reveal useful information about pre-Wisconsinan till.

Figure 13 is a stratigraphic section of all of the sediments exposed at Bluff Park, along with brief lithologic descriptions. "Old gray" till in this section is designated by the words "dark grayish-brown loam". At the bottom of the lowest exposure, the "old gray" is very dark grayish-brown in color (2.5Y 3/1). It is massive and dense, with less than 5% lithic fragments, which are mostly small gravel-sized and sub-angular to subrounded, and quite spherical. The majority of these lithic fragments are calcareous. This till has a loamy texture and contains a very small amount of shale, as shown in Figures 10 and 11. One sample of till that was taken just above the layer of crossbedded sand and till contained a small amount of coarse-sand sized gypsum, several of which were whole, twinned crystals.

The middle part of the exposure at Bluff Park is separated from the lower part by approximately 35 feet. Nine feet of "old gray" till is present a the base of this middle exposure. All characteristics of this unit are similar to those of the "old gray" at the lower exposure, except for color, which is a bit lighter (2.5Y 4/2). After the interruption of an ~8 inch layer of loose sand and gravel, this till continues for approximately 30 feet (through the upper exposure, assuming that the middle exposure is not out of place), until it reaches

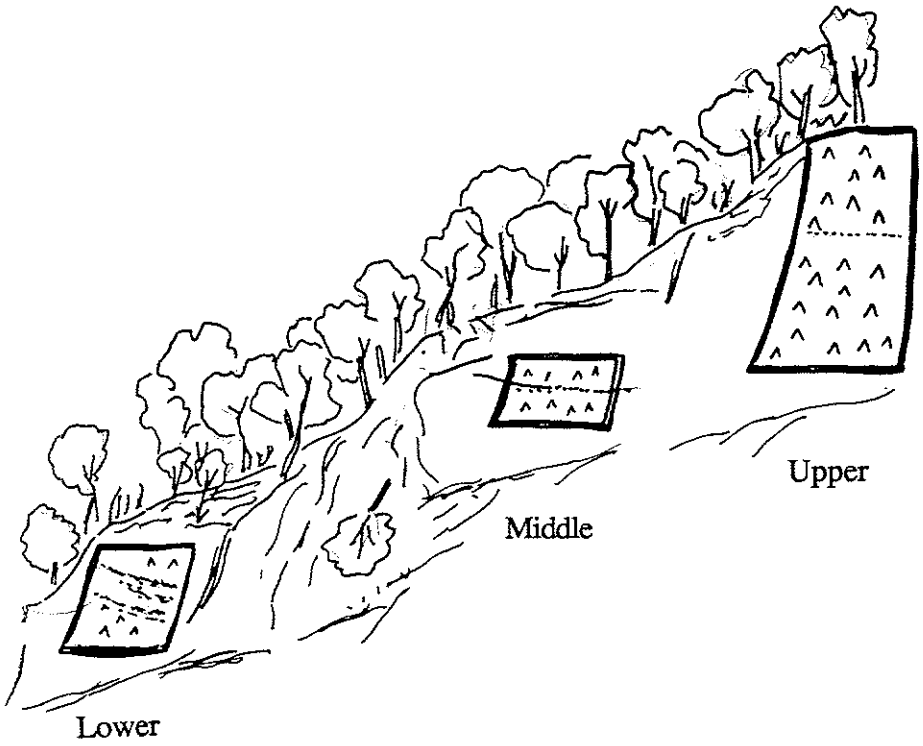


Figure 12. Relationship of the exposures at the Bluff Park site.

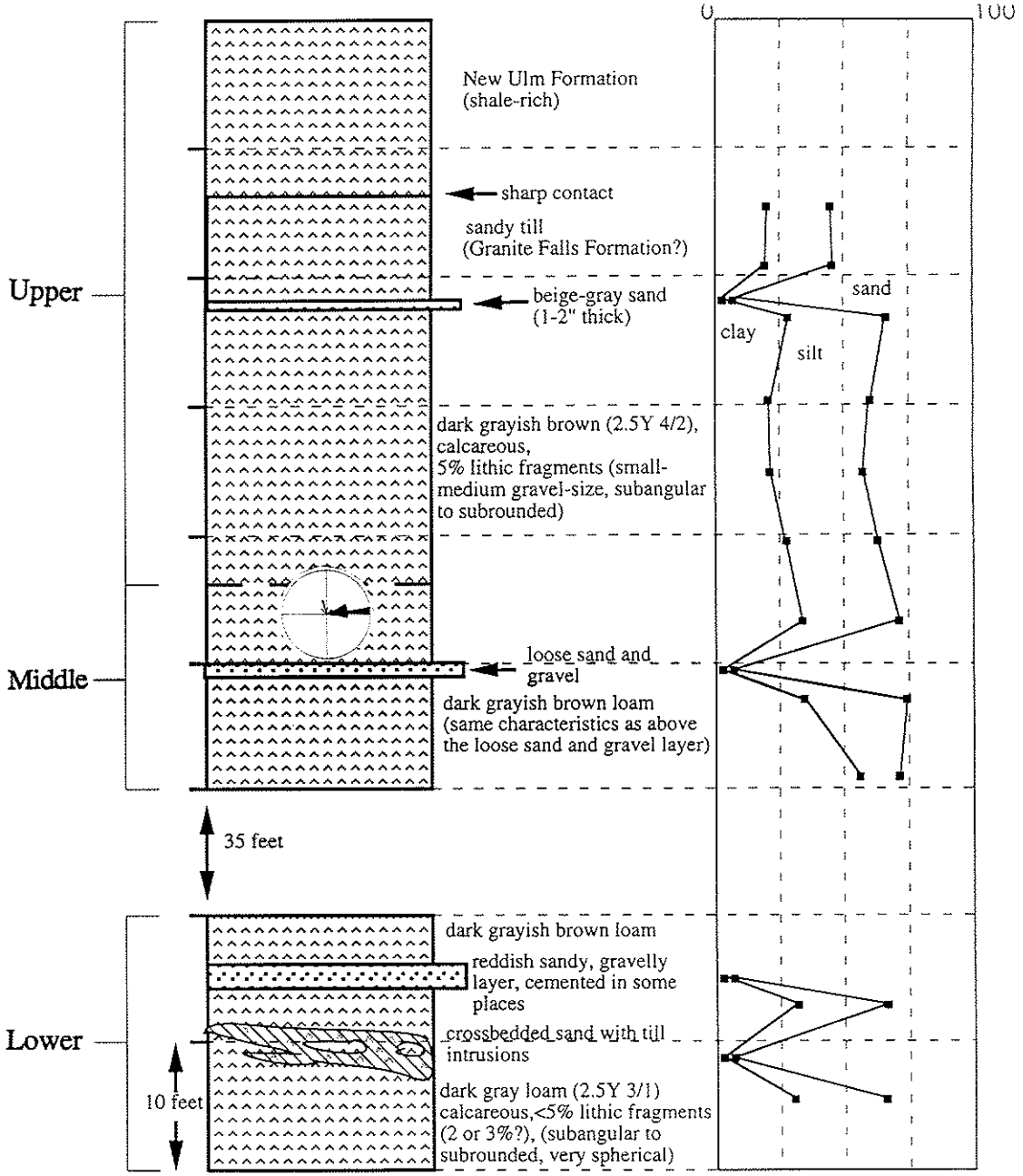


Figure 13. Stratigraphic section of Bluff Park site, with a till fabric at one location.

a sharp contact with a thin, interrupted layer of beige-gray sand. A sandy till is present above this layer of sand, and the New Ulm Formation is present above the sandy till.

The lithology of the "old gray" till suggests that it came from the northwest, and other characteristics such as texture, color and consistency are similar to other pre-Wisconsinan tills of northwest origin that have been described earlier in this paper. A fabric taken in the middle part of the exposure shows an eastward flow direction, however. This eastward flow is likely due to the fact that this site is located on the west side of a bedrock valley, so the till was deposited on an eastward-dipping slope. Although characteristics of the "old gray" at Bluff Park are quite consistent throughout the three exposures, interruptions of sand and gravel layers, the presence of gypsum at the lower exposure, and slight differences between the gray till below the thick sand layer in the lower part of the exposure with the till above this sand layer (higher percent of lithic fragments, coarser pebble size, and higher sphericity of pebbles in the till above the sand) suggest that the gray till at this site may be the result of more than one glaciation. This evidence could also mean that the till is the result of one very large glacier and a more complex depositional environment.

Happy Chef and Mudslides Sites

Site 3 consists of two exposures, Happy Chef and Mudslides (T108N, R27W), which are located close to each other along Highway 169 (Figure 3). Geoff Goodwin (1996) described the stratigraphy of the Happy Chef site, and Meg Palmsten and myself (Gramstad and others, 1997) researched these two exposures as part of the REU program during the summer of 1996. Following is a summary of this work.

Most of the stratigraphy at the Happy Chef site has been covered due to mass wasting, especially the lower part (which contains the "old gray" till). However, there is approximately ten feet of "old gray" till present near the top of this site. Goodwin (1996)

Figure 14. Lower increment of the Mudslides site (may be similar to the unexposed lower part of the Happy Chef site).

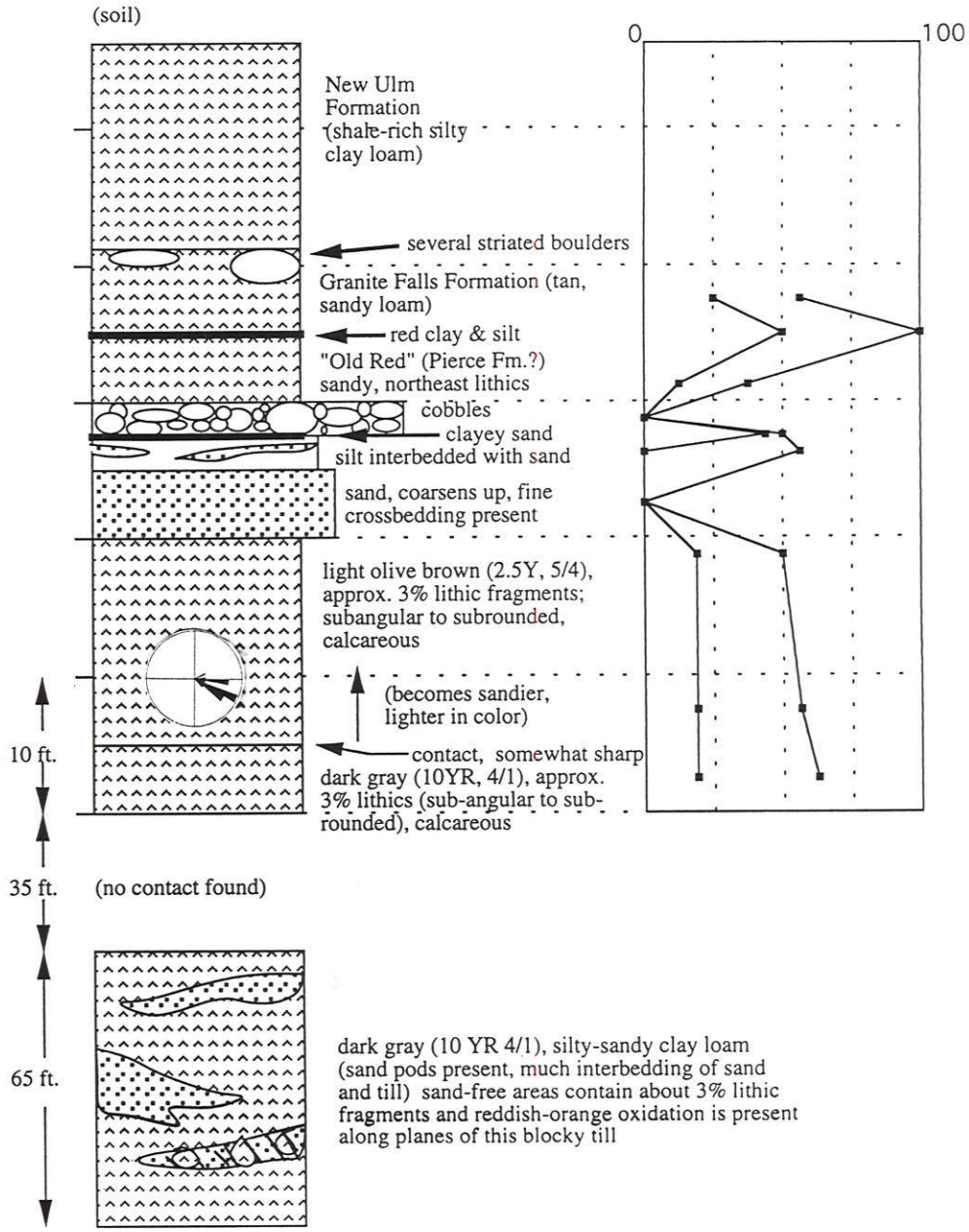


Figure 15. Stratigraphic section of the Mudslides site.

described this till as having a grayish color, with coarse sand to pebble-sized clasts that have a low sphericity and are poorly sorted. Palmsten (Gramstad and others, 1997) found that the texture of the till (plotted as *5* and*6* on Figure 10) was similar to those of other pre-Wisconsinan gray tills in the Mankato area. Goodwin (1996) interpreted the till to be supraglacial, and interpreted layers of sand and gravel positioned directly above it to be outwash deposits. Till of the New Ulm Formation is present directly above these deposits.

Figure 15 shows all of the different sediments present at the Mudslides site, along with brief descriptions of their compositions and textures. Approximately 85 feet of "old gray" till is exposed here. The lower part of the exposure is 65 feet thick, and consists of "old gray" till with layers of sand, sand pods, layers of till interbedded with sand, and layers of crossbedded sand and tilll. Several very thin, 1-2 inch layers of silt are also present. In many places, the mixing with sand has caused the till to develop a sandy texture. In the places where it is not mixed with sand, the till is a dark gray (10YR 4/1), blocky, silty clay loam with about 3% lithic fragments. Most of the lithic fragments are calcareous and rounded to subrounded. No cantact was found between this thick layer of sand and till and the sequence above. The lower part of the upper exposure contains a 5 foot thick layer of dark gray (10YR, 4/1) till. This layer may be thicker, but has been covered at the bottom. The till has a loamy texture, as shown on Figure 10, and contains about 3% lithic fragments, most of which are small-gravel sized, sub-angular to sub-rounded, and calcareous. Quartz, granite and fine-grained black rocks make up a smaller percent of the fragments. A sharp contact with a slightly lighter-colored till (dark gray near the contact, but lightening upward to a light olive brown) is present at the top of this layer. All characteristics of this lighter colored till are the same as those of the till below, except for the lighter color, and a sandier texture, which becomes increasingly so toward the top of the 15 foot thick unit. A fabric taken in this unit shows strong flow to the southeast. This could suggest flow from the northwest, but it could also be a result of the bedrock

topography here, which dips eastward. A layer of fine-medium grained, finely crossbedded sand is present above the light olive brown till, followed by a layer of silt with interbedded sand, a clayey sand layer, and a layer of cobbles. Three units of till overlie this cobble layer: The younger (upper) till is part of the New Ulm Formation; the middle, reddish till may correlate with the pre-Wisconsinan Hawk Creek Till of Matsch (Figure 6); and the lower, sandy till likely correlates with the Granite Falls Till of the Wadena Lobe (Figure 2a).

The lithology of the pre-Wisconsinan gray till at the Happy Chef and Mudslides sites suggests a complex sequence of depositional events. The Mudslides exposure contains a very thick unit of till and intermixed sand, which is overlain by a relatively undisturbed, thinner layer of gray till. Both the Happy Chef and Mudslides exposures show possible outwash deposits positioned directly above the pre-Wisconsinan gray till, (the sand and gravel at Happy Chef, and the crossbedded sand at Mudslides) but these deposits are thicker at the Happy Chef site. The Happy Chef site also lacks the presence of the reddish till and the sandy till that are present at Mudslides.

SECONDARY SITES

Three secondary sites were chosen to compare with the three primary sites. Less research was performed at these sites for various reasons, including lack of significantly exposed "old gray" till, dangerous terrain, and complex stratigraphy. The brief descriptions of these sites are intended to reinforce that fact that the "old gray" in the Mankato area is a consistent, continuous unit; to provide supplementary information about the "old gray" till that is not present at the primary sites; and to provide locations where further research may be conducted.

River Heights

Site a, River Heights, is located south of Mankato near the intersection of the Maple and Le Sueur Rivers (Figure 3). The exposure along the Maple River is at least 120 feet thick, and the lower part consists of at least 80 feet of pre-Wisconsinan gray till. Due to treacherous terrain, only brief investigations of the till were undertaken. The thick unit of till seems to be uninterrupted until its conclusion at a sharp contact with sand and gravel at the top. The till is a very well-cemented silty clay loam with subangular to subrounded lithic fragments. This site supports the fact that the "old gray" till is a thick, continuous layer, and further research here could be compared to results at nearby site 1, such as if the lake sediment is present in both places, etc.

Route 66

Site b, Route 66, is located along Highway 66 south of Mankato (Figure 3). Janet Mann (Gramstad *et al.*, 1997) researched this site as part of the REU program during the summer of 1996. She found a complex sequence of pre-Wisconsinan stratigraphy, including the possibility of up to three different "old gray" units, based upon texture, color, and contact relationships (Figure 16). Further research may provide more insight at this site. Matrix textures of the "old gray" at Route 66 is shown on Figure 10.

Contact

Site c, the Contact site, is located along Highway 99 in North Mankato (Figure 3). This site contains a small exposure of "old gray" till that is approximately ten feet thick. The lowest part of the exposure is located within six feet of the bedrock surface, and would be a nice place to explore the relationship between the till and the bedrock. Texture of this till is shown on Figure 10.

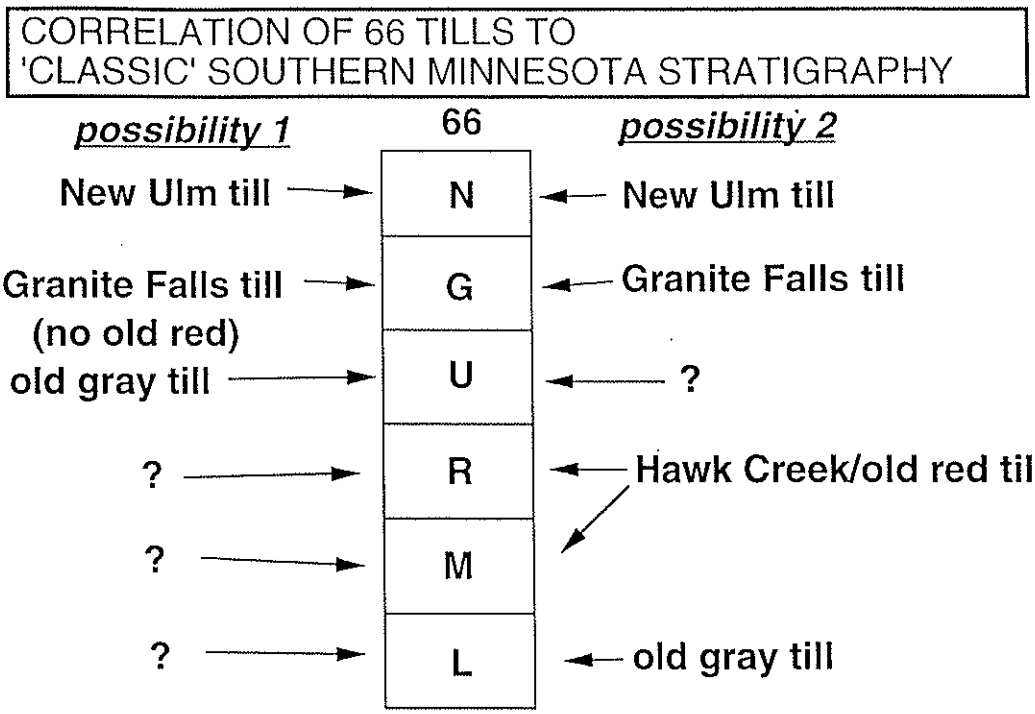


Figure 16. Two interpretations of the complex stratigraphy that is present at the "Route 66" site (Gramstad and others, 1997).

SUMMARY

Pre-Wisconsinan till is present in many places in the Mankato area. In places where the bedrock topography is relatively low, the till forms a thick, quite uninterrupted layer. It is a dark gray to dark grayish-brown loam that contains a small amount of lithic fragments. Most lithic fragments are the size of small gravel, are sub-angular to sub-rounded, and consist of carbonate, although quartz, granite, and dark mafic lithics are also present. Shale never comprises more than about six percent of the lithic fragments, and usually comprises less than five percent. The till may have been deposited from one or more glaciers, because of its interruption by layers of sand and gravel in some places.

The lithology and fabric suggest that the glacier or glaciers that deposited the "old gray" in Mankato came from a northwest direction. Lithology, texture, and other characteristics of this till are similar to those of other pre-Wisconsinan gray tills in the Midwest.

The bedrock valley that is present in the Mankato area was an important factor in the deposition of the pre-Wisconsinan gray till and surrounding sediments. Several fabrics that show a strong valleyward flow direction support this, as well as the fact that the till most likely lies directly above the bedrock surface.

DISCUSSION

Pre-Wisconsinan gray till in the Mankato area likely correlates with other gray tills that have been described in the Midwest, including members of the McCredie Formation in northern Missouri, the Wolf Creek Formation in Iowa, and the Pierce Formation in western Wisconsin (Figure 6). Unfortunately, research on the till in Mankato has not been able to distinguish whether or not the till is a result of multiple glaciations, which would aid in correlation of this thick unit. Detailed paleomagnetic research, clay mineral analysis, and

more detailed descriptions of lithology would be beneficial. These methods, however, may not be able to account for the fact that the bedrock topography in which the "old gray" till in Mankato was deposited varies greatly from those of the other pre-Wisconsinan gray tills.

At sites north of the Minnesota River (the Bluff Park, Happy Chef, and Mudslides sites) the thick unit is interrupted and even interbedded with sand, and fabrics indicate that bedrock was responsible for flow direction. South of the river (the Logjam, River Heights, and Route 66 sites) this interruption and interbedding is not present, and fabrics indicate that bedrock is not as responsible for flow direction. This suggests that the depositional environment of the till varies within the Mankato area. This variation, and the fact that the "old gray" may consist of one or more units of pre-Wisconsinan gray till, lead to many possibilities in the interpretation of its depositional environment.

The "old gray" till in Mankato could be the result of one very large glacier that remained here for a very long time. It may have remained here while extensions of it advanced and retreated over regions to the west and south, which deposited distinguishable units in these places. Multiple glaciations could also be responsible for deposition of the "old gray" till, but their visible traces (paleosols, loess), could have been erased due to scouring by successive glaciers or by erosional processes (fluvial, glaciofluvial, mass wasting) that took place in the valley environment.

The fact that pre-Wisconsinan gray till in Mankato was deposited in a bedrock valley is fortunate, because it allowed for a thick unit to be preserved. It is also unfortunate, however, because the valley's control changed the character of the glacier or glaciers that overrode it, and in doing so complicated the depositional environment of the till and other glaciofluvial sediments. These complexities may be overcome with more complete research, but until then only two conclusions can be made about the "old gray" till in Mankato: It comprises a thick, somewhat continuous layer; and it correlates with at least one, and possibly more pre-Wisconsinan gray tills described in the Midwest.

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