A fossiliferous till found in New Ulm, Minnesota

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ABSTRACT:

A till exposed along an unnamed tributary of the Cottonwood River in New Ulm, Minnesota is found to contain a number of unbroken microfossils including numerous species of freshwater gastropods, pelecypods and ostracodes as well as marine forams and fish teeth. Also contained within the till are plant fossils and wood fragments ranging in size from small seeds and twigs to entire logs. The freshwater fossil assemblage and preliminary identification of the plant fossils indicates that the animals lived in a small lake or pond in a temperate, interglacial environment with temperatures similar to those of modern-day South Dakota. It is most likely that the marine microfossils and fish teeth were reworked from older Cretaceous sediment found to the northwest.

Analysis of the sediment found at the New Ulm site indicates that it is a till that can be correlated to the pre-Wisconsinan tills of the upper mid-west such as the Whetstone Till, the Kandiyohi Till and the "old gray" till. The Whetstone Till of Grant County, South Dakota, overlies the Gastropod Silts (Gilbertson, 1990). At least three of the gastropod species found within the Gastropod Silts (*Valvata tricarinata, Valvata sincera, and Gyraulus parvus*) are the same as those found within the New Ulm site till.

Three models of deposition for the till found at the New Ulm site have been proposed based on the results of this research. The first, the entrainment model, involves the entrainment of large chunks of frozen lake sediment into the shear planes of an advancing

glacier. The sediment is deposited and mixed when the glacier retreats and the sediment melts out. The second model is an ice shelf model in which the glacier advances, creating an ice shelf over part or all of a small lake. Till is deposited beneath the ice shelf, through the water and mixes with the lake sediment on the lake bottom. Finally, the solifluction model is essentially a large land slide of till into the lake basin. The till, once again, mixes with the lake sediment on the lake bottom.

Acknowlegements:

So many people helped me during the course of this research. First of all, many thanks to the geology professors at Gustavus Adolphus College; Mark Johnson, Keith Carlson, Jim Welsh and Amy Thompson. They provided me with the knowlege needed to complete this project and gave me constant suggestions and support throughout my college career. Thanks to my friends and colleagues, Janet Mann and Scott Brown for their help both in the field and in the lab. A very special thanks to Brandon Curry for his infinite patience and help with Ostracode identification and radiocarbon dating of the wood. I appreciate the help of Darrell Kaufman, who analyzed the amino acid racemization data for this project. Finally, I would like to thank everyone in the geology department who made my four years at Gustavus unique and wonderful. Tusand tak.

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INTRODUCTION:

The New Ulm site in south-central Minnesota (NW1/4, Sec. 33, R30W, T110N) is an exposure of fossiliferous gray till. The till is exposed along a small tributary of the Cottonwood River (henceforth referred to as the South Park site) as well as along the Cottonwood River itself (henceforth referred to as the Cottonwood site). The South Park site and the Cottonwood site will be collectively referred to as the New Ulm site. The two outcrops contained within the New Ulm study area are approximately 1/4 mile apart.

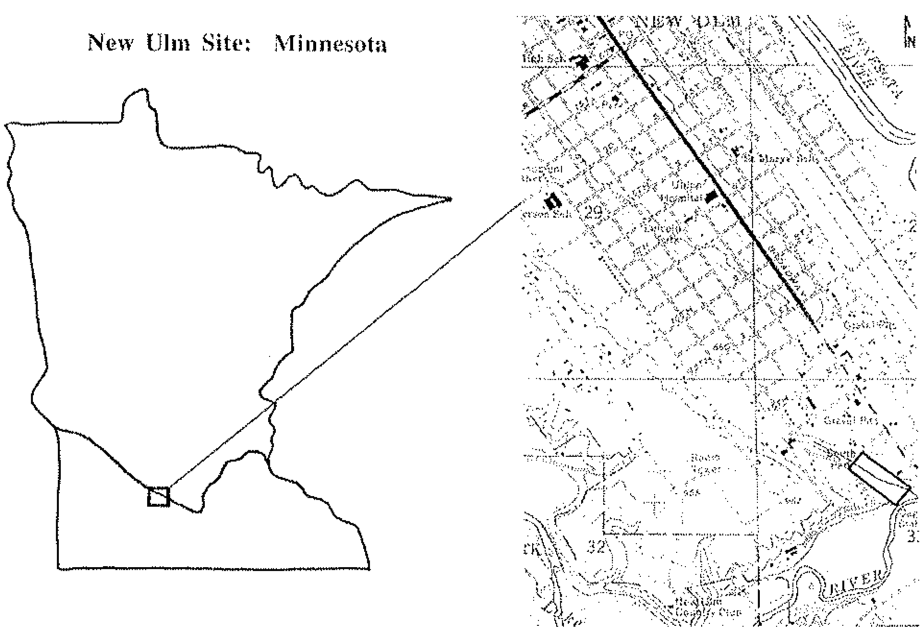


FIG. 1: Map of the New Ulm site and surrounding area.

There are three main problems that needed to be addressed throughout the course of the research conducted at the New Ulm site. First, it was important to determine whether or not the gray sediment at the site was a till. Next, the fossils needed to be identified. By identifying the fossils, an environment in which the animals and plants lived could be determined. Finally, using the information gathered from the sediment and the fossils, three possible models of depostion were made.

PREVIOUS WORK:

It is very important to take into consideration the previous geological work that has been completed in the areas surrounding the study area. Important time periods for this research include everything from the Cretaceous to the present. Close attention must be paid to the Quaternary era where glacial sediment is involved, but the underlying bedrock can also be a good indicator of things such as thickness and lateral extent of the overlying sediment.

PRE-QUATERNARY:

The Cretaceous in Minnesota was marked by the advance of epicontinental seas (Schwartz, 1954). The seas covered much of the upper mid-west, including parts of Minnesota and the Dakotas. A Cretaceous sandstone is found in parts of Minnesota and at the New Ulm site the sandstone can be found underlying the gray sediment. To the northwest, deep water clay and marl deposited in the Cretaceous seas can be found (Schwartz, 1954; Wright, 1972). Figure 2 shows a map of the bedrock geology of Minnesota and parts of North and South Dakota.

QUATERNARY:

Throughout the Quaternary, Minnesota was repeatedly covered and uncovered with lobes of the Laurentide Ice Sheet. The lobes of the Laurentide Ice Sheet deposited a complex till stratigraphy in Minnesota, much of which seems to have been since eroded (Wright, 1972; Patterson, 1996). Tills that remain exposed in southern Minnesota include both pre-Wisconsinan and Wisconsinan tills.

The source direction of the lobes of the Laurentide Ice Sheet can be determined by the identification of distinctive lithic fragments within a given till. For instance, a till in Minnesota with a northeastern source area will generally contain Precambrian lithic fragments of basalt, red sandstone and rhyolite. A till in Minnesota with a northwestern source area would contain a high number of shale and carbonate lithic fragments.

Many till units have been found that help define the Quaternary history of Minnesota. There are some pre-Wisconsinan till units as well as a number of early- and late-Wisconsinan tills. Not all of these pre-, early- and late-Wisconsinan tills extend continuously across the state of Minnesota. Some till layers have been eroded either partially or completely by the advance and retreat of overriding glaciers (Patterson, 1996).

A till stratigraphy sequence has been used to generalize the tills deposited by the main advances of the Laurentide Ice Sheet. It must be stressed that the till sequence is generalized and that recent studies done in Minnesota indicate that the stratigraphy is much more complex than the generalized till sequence indicates (Lusardi, 1996; Mann, 1998). This sequence consists of four layers, the oldest being a thick, gray clay loam till that is pre-Wisconsinan in age (Lusardi, 1996; Wright, 1972; Patterson, 1996). This gray till is often referred to as the "old gray" till. The "old gray" till has a high

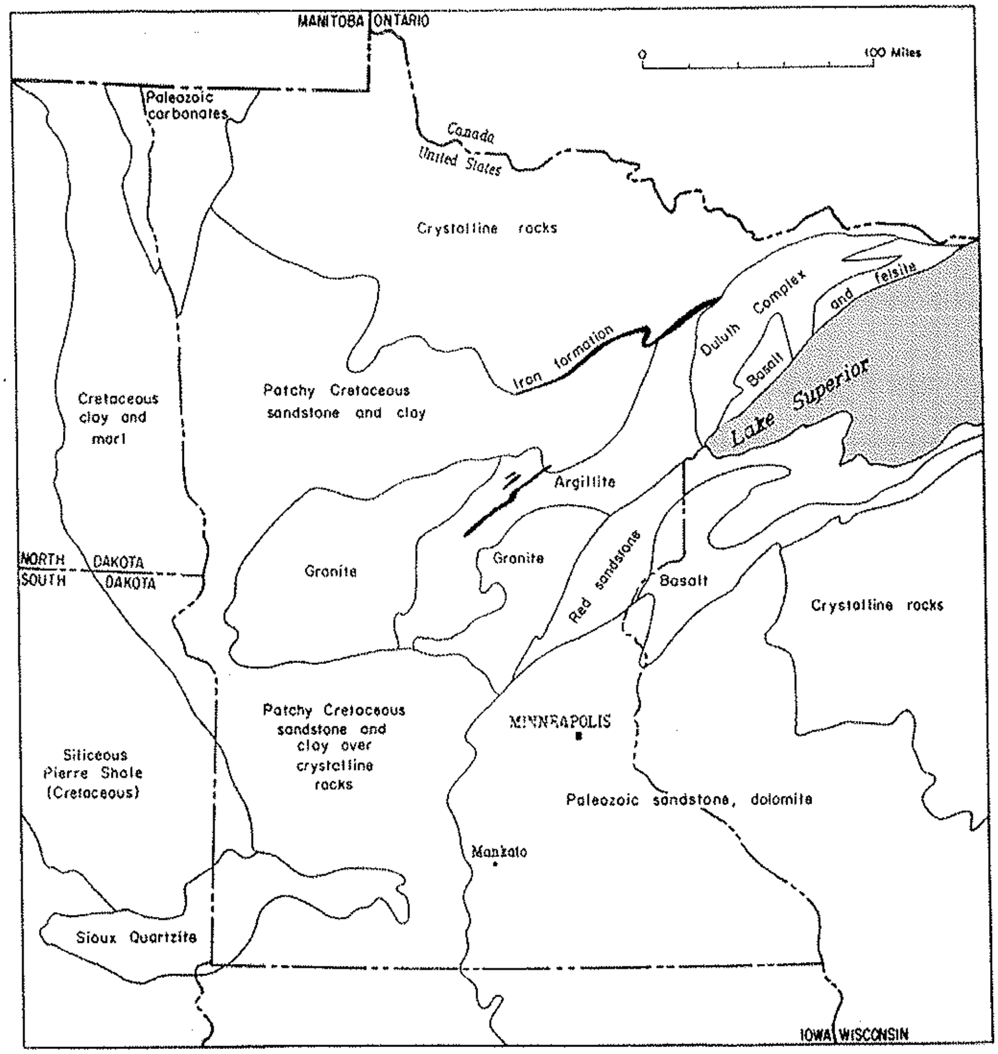


FIG. 2: Map of the bedrock geology of Minnesota (Wright, 1976).

carbonate and moderate shale lithic content (Gramstad and others, 1997). The pebbles found in the "old gray" till are few and what pebbles are found tend to be small, though occasionally a cobble-sized clast can be found (Gramstad and others, 1997). The "old gray" till has a northwest source area indicated by its high carbonate content. Tills that are thought to correlate to the "old gray" include the Whetstone Till of South Dakota and the Kandiyohi Till of southwestern Minnesota.

Researchers have attempted to take oriented paleomagnetic samples of sediment associated with the "old gray" till in an effort to see if the till had a reversed polarity. The samples exhibited reversed polarity and it was tentatively concluded that the "old gray" till was at least as old as the last polar reversal which has been estimated to be 788,000 ybp (cited in Rovey and Kean, 1994).

The next youngest till unit found and described in Minnesota is called the Hawk Creek (Matsch, 1972) or the "old red" till. The Upper Red Till of central Minnesota can also be correlated to the Hawk Creek Till (Meyers, 1986). The Hawk Creek Till is a sandy clay loam. It contains little to no shale but does contain lithic fragments of banded iron formation, agate, red sandstone and rhyolite which place its source area to the northeast (Gramstad and others, 1997). The Hawk Creek Till dates to the early-Wisconsinan (Wright, 1972).

Overlying the Hawk Creek Till is an olive yellow sandy loam till that has been called the Granite Falls Till. The Granite Falls Till has a high proportion of crystalline lithic fragments and a moderate proportion of carbonates, with shale being a minor constituant (Gramstad and others, 1997). The high proportion of crystalline lithics and Precambrian lithics suggests a northeastern source area. Radiocarbon dating was done on pieces of wood found within the Granite Falls Till, but the results were inconclusive (yielding a date of 34,000 +/- 2,500 ybp) and an approximate date of pre-late-Wisconsinan has been given to the Granite Falls Till (Gilbertson, 1990).

The youngest till found in southern Minnesota is called the New Ulm Till (Matsch, 1972). The New Ulm Till is a very extensive till that is easily identified by its yellow-brown color and its situation at the very top of the stratigraphic column of southern Minnesota (Wright, 1972). The New Ulm Till is a calcareous, pebbly clay loam (Matsch, 1972; Lusardi, 1996). The New Ulm Till is characterized by the fact that is has an exceptionally high percentage of shale due to the fact that its northwest source area included exposures of the Pierre Shale, found in present-day North Dakota (Wright, 1972).

FOSSILS:

A number of different fossils can be found at the New Ulm Site. One can find gastropod and pelecypod shells by simply breaking apart pieces of the till and searching the freshly broken surface for the distinctive white shells. By washing the clay from samples and searching the remaining washed samples, ostracodes, forams, seeds, and fish teeth can be found.

Mollusca:

The phylum Mollusca is not distinguished from other phyla by the presence of a certain morphological feature (Clarkson, 1979). It is, instead, a phylum named on the basis that all of the members within the phylum are descended from a bilaterally symmetrical, unsegmented, acoelemate animal with a dorsal exoskeleton (Pojeta, 1985). In other words, there is no feature that is unique to the mollusks. Even the above explaination of the phylum Mollusca is confusing because it seems to indicate "backwards" evolution of some the the mollusks: not only does the slug have no exoskeleton, it has no endoskeleton either.

The class gastropoda first appears toward the end of the Cambrian (Runnegar, 1985). It is difficult to identify fossil gastropods to the species level because most of them are classified based on their soft part morphology (Jablonski, 1985) but with some species, identification can be done by looking at the symmetry and shape of the gastropod shell (Runnegar, 1985).

Gilbertson (1990) described a layer found along the Whetstone, Yellow Bank and Chippewa Rivers in Grant County, South Dakota in which a number of gastropod shells and other fossils were found. Gilbertson refers to this layer as the Gastropod Silts. The Gastropod Silts are a massive gray layer found overlying the Yellow Bank Till and underlying the Whetstone Till (Gilbertson, 1990). Pollen, algae, seeds, clams, ostracodes and microtine rodent remains have also been found by Gilbertson and his colleagues in the Gastropod Silts.

As is the case with fossil gastropods, fossil pelecypods are difficult to identify on the basis of their shells alone (Meglitsch, 1967). Pelecypod soft part morphology is much more distinctive between species than is the hard part morphology.

Ostracodes:

Ostracodes are small, bivalved crustaceans that belong to the phylum Arthropoda (Figure 3). The ostracodes are mainly marine or

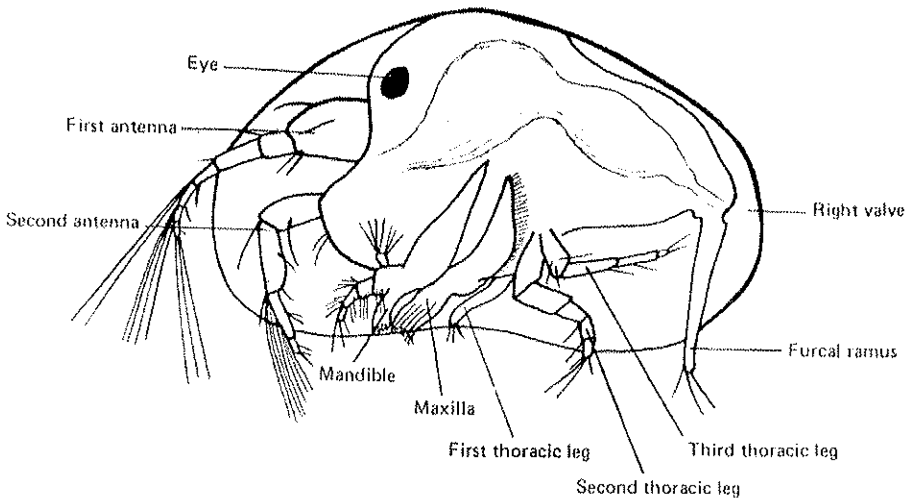


FIG. 3: Drawing of an ostracode illustrating life position in the shell (Eddy and Hodson, 1961).

freshwater animals, however, there are a few terrestrial species that have been discovered (Curry, 1998). Ostracodes are found in many different types of environments. Many situate themselves in loose lake bottom sediment in much the same way a clam would (Moore and Pitrat, 1961). Others attach themselves to rocks or plants in shallow lake environments (Moore and Pitrat, 1961). Still others are nektic (swimming) creatures (Curry, 1998). The energy of the environment in which the ostracode lived can be inferred from the size and the shape of the ostracode shell (Curry, 1998). For instance, an ostracode living in the swift currents of a river would have to have a stronger shell than that of a lake-dwelling ostracode.

The Scarborough Bluffs of Toronto, Canada contain a controversial diamicton in which ostracode remains have been found (Schwarcz and Eyles, 1991). This unit does not correlate to the till at the New Ulm site, however, the method proposed for the deposition of the diamicton is similar to one of the models proposed for the deposition of the New Ulm site till. It is believed that the diamicton in the Scarborough Bluffs was deposited beneath an ice shelf or from icebergs (Scwarcz and Eyles, 1991). As the till settled through the water, the sediments broke up and were easily mixed with the lake sediment and animals on the lake bottom. The fact that the till settled through water makes the mixing that occurred on the lake bottom low energy thus, the ostracodes were preserved whole and not crushed. The Scarborough Bluffs site is controversial not because the model is improbable, but because the textbook definition of a till specifically states that a till is homogeneous, unsorted sediment that is deposited directly from a glacier (Ehlers, 1996; Goldthwait, 1971; Bowen, 1978; Mahaney, 1976). The sediment cannot be reworked as it has been in the case of the Scarborough Bluffs. This controversy has been sidestepped by calling such deposits aquatic or marine till (Goldthwait, 1971).

Another till deposit that is causing some controversy is a till found in Antarctica beneath Ice Stream B. The till contains rare marine diatoms that are virtually unabraided. It has been proposed that the reason the diatoms have not been crushed is that the fine grained matrix in which they are contained is super-saturated with water, making the pore-water pressure great enough for the sediments to slide easily across eachother (Tulaczyk and others, 1998). The sliding motion and the large amount of water lessen the stress on the larger and more fragile particles contained within the sediment so the particles are not abraided or broken (Tulaczyk and others, 1998).

There are other reports of fossiliferous tills that have been found in Ireland and parts of Great Britain (Goldthwait, 1971). These till units generally contain fossils that are marine in origin and are usually descibed as being marine or aquatic tills (Goldthwait, 1971).

METHODS:

Various techniques for describing and correlating sediments were used in the first stages of this research. The sediment at the New Ulm site was described by using Munsell Color Charts and by

Amino acid analysis of the *Valvata tricarinata* specimin was completed by Dr. Darrell Kaufman at Utah State University. The amino acid ratio was used to make a more definite approximation of the age of the fossils found at the New Ulm site. The wood fragments were subjected to radiocarbon dating techniques under the supervision of fellow researcher, Scott Brown and identification of the pine cone was completed by Dr. Cindy Johnson-Groh of the Gustavus Adolphus College Biology Department.

OBSERVATIONS AND DATA:

SEDIMENT DATA:

As stated in the introduction of this report, there were three main problems that needed to be addressed thoughout the course of this research. The first question that needed to be answered was whether or not the sediment at the site was a till. Techniques used to determine the origin of the sediment were outlined in the methods section of this paper.

No definite upper or lower contacts have been found between the sediment of the New Ulm site and adjacent stratigraphic layers (Figure 4).

However, it can be inferred from the sequence of layers observed while walking downstream that the sediment overlies a Cretaceous sandstone. Till is commonly found filling bedrock valleys and depressions that were present prior to glacial advance. The sediment found a the New Ulm site fills a depression found in the underlying Cretaceous sandstone. The depression was described in a 1996 thesis by Jonathan Blaha (Figure 5).

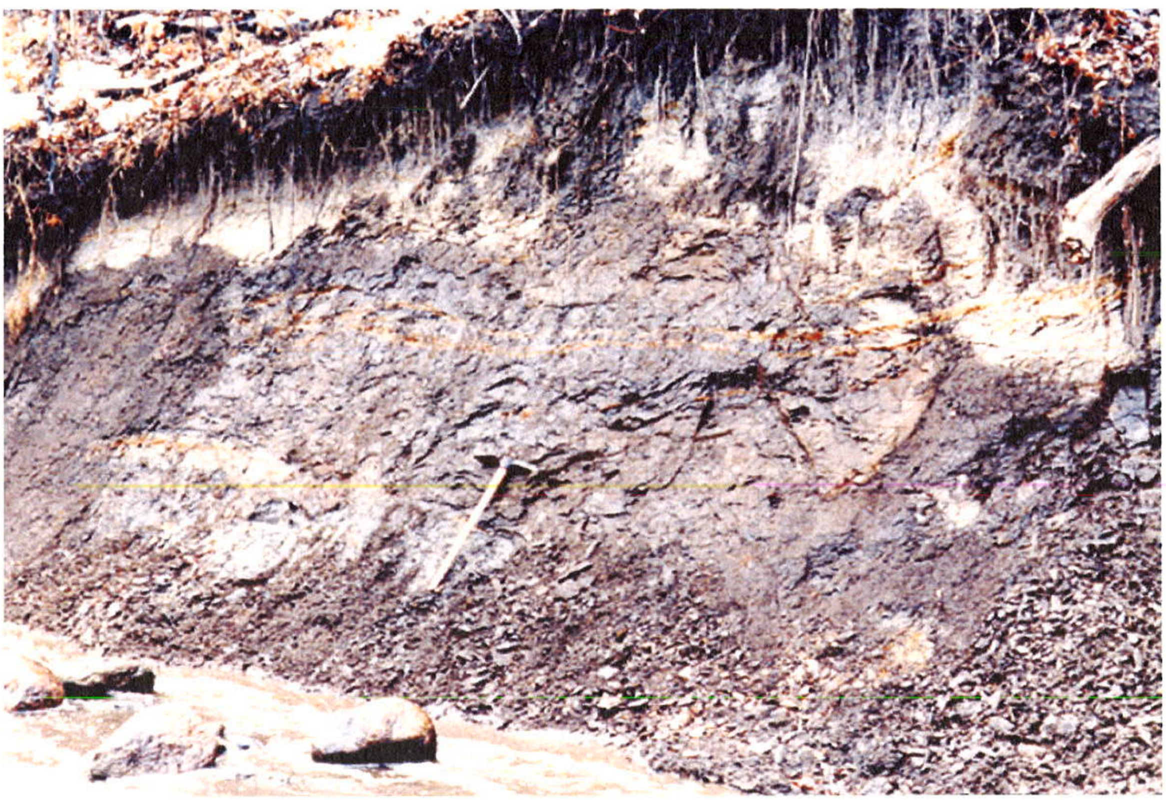


FIG. 4: Photograph of South Park site outcrop.

The sediment found at the New Ulm site has a glacial origin, but the details of its deposition may be somewhat different from textbook examples of a till. Something happened during the course of glacial advance and retreat that allowed the fossils and wood fragments to be incorporated into the sediment without being crushed. Not only does the till at the South Park site contain fossils

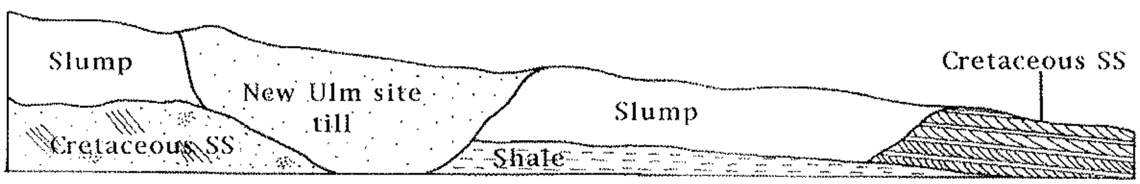


FIG 5: Cross section of bedrock of the New Ulm area showing the slight dip in the Cretaceous sandstone (modified from Blaha, 1996).

and wood, but it is also intermixed with layers of more silty sediment. There is no specific zone within the outcrop in which the fossils and wood are found. The thorough mixing of sediment suggests that the till was deposited in such a way that it was able to mix both with silty lake sediment that contained the freshwater plant and animal remains as well as non-lacustrine debris such as the logs and land snails.

The till found at the New Ulm site is olive-gray (5Y 3/2) when damp (Figure 6). Oxidized layers were dark yellow-orange (10YR 6/6) when damp and silty layers ranged from medium gray to light olive-gray (N5-5Y 4/1) when damp. The South Park site is intermixed with more silty layers and deformed (Figure 7). There is evidence of microfaulting and lamination of sediments at the South Park site (Figures 8,9). The Cottonwood site, however, shows little to no deformation and there is no noticeable layering of sediments.

FIG. 6: Photograph of till at the New Ulm site.

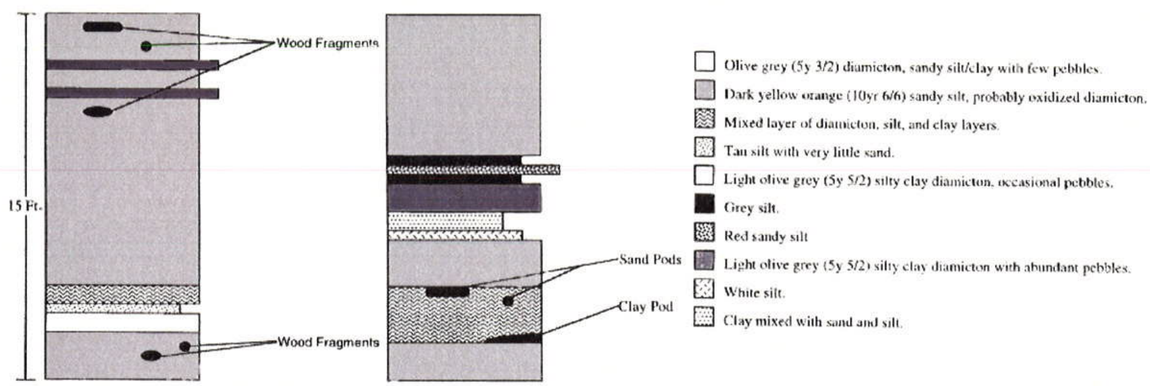


FIG. 7: Two stratigraphic columns taken approximately four feet apart at the South Park site.

FIG. 8: Photograph of microfaulting at the South Park site.

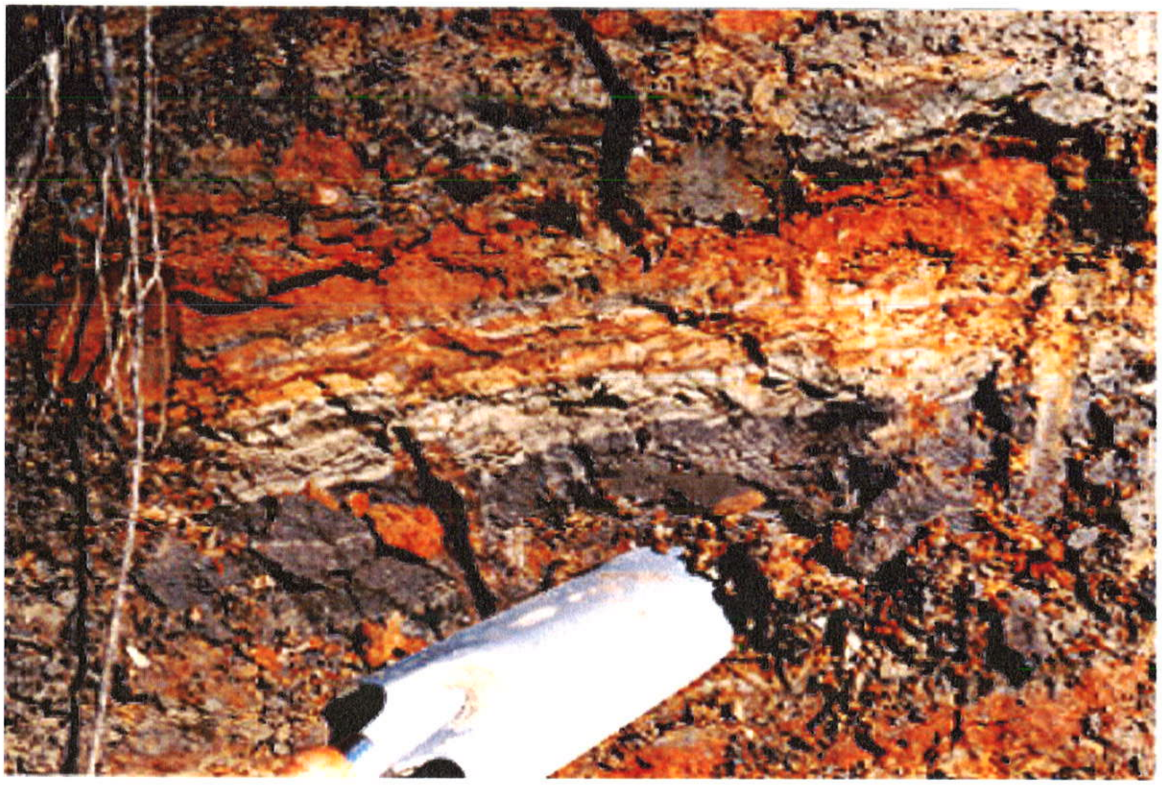


FIG. 9: Photograph of lamination at the South Park site.

Pebble fabrics were taken at the South Park site in an effort to determine a flow direction for the glacier that deposited the till. The plot of the pebble fabrics indicates a possible northwest source area (Figure 10). Orientations of the wood fragments were also taken and plotted to find a flow direction. A similar northwest source can be inferred from the plot of the wood orientations.

Pipet analysis of the till at the New Ulm site is most similar to other pre-Wisconsinan gray tills of Minnesota and South Dakota. Figure 11 shows a sand/silt/clay ratio of the South

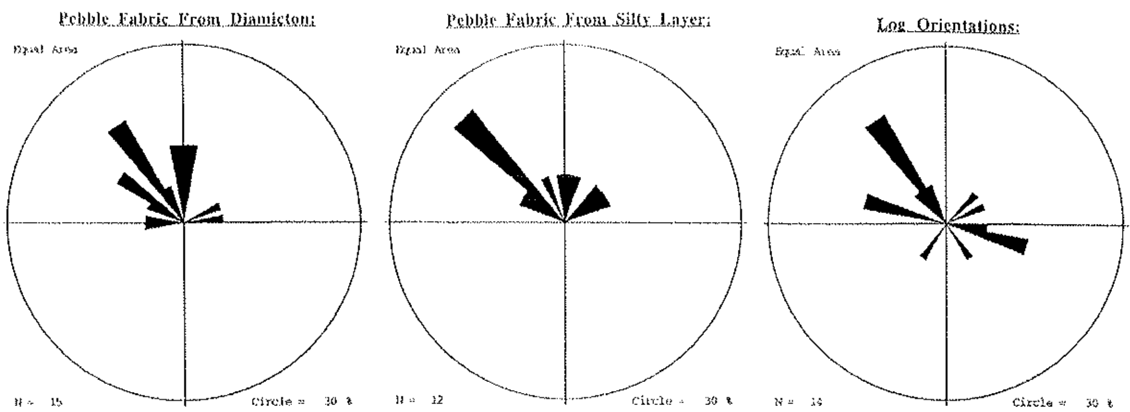


FIG. 10: Stereonet graphs of a.) pebble fabric at the South Park site, b.) pebble fabric at the South Park site, c.) wood orientations at the New Ulm site.

plotted against sand/silt/clay ratios of other gray tills such as the Whetstone of South Dakota, the Kandiyohi of southwest Minnesota and the "old gray" of south central Minnesota.

The 1mm sand fraction from each of the pipet samples was counted to obtain crystalline/carbonate/shale ratios for the South Park site till. These ratios were compared to ratios of crystalline/carbonate/shale ratios for other gray tills of Minnesota and South Dakota that could correlate to the New Ulm site till. Figure 12 is a triangle plot of the South Park ratios plotted against the ratios

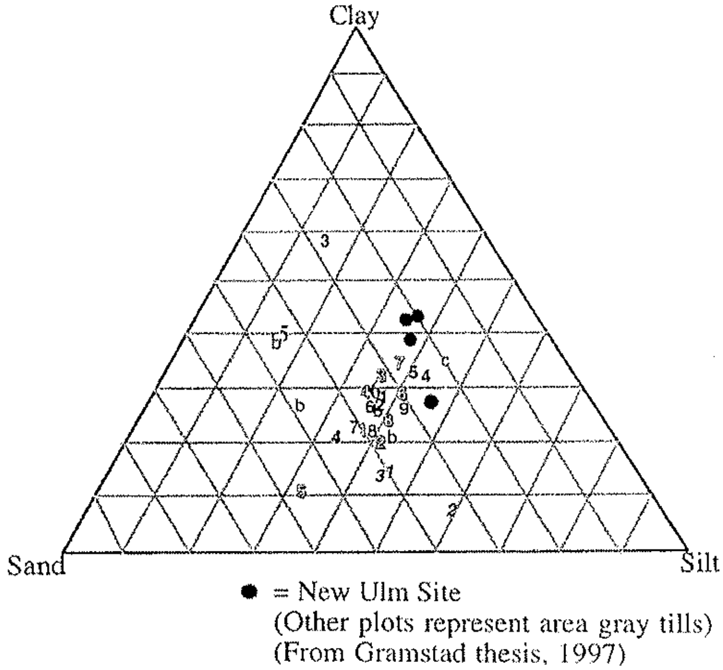


FIG. 11: Sand/Silt/Clay diagrams of South Park site till plotted against area gray tills (modified from Gramstad, 1997).

of the other gray tills. The carbonate ratio of the South Park site is somewhat lower than that of the regional gray tills.

Gravel- to cobble-sized clasts were cleaned and searched for striations. Approximately half of the clasts found within the till had striations on at least on face. Striations found on the clasts can be interpreted as being glacial abrasions, however, there is no way to determine whether or not the striated clasts have been reworked from older glacial deposits.

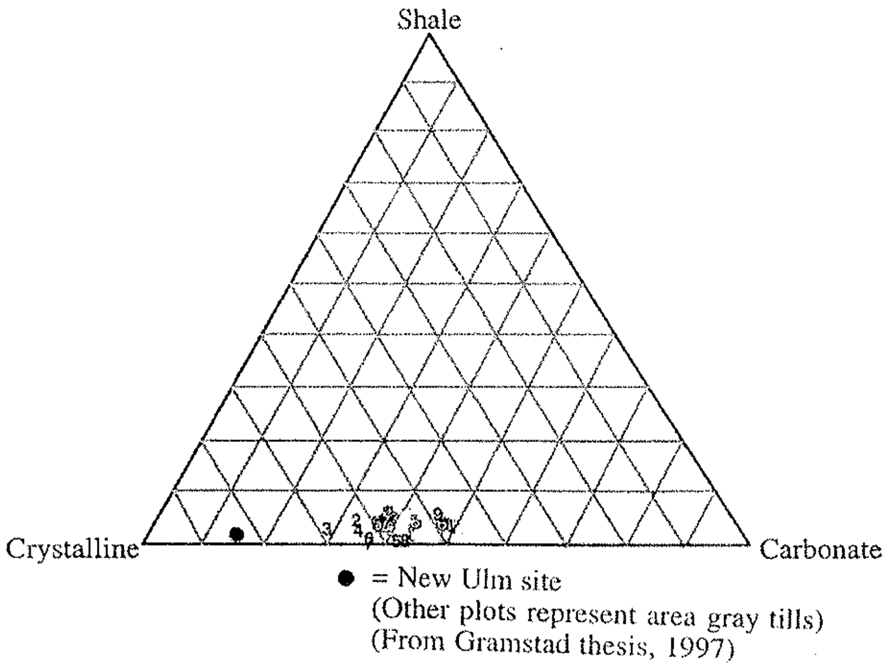


FIG. 12: Crystalline/Carbonate/Shale ratios of the South Park site till plotted against area gray tills (modified from Gramstad, 1997).

The sediment found at the New Ulm site can be classified as a till on the basis of its grain size distribution, the fact that it contains a number of striated clasts and its situation within a bedrock valley. The pebble fabrics and wood orientations indicate a possible north west source area for the New Ulm site till that is similar to that of other gray tills of Minnesota and South Dakota. The pipet analyses of the South Park site samples overlap with data from regional gray tills. These facts create a strong basis for identifying the sediment at the New Ulm site as a till and for correlating the New Ulm site till to regional pre-Wisconsinan gray tills.

FOSSIL DATA:

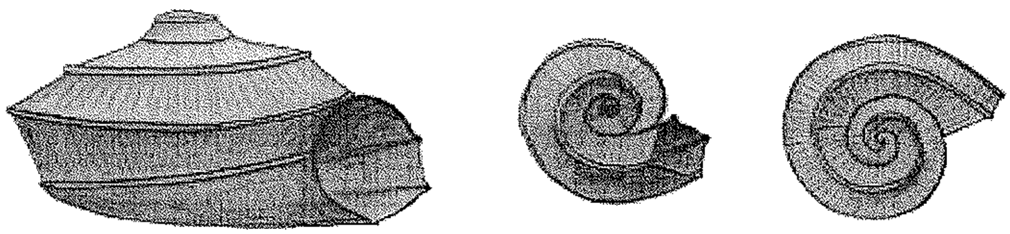
The fossils found within the New Ulm site till can be divided into five main categories; freshwater fauna, terrestrial fauna, freshwater flora, terrestrial flora and marine fauna. The five main categories can be further subdivided into class and, in some cases, genus and/or species. The following pages will simply describe the fossils that were found within the till and describe possible environments in which they lived.

Freshwater Fauna:

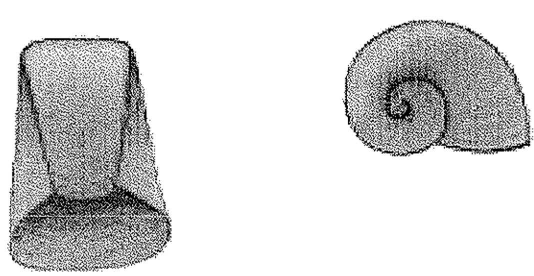
The freshwater fauna of the New Ulm site are comprised of three separate classes; the gastropoda (snails), pelecypoda (clams), and the ostracoda (ostracodes). The pelecypods were the most difficult to identify and therefore, many of them were not useful in determining a living environment for these creatures. Problems also occurred once the fossils were recovered from the till. Many of them, especially the ostracodes, were extremely fragile and crumbled before they could be properly identified.

Gastropods:

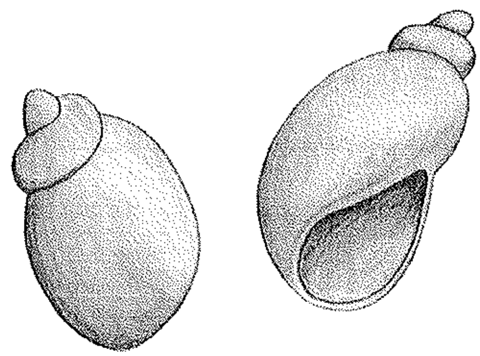
G1: *Valvata tricarinata* (8 samples)
Length=4mm Width=3mm
Dextral, carinate spiral ridge, slightly conispiral.
Nearshore environment, freshwater, 1-3m. depth, sand-gravel bottom.



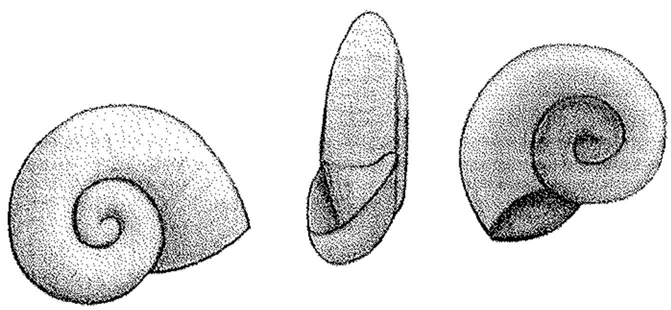
G3: Unidentified (1 sample)
Length=1.5mm Width=.75mm
Isotrophic, planispiral.



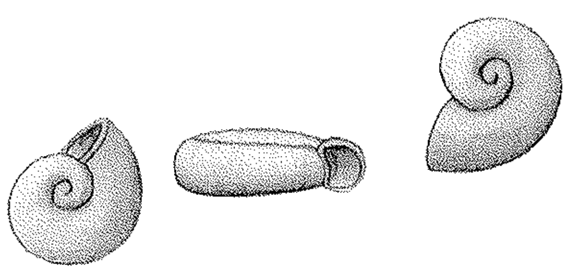
G4: Unidentified (12 samles)
height=5mm Width=2.5mm
Dextral, ovoid.



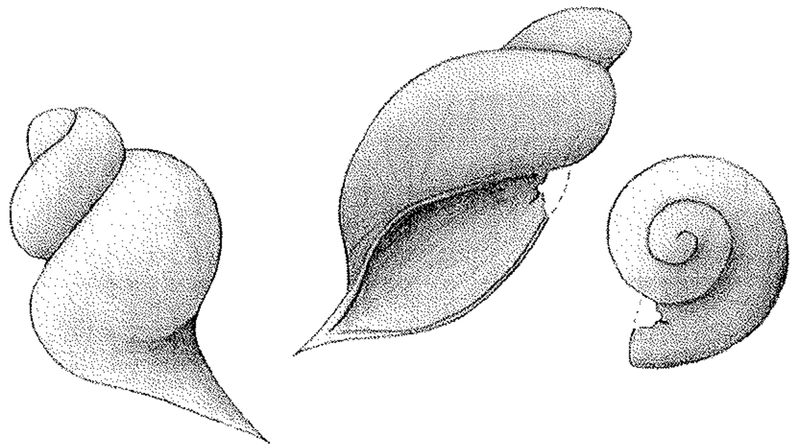
G5: *Gyraulus sp?* (5 samples)
Length=2.5mm Width=1.5mm
Dextral, planispiral, discoidal, anistotrophic, thinned aperture.
Small lake environment, freshwater.



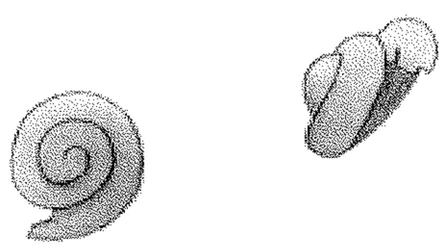
G6: *Gyraulus sp?* (4 samples)
Length=1mm Width=.3mm
Dextral, planispiral, discoidal, anisotrophic, thickenned aperture.
Small lake environment, freshwater.



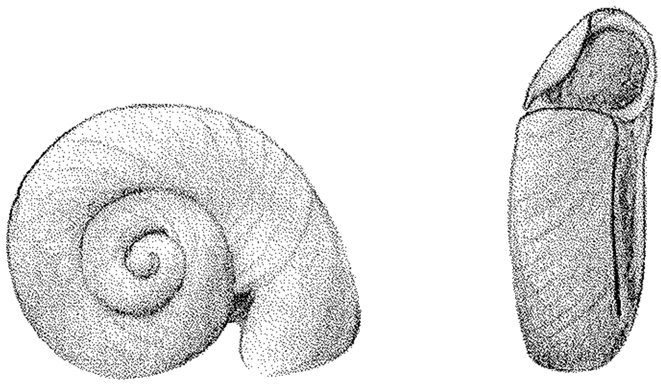
G7: Unidentified (6 samples)
Height=4.2mm Width=2mm
Dextral, fusiform?



G9: *Valvata sincera* (1 sample)
Length=1.5mm Width=.5mm
Dextral, aperture broken.
Small lake environment, near shore, freshwater.

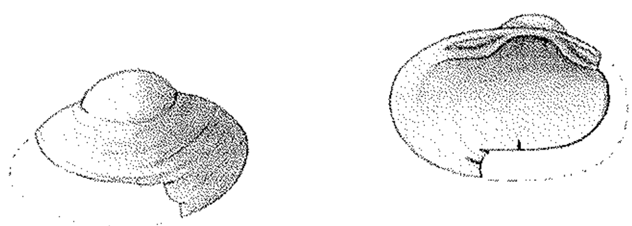


G10: *Planiborula armigera?* (1 sample)
Length=3.5mm Width=2.5mm
Dextral, thickenned aperture.
Stagnant freshwater environment, mud bottom, usually found attached to logs.

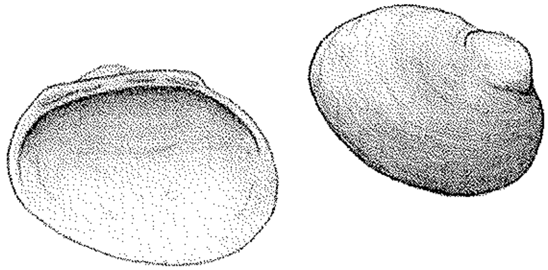


Pelecypods:

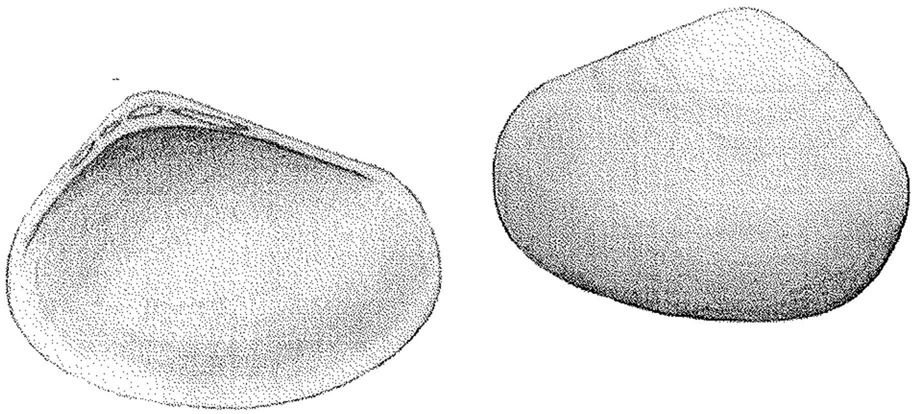
P1: Unidentified (1 sample)
Length=2.75mm Width=1.75mm



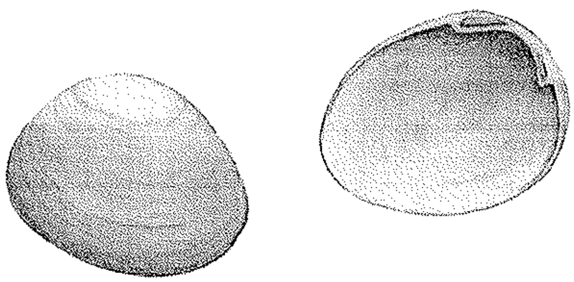
P2: *Sphaerium bakeri?* (1 sample)
Length=3.5mm Width=3mm
Small lake environment, freshwater, sand bottom, 1.5-2m. depth.



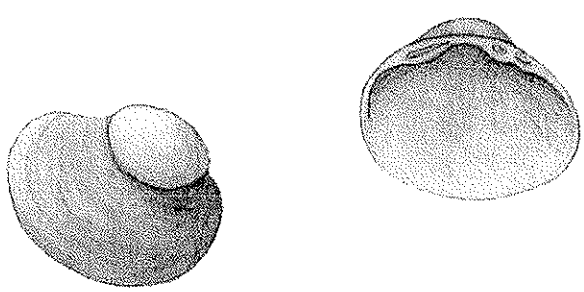
P3: Unidentified (1 sample)
Length=3mm Width=2mm



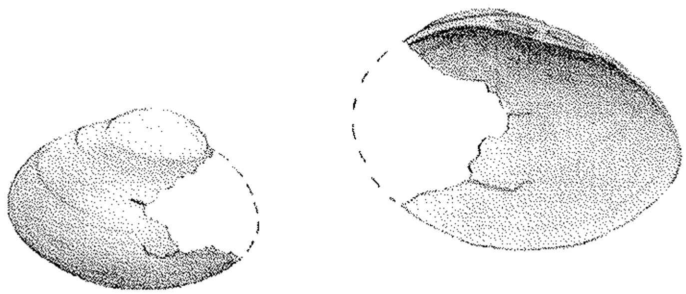
P4: Unidentified (2 samples)
Length=1mm Width=1mm



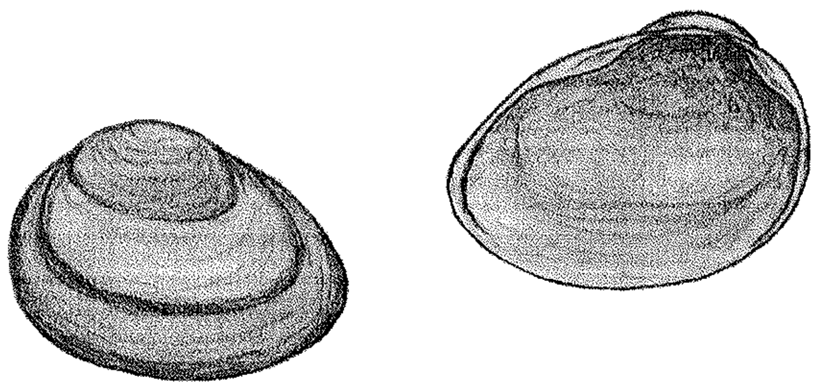
P5: *Sphaerium sp?* (1 sample)
Length=1.5mm Width=.75mm
Swamp or shallow pool environment.



P6: Unidentified (1 sample)
Length=2mm Width=1.5mm

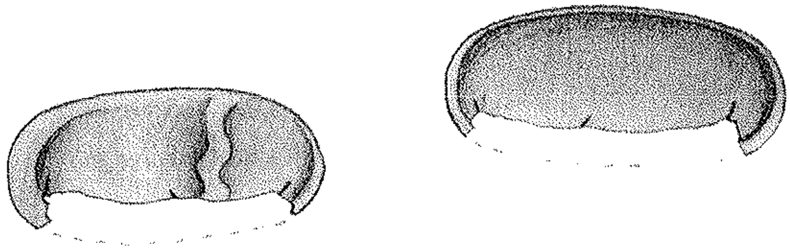


P7: Unidentified (1 sample)
Length=1.5mm Width=1mm
Zebra striped outer shell.

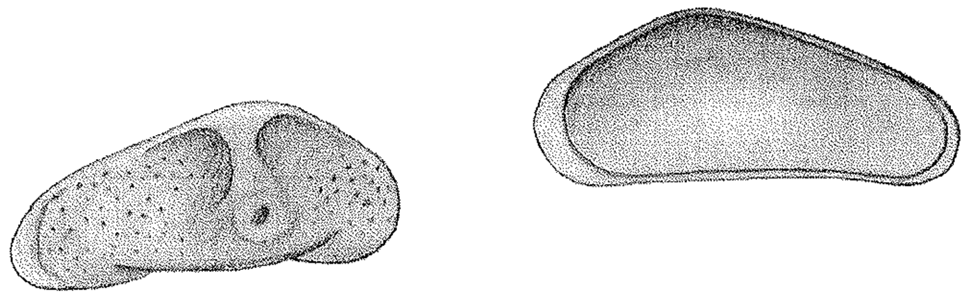


Ostracodes:

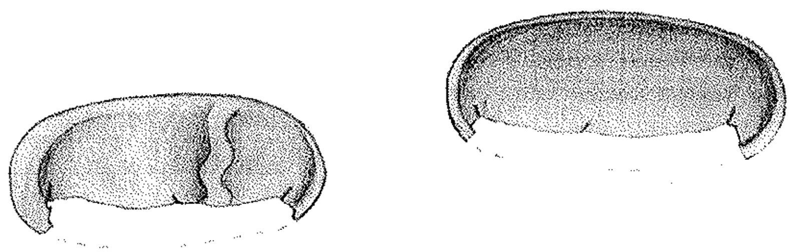
O1: Unidentified (1 sample)
Length=.3mm Width=.2mm
Black in color, possibly marine.



O2: Unidentified (1 sample)
Length=.5mm Width=.2mm
Black in color, possibly marine.

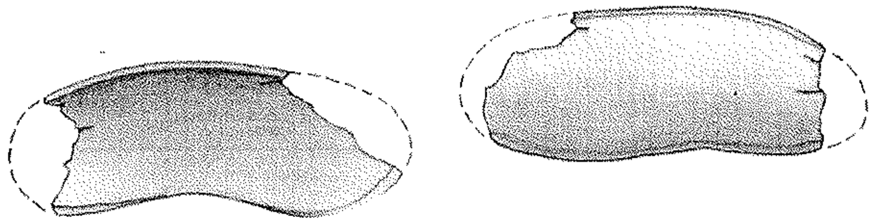


O3: Unidentified (1 sample)
Length=.5mm Width=.2mm
Black in color, possibly marine.

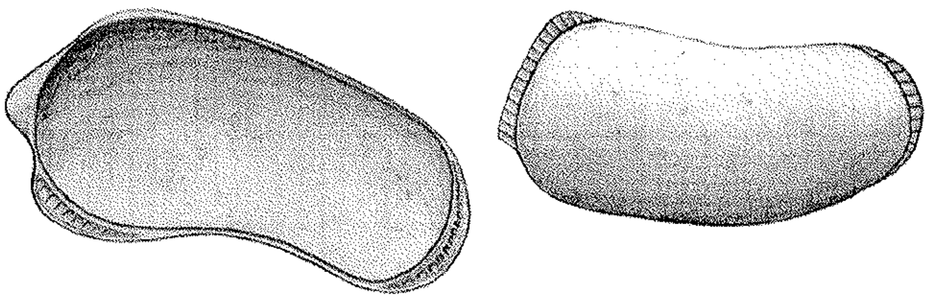


O4: *Cypridopsis virdua* (2 samples)
Length=1mm Width=.3mm
Nektic, freshwater.

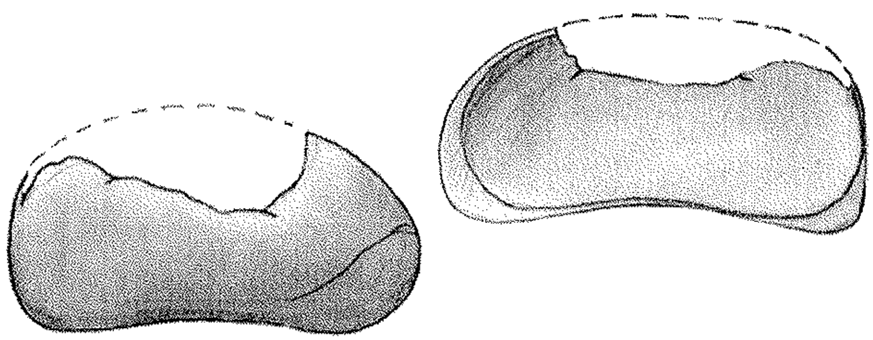
O5: Unidentified (2 samples)
Length=.6mm Width=.3mm



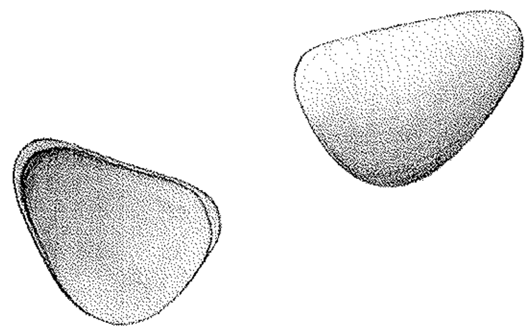
O6: *Candonid sp?* (2 samples)
Length=.3mm Width=.25mm
Freshwater.



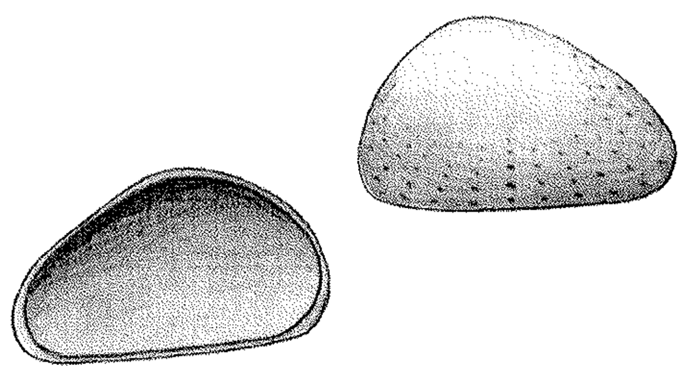
O7: *Candona rawsoni* (female) (4 samples)
Length=1mm Width=.75mm
Small lake environment, freshwater.



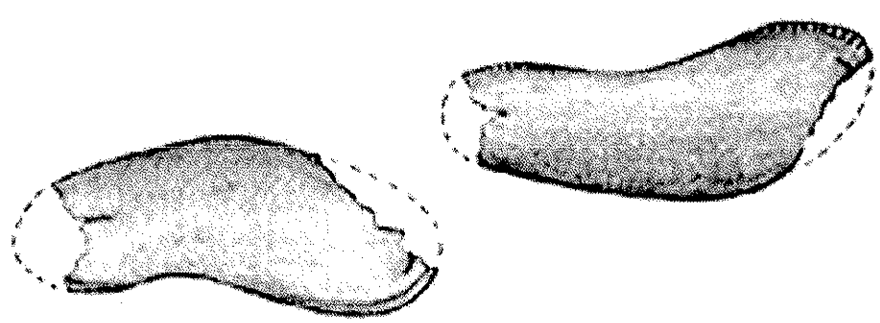
O8: *Advenocypris sp?* (2 samples)
Length=.25mm Width=.15mm
Still pool or small lake environment, freshwater.



O9: *Cypronotus sp?* (1 sample)
Length=1.5mm Width=.75mm
Still water environment, freshwater.

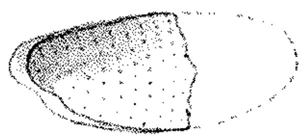


O10: Unidentified (1 sample)
Length=1.5mm Width=.6mm

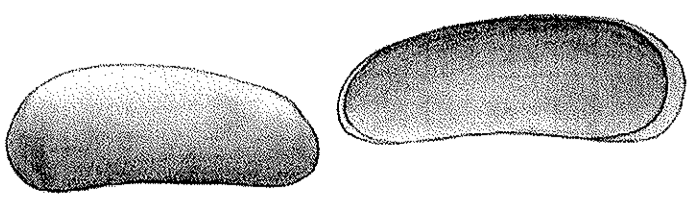


O11: *Candona rawsoni* (juvenile) (14 samples)
Length=.5mm Width=.2mm
Small lake or pond environment, freshwater.

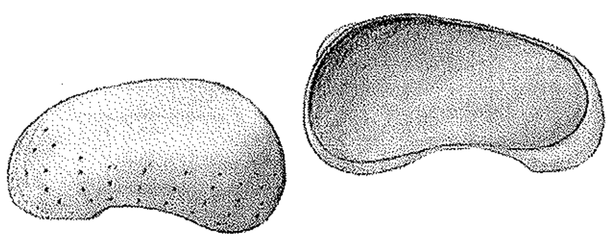
O12: Unidentified (1 sample)
Length approximately 5mm



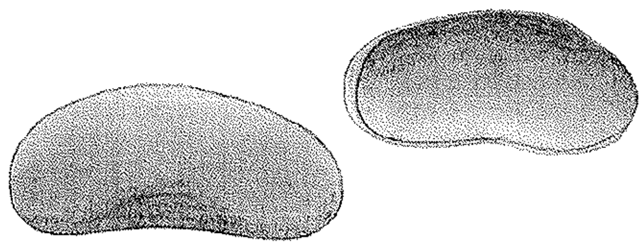
O13: Unidentified (2 samples)
Length=1mm Width=.3mm



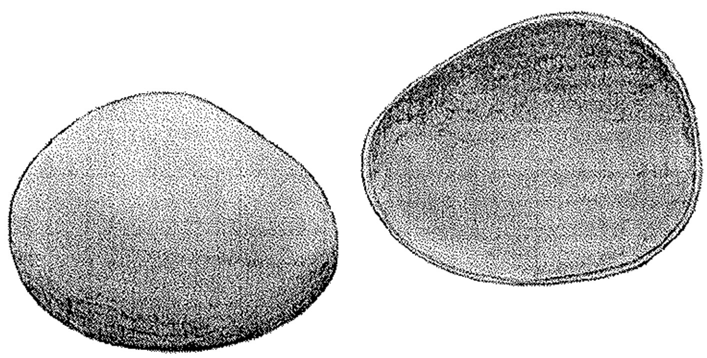
O14: *Candona rawsoni* (male) (1 sample)
Length=1.25mm Width=.75mm
Small lake or pond environment, freshwater.



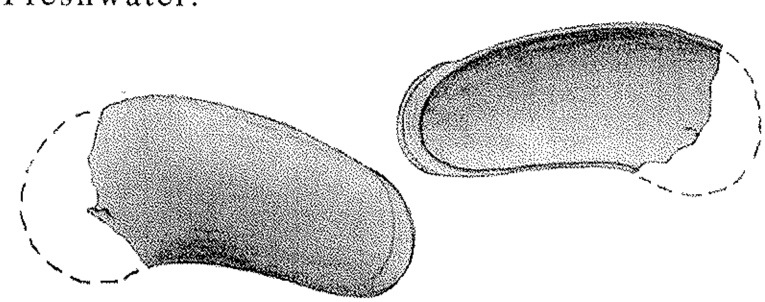
O15: *Cyclocypris laevis?* (2 samples)
Length=.75mm Width=.6mm
Nektic, freshwater.



O16: *Candonid sp?* (2 samples)
Length=1.5mm Width=.75mm
Freshwater.



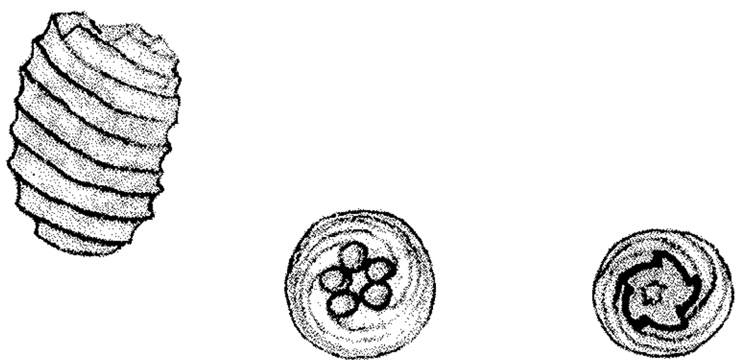
O17: *Candonid sp.* (juvenile?) (2 samples)
Length=1.5mm Width=.75mm
Freshwater.



Calcareous Algae?

C1: 4 samples
Length=1mm Width=.6mm
White in color, hollow.

C2: 4 samples
Length=.6mm Width=.3mm
Black in color, hollow.

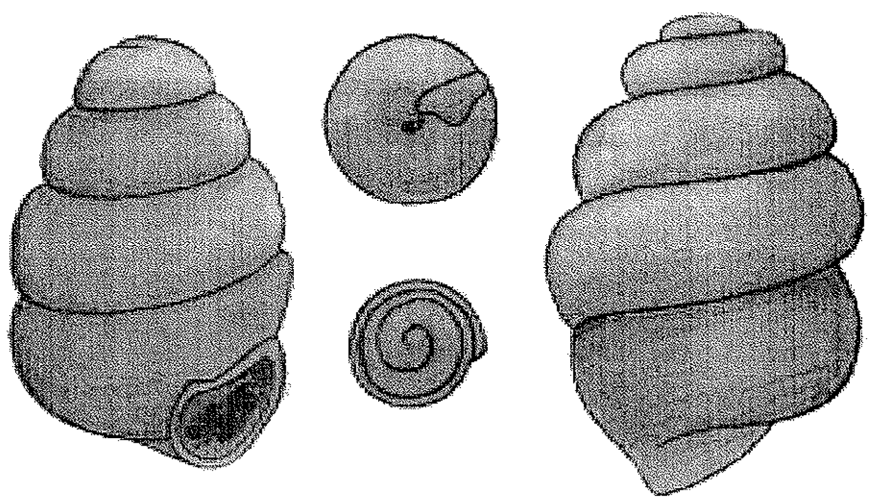


Terrestrial Fauna:

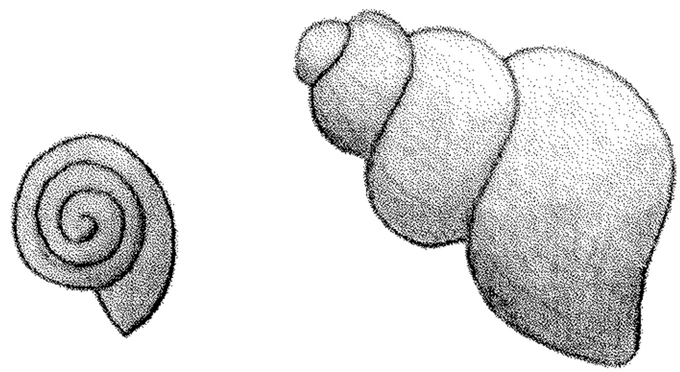
Only three possible terrestrial fauna were found within the New Ulm site till. Two land snails have been identified from all of the gastropods. There are no land clams and terrestrial ostracodes are extremely rare and much larger than any of the ostracodes found within the New Ulm study area. One vertebrate rib bone was found within the till. It is uncertain whether this rib bone is from an aquatic or terrestrial creature. I have placed it within the terrestrial fauna section simply because there have been reports of microtine rodent remains being found within the Gastropod Silts (Gilbertson, 1990).

Gastropods:

G2: *Gastrocopta pentodon* (4 samples)
Height=1.5mm Width=1mm
Dextral, pupaeform.
Damp terrestrial environment.

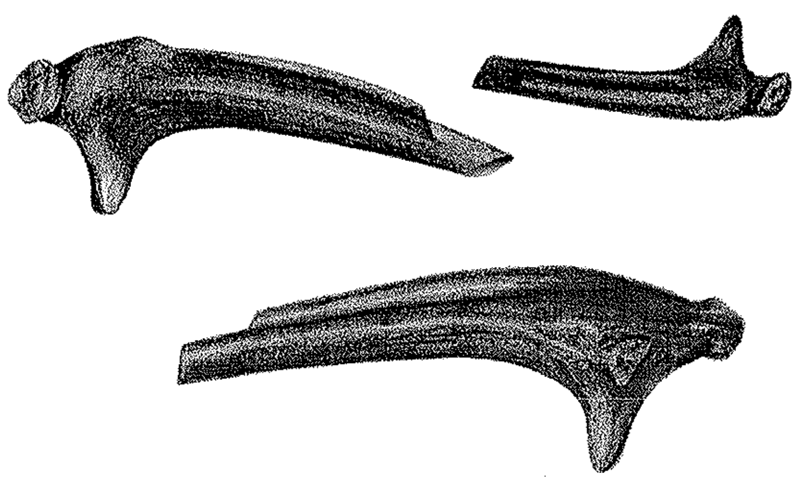


G8: *Pomiatopsis lapidaria?* (3 samples)
Height=2.5mm Width=1.5mm
Dextral, aperture broken.
Very damp environment, can be found in water.



Vertebrates:

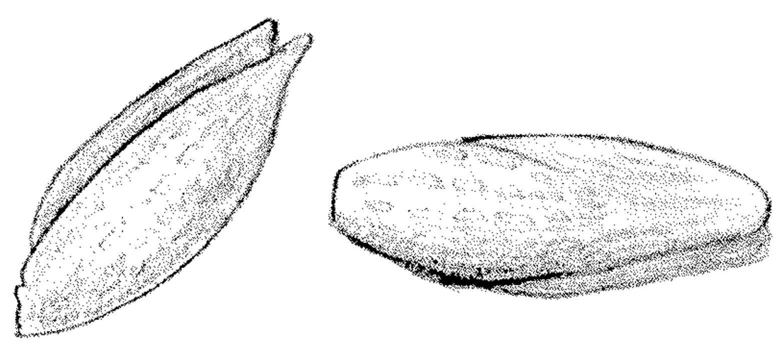
V4: Vertebrate rib bone (1 sample)
Length=3mm Width=1mm
Black in color, possible rodent?



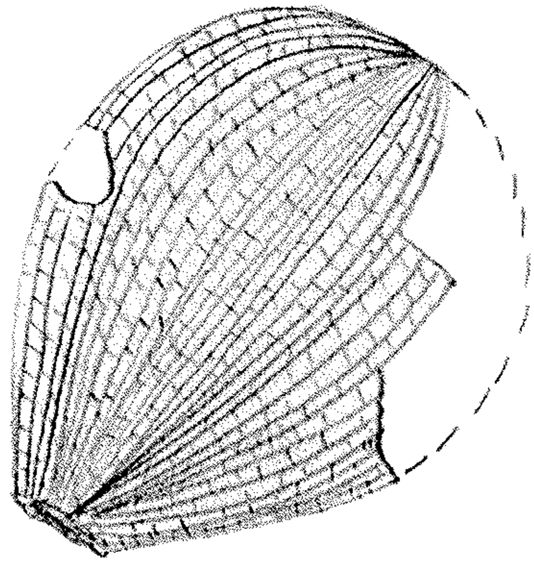
FRESHWATER FLORA:

Freshwater plant remains were commonly found within the till at the New Ulm site. The plant remains included stems, leaves and seeds. The leaves and stems were impossible to retrieve from the till without breakage. Often a piece of plant could be taken from the sediment, but once it was dried the slightest movement would crush it. Many of the destroyed plant remains looked similar to weeds (such as cabbage weed) found in modern day shallow lakes.

PL3: Seed of *Najas flexilis* (2 samples)
Length=3mm Width=.75mm
Dark brown color, leathery texture.
Shallow water environment.



PL7: Leaf (1 sample)
Length=1.5mm Width=1mm
Brown color.



TERRESTRIAL FLORA:

Terrestrial flora fossils were found in both microscopic and macroscopic form. Many of the microfossils were seeds and were, therefore, difficult to identify. There are so many types of plants with varying seed shapes, textures and colors that one would have to dedicate his entire life to the identification of plant microfossils in order to make sense of an assemblage. Macroscopic fossils included logs, branches and one complete pinecone. The wood fragments were initially identified as conifer by looking at transverse sections of a sample under a microscope. Coniferous tree cells differ from deciduous tree cells as shown in Figure 13.

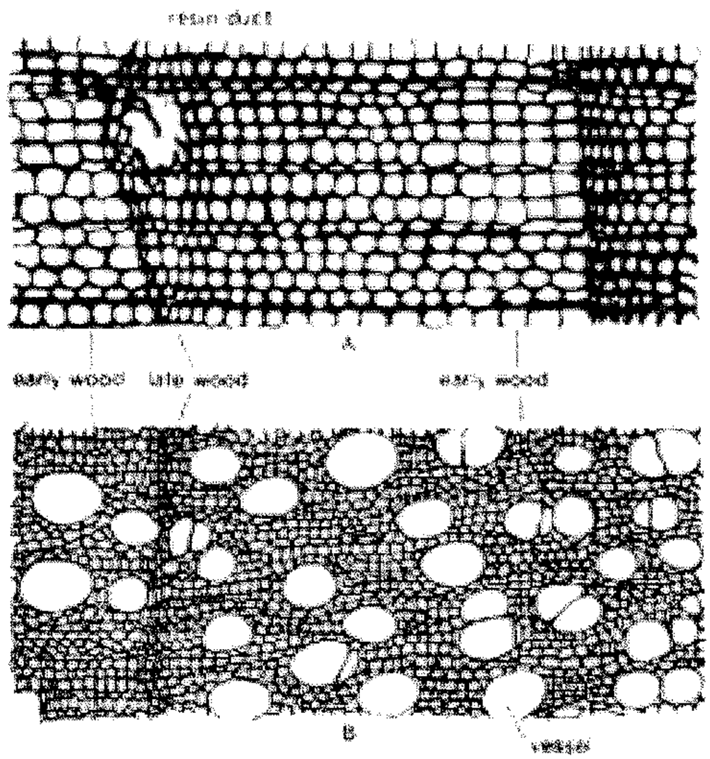
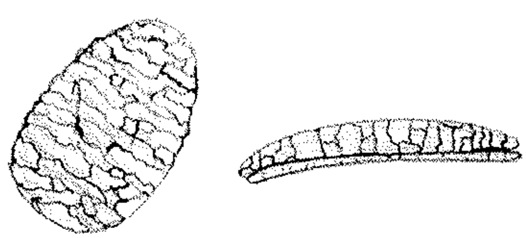


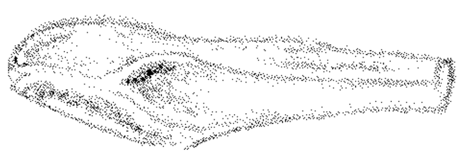
FIG. 13: Drawing of transverse sections of coniferous vs. deciduous tree cells (West, 1968).

PL1: Seed (1 sample)
Length=3mm Width=1.5mm
Tan color, very irregular surface.

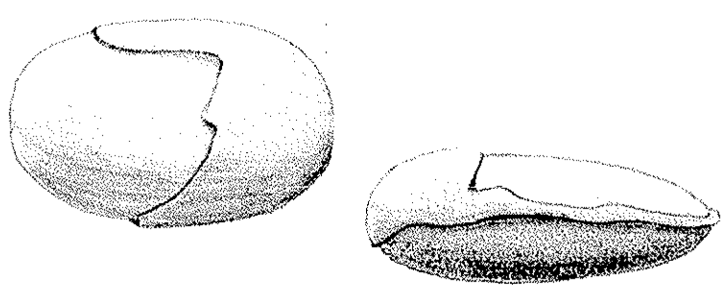


PL2: Seed? (3 samples)
Length=2mm Width=.5mm
Dark brown color.

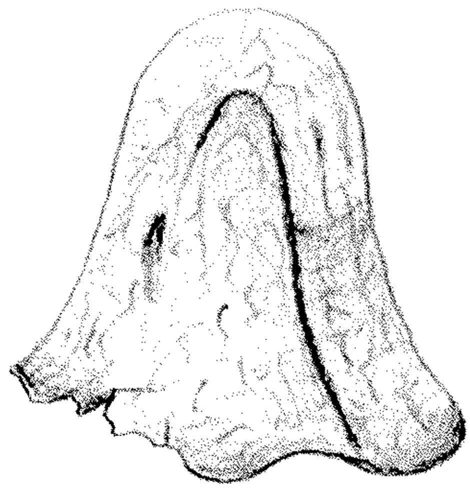
PL4: Seed (1 sample)
Length=1.5mm Width=.3mm
Brown color, raisin texture.



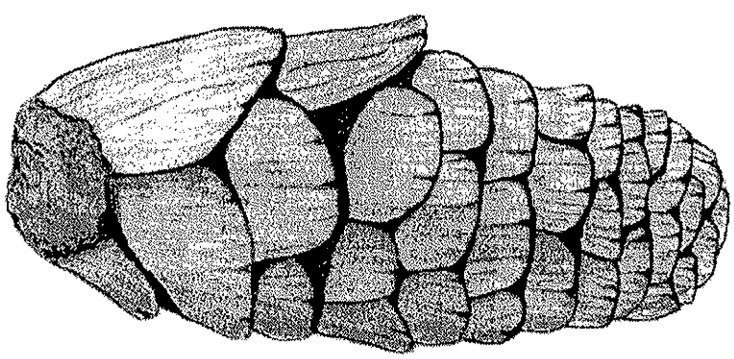
PL5: Seed (1 sample)
Length=.75mm Width=.5mm Height=.25mm
Light yellow color.



PL6: Birch seed? (1 sample)
Length=.5mm Width=.3mm
Brown color.



PL8: Black spruce pine cone (1 sample)
Indicates transitional forest, wet environment.

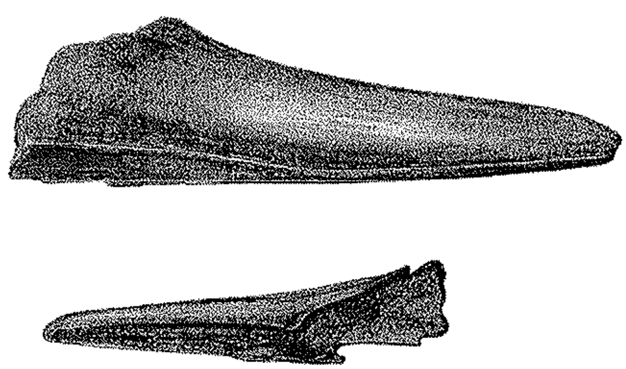


MARINE FAUNA:

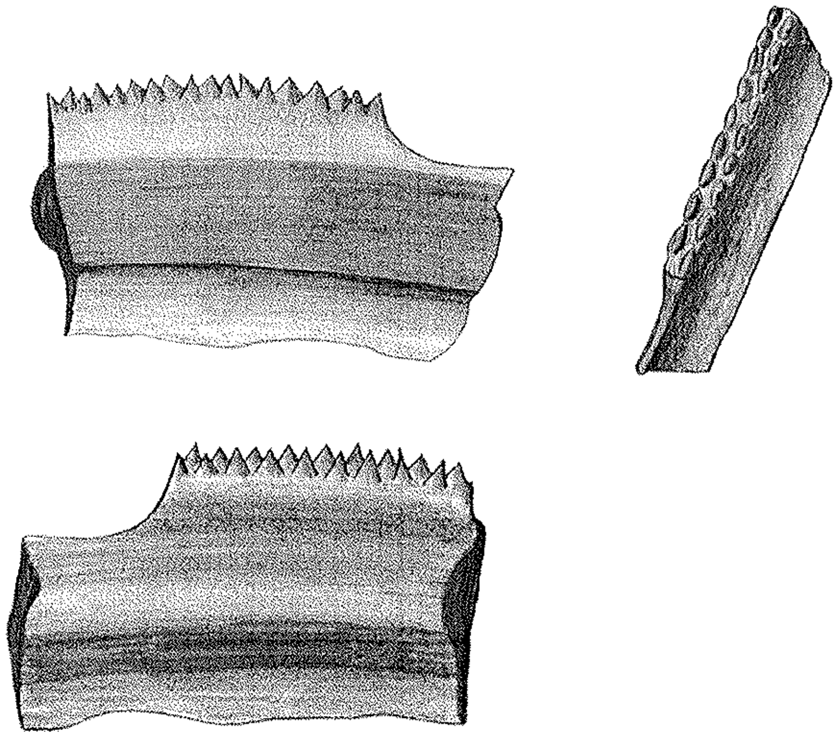
The last marine episode that occurred in the upper mid-west was during the Cretaceous. Therefore, the marine fauna can be explained as being re-worked from older Cretaceous sediment. Cretaceous sediment can be found in North Dakota to the north west, which seems to be the source area for the glacier that deposited the New Ulm site till (see Figure 1). There are two types of marine fossils that are found at the New Ulm site; forams and fish teeth. The forams seem to be replaced by silica, making them stronger than the freshwater fossils and, therefore, more easily reworked over time without being broken. The fish teeth also seem to be replaced by a mineral which makes them stronger, possibly calcite. Since the fish teeth have not yet been identified, it is possible that they were not reworked from older sediment, but were living in the same environment as the freshwater organisms previously described.

Fish Teeth:

V1: Fish tooth (Shark?) (1 sample)
Length=5mm Width=1mm
Black in color, root broken off.



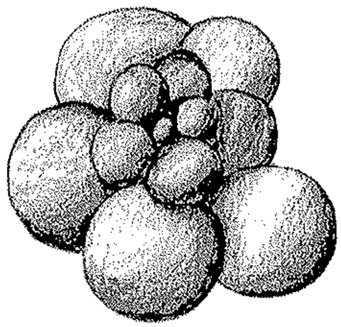
V2: Fish tooth (Jaw?) (1 sample)
Length=1.5mm Width=.2mm Height=1mm
Black in color.



V3: Fish tooth (2 samples)
Length=1mm Width=.2mm
Light yellow color.

Forams:

F1: *Hedbergella sp?* (15 samples) (Pictured below on left)
Diameter=.2-.5mm
Marine.



F2: *Globorotaloides variabilis?* (2 samples) (Pictured above on right)
Diameter=.3mm
Marine.

Dating Techniques:

When correlating tills it is essential to gain an understanding of the age of the sediment that is being studied. The wood and fossils within the New Ulm site till provided good opportunities for dating the sediment within the study area. The wood fragments were dated using radiocarbon techniques and one species of gastropod was analyzed using amino acid racemization techniques.

Radiocarbon Dating:

Radiocarbon dating of pieces of wood found at the New Ulm site was completed under the supervision of fellow researcher, Scott Brown. A piece of black spruce wood taken from the New Ulm site was sent to the Illinois State Geological Survey for analysis.

The outcome of radiocarbon testing yielded a date too old to be calculated. The results indicate that the age of the wood is greater than 53,900 radiocarbon years before present ($\delta\ _{13}C$=-25.1 per mil. PDB). Due to the well-preserved nature of the wood, one can assume that it was covered with sediment rather quickly after the tree died. Thus, it can be said that the till in which the logs are contained is also greater than 53,900 years old.

Amino Acid Racemization:

Amino acid racemization is not necessarily a technique that produces an absolute age for a fossil. Instead, the results are ratios that can be compared to ratios from other sites. Therefore, amino acid racemization produces a relative age for the fossil (Easterbrook, 1988). Many variables are involved in amino acid racemization analysis, some of the most important being temperature, post-depostional water amounts, animal species and amino acid type

(Rutter and Catto, 1995). Once all the variables are taken into account, the results can still have a large margin of error.

Every amino acid contains carbon atoms that make the entire molecule asymmetrical. When polarized light is passed through the amino acid molecule, the light bends either dextrally (D-form) or levrally (L-form) (Rutter and Catto, 1995). All living organisms have L-form amino acids but D-form amino acids are usually only produced after an organism dies. There is a constant level of amino acids that is distinct for each species. When an organism dies, the L-form amino acids transform in a linear, predictable way into D-form amino acids (Easterbrook, 1988). If we know the level of amino acids for a given species, we can determine the ratio of D-form amino acids to L-form amino acids in that species and approximate how long ago the animal died. Once we know the ratio, we can compare it to ratios taken from the same species in other areas of the world. Dates can be obtained by comparing the ratios of fossils that have been dated absolutely through other dating methods to ratios from the sediment being studied (Rutter and Catto, 1995).

Amino acid racemization ratios for the New Ulm site were obtained from four samples of the gastropod *Valvata tricarinata.*

Table 1 is a list of the D/L ratios for each of the three types of amino acids found in the four *Valvata tricarinata* specimins from the New Ulm site.

TABLE 1: D/L ratios for the gastropod *Valvata tricarinata* found at the New Ulm site.

	Aspartic	Glutamic	Isoleucine
A	.48	.25	.25
B	.48	. 22	.21
C	.49	.24	.22
D	.55	.28	.27
Avg.	.50	.25	.24
SD	.04	.02	.03

Compares to *Valvata hummeralus* ~160ka
Burmester core, Utah Asp=.57 Glu=.34 Ile=.30

Compares to Lymnaea ~140ka
Little Valley Alloformation, Utah Asp=.52 Glu=.35 Ile=.28

Compares to Lymnaea 17ka
14C-dated Bonneville Alloformation, Utah Asp=.35 Glu=.15 Ile=.09

The data give a date that is approximately 140-160ka when compared to sites in Utah. However, the temperature variable is very important to consider. When running samples, the researcher must make an approximation of the temperature of the environment in which the organisms lived as well as the post-depositional temperature of the sediment. A discrepancy of two degrees celcius in the initial estimate of temperature can cause up to a 50% error in the ratios for some amino acids. The temperature of southern Minnesota has most likely been significantly colder since the Illinoian advances than have been the temperatures of Utah. Assuming lower temperatures in Minnesota, we can say that the New Ulm site fossils are significantly older than the dates produced by the fossils found in Utah indicate.

In order to find a more accurate age for the fossils using amino acid racemization, it would be necessary to find other amino acid ratios from areas more similar in temperature to the New Ulm study area. Research done on fossils in the upper mid-west would be ideal for acquiring ratios that could be compared to the New Ulm site ratios.

DISCUSSION:

One of the main goals of this research was to come up with a hypothesis that explains how the fossils and wood were incoporated into the New Ulm site till without being crushed and broken. There are three possible models for deposition of the New Ulm site till that have been proposed based on the data obtained from the New Ulm site. These three models are; the quarrying model, the ice-shelf model and the solifluction model.

1.) The Quarrying Model: The quarrying model begins when an advancing glacier picks up large chunks of lake sediment (possibly frozen). The chunks of lake sediment act like a boulder and are incorporated into the shear planes of the glacier (Figure 14). When the glacier retreats, the lake sediment melts out and mixes with the basal till.

One would expect that sediment deposited in this way would be well mixed with zones of both whole and broken shells. This is the case with the New Ulm site. The South Park site fossils are generally unbroken while the fossils found at the Cottonwood site are rarely found in their entirety. The zone of broken shells at the Cottonwood site could be indicitive of the edge of one of the blocks of lake sediment.

2.) Ice-shelf Model: The ice-shelf model is similar to models suggested for the ostracode-rich marine till found at the Scarborough Bluffs in Toronto (Schwarcz and Eyles, 1990). An ice shelf forms when the glacier advances over a lake. The glacial sediments are

Stage One: GLACIAL ADVANCE
Lake loses water, climate cools.
Lake sediments freeze into large blocks,
glacier overrides the frozen sediment.

Stage Two: QUARRYING
Glacier picks up frozen lake
sediment in the same manner
it would quarry bedrock. Sediments
are transferred along shear planes.

Stage Three: GLACIAL RETREAT
Glacier retreats,till and lake sediments
melt out. Sediments mix as they melt out.

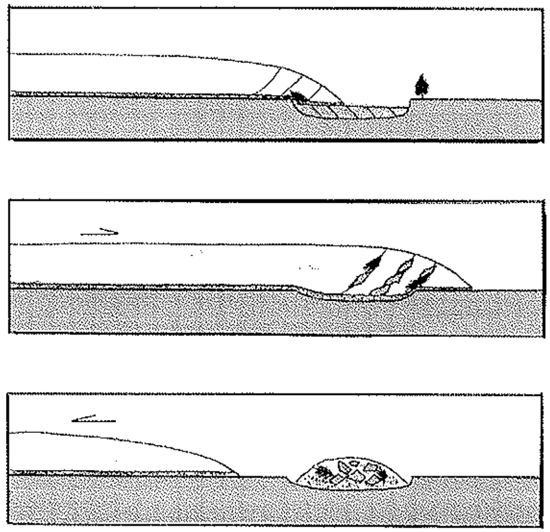


FIG. 14: The quarrying model.

deposited through the water beneath the ice shelf and mix with the lake sediments on the lake bottom. The till is exposed when the lake dries up (Figure 15).

The sediments deposited in this manner would exhibit a fining upward sequence. There was no fining upward sequence observed at the Cottonwood site, however, the South Park site did show some fining upward layers.

Stage One: GLACIAL ADVANCE
Glacier advances forming
an ice shelf on the lake.

Stage Two: DEPOSITION
Till is depoosited into the water
from beneath the ice shelf and
from icbergs that have calved from the
main part of the glacier.

Stage Three: MIXING
Till is deposited into the water in clumps.
The clumps break apart in the water and
mix with the lake sediments on the bottom.

Stage Four: GLACIAL RETREAT
Glacier retreats and mixed till
and lake sediments are left behind
in former lake bed.

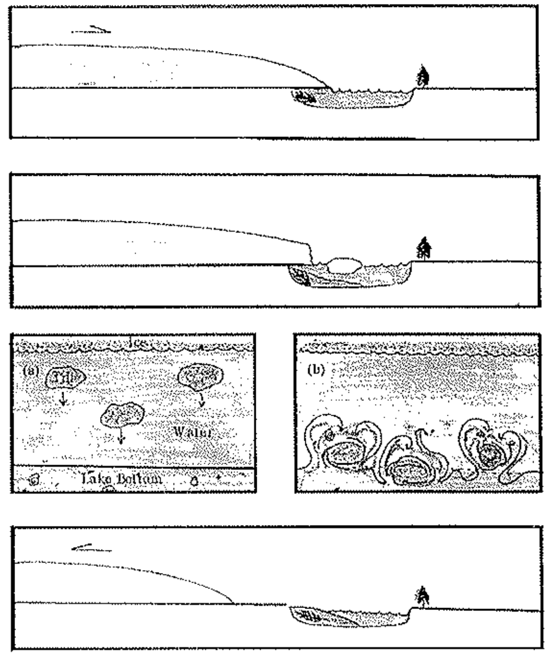


FIG. 15: The ice-shelf model.

3.) <u>The Solifluction Model</u>: Solifluction occurs when water-rich sediment is frozen and unfrozen repeatedly, causing the sediment to flow in a catastrophic manner. The solifluction model is a model in which a large quantity of till experiences solifluction into a lake where the till mixes with the lake sediment on the lake bottom (Figure 16). Once again, one would expect to observe a fining upward sequence in the sediments.

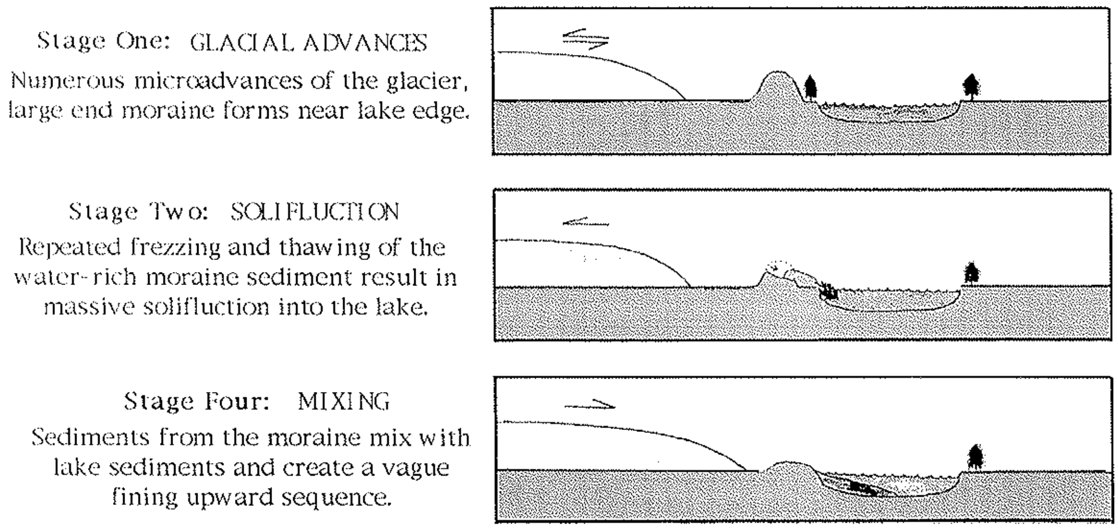


FIG.16: The solifluction model.

CONCLUSIONS:

Evidence gathered during the course of this research indicate that the sediments found at the New Ulm site have been depostied by a glacier. The sediments are clearly unsorted at the Cottonwood site. Unsorted sediment at the South Park site is intermixed with layers of a more silty, laminated sediment. The sediment is situated in a bedrock valley or depression, which is a depositional environment characteristic of till.

The till at the New Ulm site is most similar in composition, color and texture to pre-Wisconsinan gray tills of the Minnesota River Valley as well as the gray tills of North and South Dakota. At least three of the gastropod species identified from the New Ulm site till are the same as species found in the Gastropod Silts of Grant County, South Dakota, which is overlain by the gray, pre-Illinoian Whetstone till (Gilbertson, 1990).

Dating of the fossils and wood fragments from the New Ulm site till indicate an age of at least 160ka. The fossils assemblage indicates that these creatures lived in an interglacial environment with temperatures quite similar to those of modern day South Dakota. Most of the fossils were freshwater creatures that lived in a small lake or pond environment, though some of the fossils were terrestrial gastropods. The forest was most likely a transition forest; very damp and cool with a limited number of tree species. The marine fossils were probably reworked from older, Cretaceous sediment currently found in North Dakota, to the northwest of the study area. Pebble fabrics completed at the New Ulm site indicate a northwest source area for the till.

Given the fact that the Cottonwood site is homogenous and contains mostly broken fossils while the South Park site is intermixed with silty sediment and contains unbroken fossils, I believe the most likely model for deposition of the New Ulm site till is the entrainment model.

Further Work:

There is much more work that can be done on the New Ulm site. The outcrops themselves could be studied in more depth. Many stratigraphic columns could be made in an effort to determine if there is any lateral or vertical patterns of sediment within the study area. By looking for patterns in the sediment, one would be able to make a stronger conclusion about how the sediment was deposited.

There are many fossils that were not identified during the course of this research. It would be good to continue working on fossil identification. Also, it is a certainty that there are fossil species that have yet to be retrieved from the New Ulm site till. More samples should be washed and searched in order to make a more distinct fossil assemblage for the New Ulm site till.

The till should be correlated more definitely to regional tills. More comparing of grain size and type should be done in order to correlate this till to other gray tills of the area. Samples from area gray tills should be washed and searched for microfossils to determine whether or not they contain fossils similar to those found in New Ulm. The area should be searched for outcrops to determine the lateral extent of the New Ulm site till.

The New Ulm site has proven to contain much more information than could be extracted in the year that I have been working with it. There is much more work that can be done and, I am certain, many more interesting things to be discovered.

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