

Geomorphic and Sedimentologic Origins of a Terrace
In Seven Mile Creek Park, Nicollet County, Minnesota

By

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Under the supervision of Dr. Julie Bartley

ABSTRACT

A terrace located in Seven Mile Creek Park, Nicollet County, MN, sitting 3-5 meters above the current floodplain of Seven Mile Creek, was studied to determine depositional environment following glacial retreat 10,000 years ago. Seven Mile Creek is a tributary to the Minnesota River, and drains a 36.8 square mile watershed. Based on sedimentary analysis of samples collected from terrace strata, the terrace is interpreted to have been formed by intermittent deposition of fluvial and colluvial materials. An attempt to constrain the age of deposition by optically stimulated luminescence dating was unsuccessful, but the data results suggest that following glacial deposition, sediment transport distances were short.

Acknowledgements

I would like to thank the Gustavus Geology faculty- my advisor Dr. Julie Bartley, Dr. Laura Triplett, and Dr. Jim Welsh, all of whom helped me so much during my time at Gustavus. My experience here simply would not be the same without them- I learned many valuable lessons from each of them, both in the classroom and in the field. Special thanks also goes to Dr. Tammy Rittenour, who allowed me to learn the OSL process in her lab- something that undergrads rarely have the opportunity to do. I want to thank Sigma Xi, the Scientific Research Society, for funding allowing OSL dating, and the Gustavus Geology Dept. for additional funding and facilities. Many thanks to my field partner, Adam Lund, for being a fantastic field partner. Thanks to Tara Selly for keeping me on track throughout the summer, and the rest of my peers in geology, for being so fantastic and supportive. Finally, thanks to my mother and father for their love and support throughout my life.

Without these people, none of this would have been possible.

You all rock

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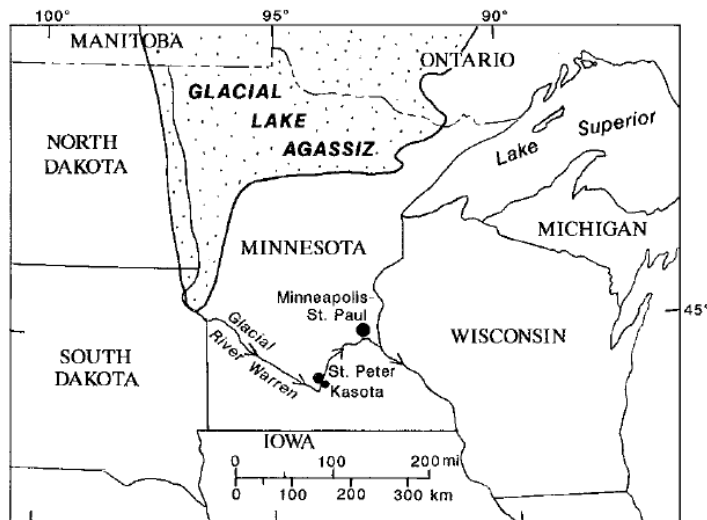
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Introduction

Approximately 11~12ka, when the Des Moines lobe of the Laurentide Ice Sheet retreated north, river and stream systems in south-central Minnesota responded to a landscape altered by thousands of years of glacial and inter-glacial phases. During the retreat, Glacial Lake Agassiz, an enormous melt-water lake, at times larger than all of the present Great Lakes combined formed in south-central Canada, eastern Dakotas, and northwestern Minnesota (Ojakangas & Matsch, 1982). As water levels in Lake Agassiz rose, a moraine dam was overtopped releasing Glacial River Warren, which ultimately carved the present day Minnesota River Valley (Ojakangas & Matsch, 1982).



<Figure 1: The Upper Midwest, showing Glacial Lake Agassiz, Glacial River Warren, and St. Peter.

(Johnson, M.D. 1998)

River Warren is the most influential recent geologic event in the area; it set the stage for the evolution of Seven Mile Creek. When base-level drops, tributaries down-cut to reestablish equilibrium. Today, Glacial River Warren's channel is occupied by the much smaller Minnesota River, which is the local base level for small tributaries like Seven Mile Creek. This thesis investigates the geomorphic and sedimentologic origins of a terrace in Seven Mile Creek watershed, which is thought to have been left behind as Seven Mile Creek down-cut to reach equilibrium with base level (Jennings et. al, 2010).

The basis for this research comes from work by Jeremy Bock (2010), who created the first surficial geologic and geomorphic map of Seven Mile Creek Park (Figure 1). Bock used a high-resolution digital elevation map (DEM) of the park to define three levels of terrace features by elevation above the current floodplain, as well as alluvial fans and colluvial shelves. The different levels of terrace features indicate intermittently stable local base level (Jennings et. al, 2010). This study investigates the sedimentologic origins and geochronology of one of Bock's defined terrace formations. The terrace feature sits 3-5 meters above the current floodplain; there are terraces both above and below the terrace of this study. Based on location, the terrace of the study must be older than the terrace below it, and younger than the overlying terrace. Geochronology was used to attempt to constrain timing of terrace deposition.

The terrace featured in this study is located in the south-east part of Seven Mile Park, approximately 50 meters south of the current channel, as marked by the arrow in Fig. 1.

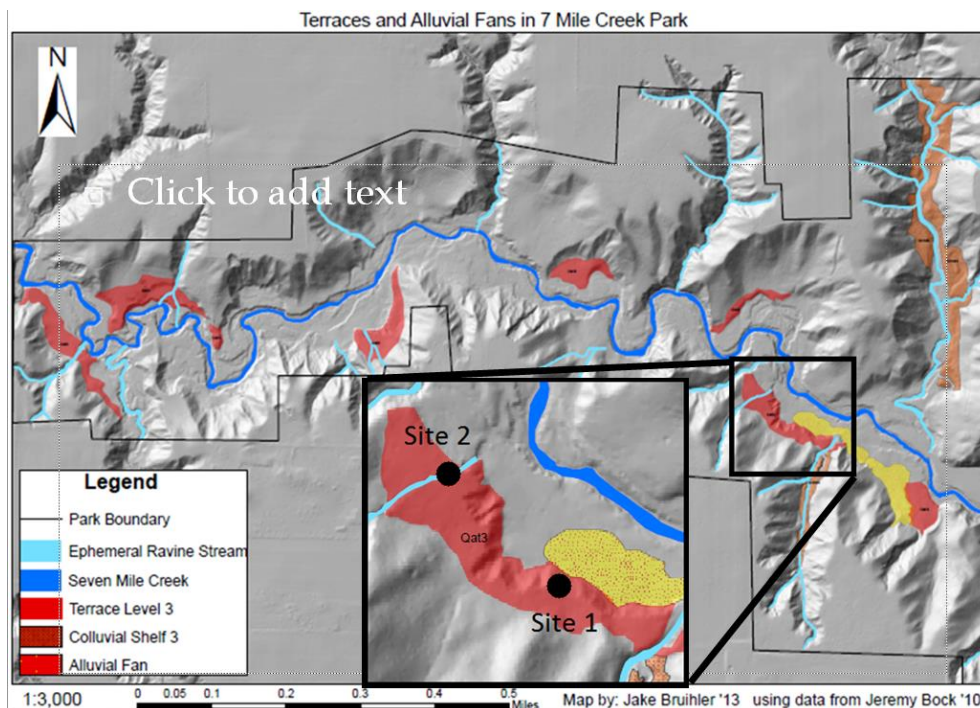


Figure. 2- Digital Elevation Model of Seven Mile Creek, terrace (red) of study is enlarged in box; sample locations are marked

This thesis questions the origins of the terrace feature. Initial field observations indicate that the terrace may have formed from a combination of two types of deposition- fluvial, and colluvium. Fluvial sediments are stream deposits. Colluvium deposits are the result of destabilization on a slope, in which sediment is driven by gravity, usually in the presence of water. The purpose of this study is to understand the origin of the terrace formation. This will improve knowledge of stream evolution in a post-glacial setting, and provide a better understanding of the geologic history of Seven Mile Creek Park.

Geologic Setting

Seven Mile Creek has incised through several geologic units. The lowermost exposed unit is the Jordan Sandstone, which was deposited on the shores of an ancient inland sea during the Cambrian Period. The Ordovician-aged Oneota Dolomite, which sits atop the Jordan at other localities in the area, is not visible in outcrops in Seven Mile Creek. Unconformably overlying the Jordan Sandstone in Seven Mile are several packages of Quaternary till, sand, & gravel. The valley floor of Seven Mile Creek is underlain by Quaternary fluvial deposits.

According to Meyer, et. al. (2012), there are four distinct till packages found in Seven Mile Creek Park. The lowermost till is the Moland Member till, which was deposited by an early phase of the Des Moines lobe. Thin layers of sand and gravel are present in the Moland Member. Above the Moland lie both the Lower Heiberg Member, and a sand and gravel layer (Qsm). The Qsm is intermittently present, and was deposited by Des Moines lobe melt water. Above the Lower Heiberg and Qsm lies the Upper Heiberg. This is the uppermost till (youngest) is the Upper Heiberg member. The Heiberg members are essentially the same, however glacial

advance is thought to have paused or retreated slightly, as there is organic material found in well logs between these till units.

Post glacial sediments in Seven Mile Creek Park are predominantly sand and gravel deposited in horizontal layers by modern streams in channels. Many modern streams re-occupy glacial channels, so unit may be coarser in places because of reworking of glacial sediment (Jennings, 2010).

Previous Work

Charles Matsch (1972) published work about the glacial stratigraphy of southwestern Minnesota. He also discussed terrace features within the Minnesota River Valley. However, following the publication of the Nicollet County Geologic Atlas, much of this work is outdated. Till units identified by Matsch have been consolidated and renamed in the County Atlas.

Meyer et. al. (2012) produced the Nicollet County Geologic Atlas. Jennings et. al, (2010) investigated the surficial geology of Seven Mile, identified till and rock units present, and discussed ravine dynamics and stratigraphy within the Park. According to Jennings, the till units found in Seven Mile Creek Park are the Upper and Lower Heiberg members. The Heiberg members are separated in places by a thin sand layer. These sand bodies may have been deposited by melt water from the Des Moines lobe. Both Heiberg members are thought to have been deposited by the Des Moines lobe of the Laurentide Ice Sheet.

Bock (2010) created a geologic map of Seven Mile Creek. Many geomorphic features were identified using a Hi-Res DEM. This work was vital to my thesis; it made small features visible and ultimately made the fieldwork much faster and easier.

Methods

The terrace was studied at two different sites (Figure 2). The sites are approximately 100 meters apart. Site 2 sits approximately 5 meters above and 100 meters west of Site 1; this difference in elevation is caused by the slope of Seven Mile Creek. Sites were chosen based on accessibility and presence of exposed stratigraphy.

Samples were collected in sediment layers that were chosen based on >2" bed thickness, to avoid inter-layer contamination. Approximately 100g of each sediment sample was scooped into sediment cups and sealed.

Two 2.5" diameter clear tubes (one tube at each site) were pounded deeper into stratigraphy, to collect sediment from deeper in the terrace without causing further damage to a vulnerable surface. Each core was divided into four even sections, which provided material for rough grain size distribution from deeper in the terrace. This provided an additional four sediment samples per site.

At Site 1, two samples were collected different elevations on the terrace face ~2 meters apart vertically (one near the top, the other near the bottom) on the terrace face within close proximity of each other (Figure 3). A small hole was dug at the lower location, exposing a thick sand lens. The upper location was previously exposed from slumping events. One tube sample was also collected at this upper location.

At Site 2, a small waterfall cut a fantastic exposure, and five samples were collected in a vertical sequence, within each distinct layer. A tube sample was also collected at the waterfall site.

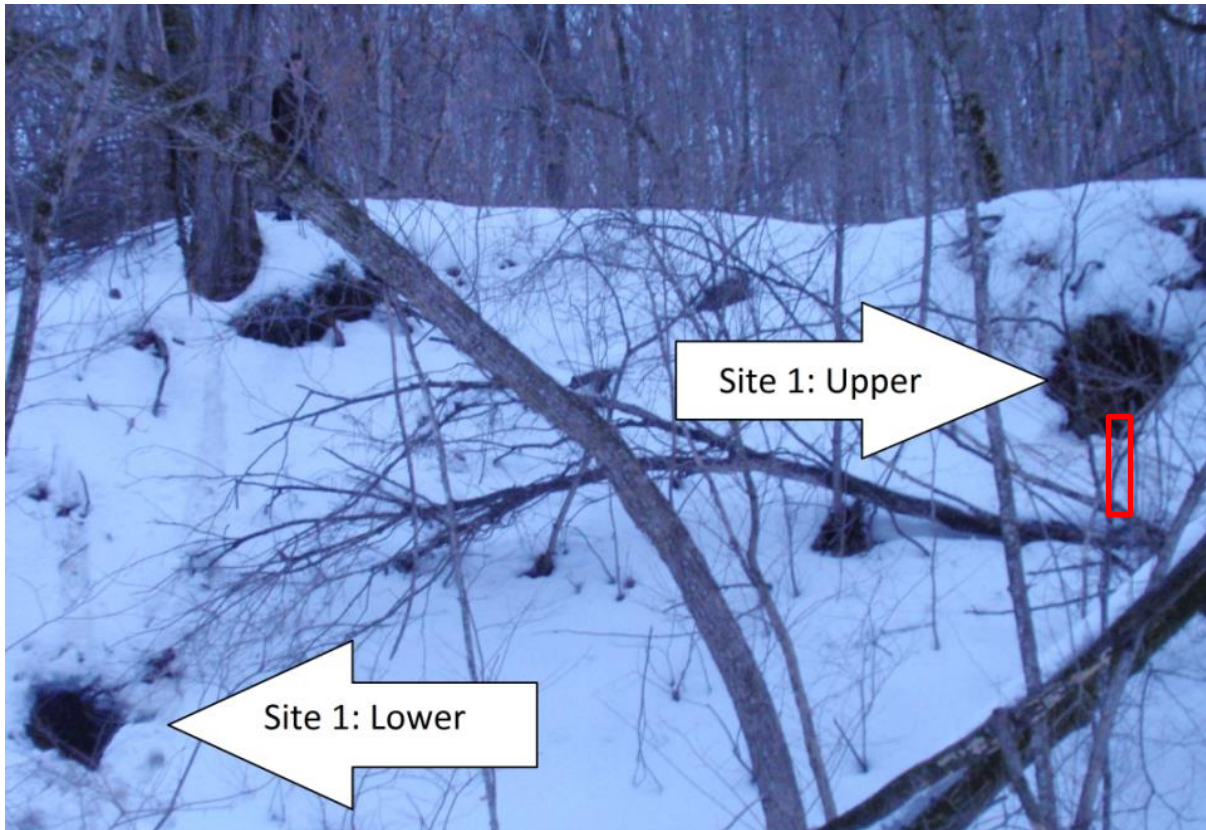


Figure 3 (above): Site 1 Locations:

(1-1) Lower and (1-2) Upper. Terrace face starts slightly below Site 1-1. Site 1-1 is ~2 meters below Site 1-2

Blue rectangles on Figures 5-7 indicate sediment sample collection layers. Tube samples were collected in areas with Red rectangles. OSL sample locations are marked by Green Circles

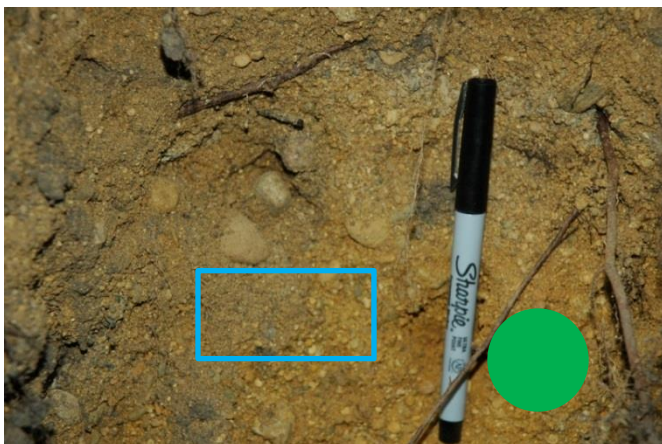


Figure 5 (above): Site 1-1: note massive coarse sand lens



Figure 6 (above): Site 1-2: Note bedding planes and keys for scale.

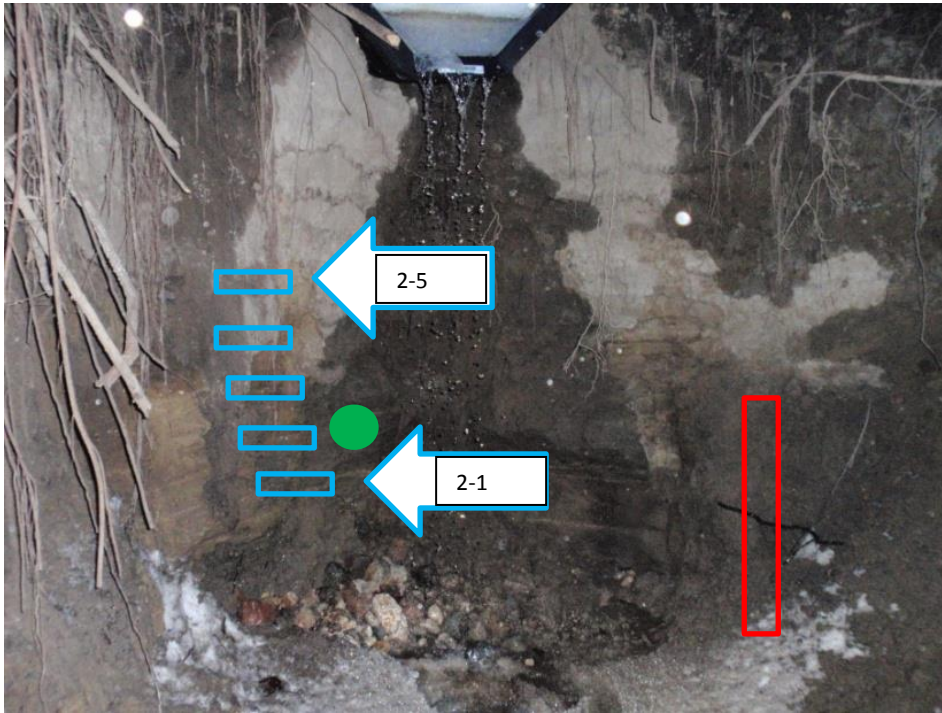


Figure 7: Site 2

Location:

Waterfall- note

bedding in bottom

1/2 of photo

“Standard” samples were collected by Lund (2013) from known colluvium/alluvium, fluvial sediments, and till deposits in the park. These standards were collected for comparison with samples collected from sampling sites on the terrace. It is worth noting that the standards were collected from only one location per standard. In reality, these standards cannot be entirely accurate. One sample collected from one known location of a known geomorphic feature cannot accurately portray a ‘standard’ to compare other samples to. Sediments will vary between locations, and even within a single location. Regardless, the standards serve the general purpose for comparison of samples collected from terrace sites in this study to a typical sediment found in Seven Mile Creek Park. Standards underwent the same sedimentologic analysis as the rest of the samples from the terrace in this study.

Samples were freeze-dried overnight to remove moisture. The samples were then weighed and sieved down the Φ scale (-1 \rightarrow 5) on a mechanical sieve shaker. Each step of the Φ scale represents a halving of grain size (2000 μ m \rightarrow 1000 μ m \rightarrow 500 μ m... \rightarrow 62.5 μ m), and separates grains from very coarse to very fine. Sieved grains were then massed and compared to pre-sieve total mass. Loss was typically <1%, and can be attributed to grains vibrating out of sieve set, and loss between containers and sieves.

Statistical analysis of sediments was done using an application called GRADISTAT Version 8.0, developed by Dr. Simon J Blott and Kenneth Pye (2001). Statistics calculated include degree of sorting, textural group, sediment name, and averages between samples. These statistics allow for comparison between other methods of grain size analysis, notably the Folk and Ward (1957) method.

After sample materials were weighed, the sediments were visually analyzed for mineral content and grain shape under low-power microscopy. Percentages of mineral content were visually estimated, as was rounding. These analyses are useful for determining sediment source and helpful in determining sediment source material, and grain shape (degree of rounding) is telling of the distance travelled (Twenhofel, 1945).

Samples were also collected from Site 1-1 and Site 2-2 for Optically Stimulated Luminescence (OSL) dating. OSL dating is used to constrain geochronology of sediment deposition. A 10 inch long steel pipe was pounded into bedding >2" thick (again to prevent inter-layer contamination). Exposure to light makes OSL ineffective, so pipes were capped immediately, and the ends (which were exposed to light) were not used in OSL analysis. At Utah State University's Optically Stimulated Luminescence (OSL) lab, sediment samples were

prepared be run on the Risø OSL reader, which measures photoluminescence of quartz grains, giving a burial date for terrace sediment.

Essentially, when a sand grain (quartz or feldspar) is buried, it is exposed to small amounts of radiation naturally occurring in the substrate. This radiation damages the crystal structures, leaving measureable deformations in the crystal lattice (i.e. point defects). When the crystal is exposed to radiation (sunlight), the deformations are erased, and the crystals are 'reset.' In the lab, the OSL reader exposes the crystals to radiation and measures the resulting luminescence. The photoluminescence measured is corollary to the amount of radiation received in the substrate; together, these data are used to calculate how long sediment has been buried (Murray and Wintle, 2000, 2003). The procedure used at Utah State follows the Standard Aliquot Regenerative Dose (SAR) method. Murray and Wintle (2000, 2003) developed the SAR and revised SAR protocol for OSL dating. The SAR & revised SAR protocol are the most widely used OSL dating protocols.

Results

Site 1- Terrace Face

Samples at Site 1 were collected from the terrace face. The face of the terrace at this location was close to vertical, with plants and trees growing in a thin soil layer which had slumped down the slope. This vegetation caused some bioturbation of sediments at both the lower and upper sampling locations. At the lower site, a thick, coarse sand lens was exposed. At the upper exposure, strata had previously been exposed through mass wasting.

Site 1-1 (Lower Terrace Face)

No bedding was observed within the lower lens; the sediments were unsorted, with a wide size variety, ranging between clay and small cobbles. Statistically, the lens was classified as poorly sorted sandy gravel. The majority (% mass) of this sediment fell in the grain size range of -1Φ to 2Φ . The mean grain size and rounding classified as very coarse, sub-angular sand. Kurtosis was leptokurtic, indicating a concentration of mass near the middle of the grain size scale. Further analysis of sediment can be seen in Table 7 and Figure 12.

OSL results at this site (sample USU-1165) were calculated to be 34.8 ± 7.8 ka. The dose rate used was 2.29 ± 0.10 Gy/ka. Sixty aliquots were measured; of these only twenty aliquots were used for this calculation due to issues with partial bleaching of quartz grains in the sample. Further OSL data can be seen in Figure 13.

Site 1-2 (Upper Terrace Face)

Bedding is present in thin, nearly horizontal layers. Sediment appeared to be medium grained sand, with a typical tan color. Some grading was present in the beds. Sediments in this sample site had less grain size variation than those at the lower site. Statistically, this site was classified as poorly sorted slightly gravelly sand. The majority (% mass) of sediment lies in grains between 1Φ to 3Φ . The mean grain size and rounding classified as sub-rounded medium grained sand. Kurtosis was leptokurtic, indicating a concentration of mass near the middle of the grain size scale. Further analysis of sediment can be seen in Table 7 and Figure 10.

Site 1: Tube Samples

Tube samples were collected to obtain sediment for analysis without removing large amounts of sediment from a vulnerable surface. Statistically, sediments from this tube classified between moderately and poorly sorted slightly gravelly sand. The majority (% mass) of sediment lies in grains between 1Φ to 3Φ . The mean grain size and rounding was classified as sub-rounded to sub-angular medium sand. Kurtosis was leptokurtic, indicating a concentration of mass near the middle of the grain size scale. Variation in these samples was wide; this was expected because of the tube splitting. Further analysis can be seen in Table 7, as well as Figures 10 and 11.

| Table 7 | Site 1.1 | Site 1.2 | Site 1 Tube |
|--------------------|--|--|--|
| Sieveing Error (%) | 1.2% | 1.3% | 1.6% (average) |
| Sorting | Poorly | Poorly | Poorly ($\frac{1}{4}$, $\frac{3}{4}$) Moderately ($\frac{2}{4}$, $\frac{4}{4}$) |
| Textural Group | Sandy Gravel | Slightly Gravelly Sand | Slightly Gravelly Sand |
| Mean | Very Coarse Sand | Medium Sand | Medium Sand |
| Skewness | Fine Skewed | Symmetrical | Symmetrical |
| Kurtosis | Leptokurtic | Leptokurtic | Leptokurtic |
| Mineralogy | 50% Quartz 20% Feldspar 30% Clasts | 70% Quartz 20% Feldspar 10% Clasts | 60-70% Quartz 15-20% Feldspar 15-20% Clasts |
| Rounding | Sub Angular | Sub Rounded | Sub Round.-Sub Ang. |

Table 7 describes the statistical and lab analysis of sediment samples from Site 1

Site 2- Waterfall

At Site 2 (Figure 8), five samples were collected in vertical succession (top to bottom) in distinct layers of sediment at the waterfall cut. A tube of sediment was also collected here, in the same fashion and for the same reasons as at Site 1. Visual analysis of the cut identified distinct layers of sand/gravel divided by packages of un-layered material; likely slightly re-worked till. Bioturbation was less prevalent in these samples, as the flowing water and depth

beneath soil discourages plant growth. Further analysis was completed for each of the samples, and is shown in Tables 8 (sediment samples) and 9 (tube samples), as well as Figures 10, 11, and 12.

Sample 2-1: (Lowermost Waterfall Sample)

No bedding planes were present; sediment was dark brown in color. Sediment was poorly sorted; many grain sizes (pebbles, sand, and clay) were visible to the naked eye. Statistically, this sample was classified as poorly sorted gravelly sand. There is no clear majority (% mass) of sediment; but the mass distribution of this sample fell between grain sizes -1Φ to 4Φ . The mean grain size and rounding classified as well rounded medium sand. Kurtosis was mesokurtic, which indicates that concentration of mass is near the middle, but is more widely spread than a leptokurtic kurtosis. Further analysis can be seen in Table 8 and Figure 12.

Sample 2-2

Fine grained laminar bedding was present in this distinct sand layer. A few small pebbles were sporadically inter-bedded in this sample. Statistically, the sample is characterized as poorly sorted slightly gravelly sand. The majority (% mass) of sediment falls between 1Φ to 4Φ . The mean grain size and rounding classified as sub-angular fine sand. Kurtosis was very leptokurtic, indicating a high concentration of mass in the middle of the grain size scale. Further analysis of sediments can be seen in Table 8 and Figure 11.

OSL results at this site (sample USU-1166) were calculated to be 13.8 ± 2.5 ka. The dose rate was 1.67 ± 0.08 Gy/ka. Fifty three aliquots were measured; however only thirty six aliquots were used due to issues with partial bleaching. Further OSL data can be seen in Figure 13.

Sample 2-3

This layer is a non-bedded massive package of dense, brownish gray poorly sorted material. The layer appeared to be very poorly sorted- grain sizes ranged from silt particles to small cobbles ~6cm in diameter. Statistically, this sample is classified as very poorly sorted, slightly gravelly muddy sand. The mass of this sample was not confined to a peak; there was no clear majority (% mass) of sediment; it falls between 0Φ to 5Φ . The mean grain size and rounding classified as sub-angular to angular fine grained sand. Kurtosis was platykurtic, indicating that there was no clear concentration of mass. Further analysis of sediments can be seen in Table 8 and Figure 12.

| Table 8 | Site 2.1 | Site 2.2 | Site 2.3 |
|--------------------|---|--|--|
| Sieveing Error (%) | .7% | 2.6% | .4% |
| Sorting | Poorly | Poorly | Very Poorly |
| Textural Group | Gravelly Sand | Slightly Gravelly Sand | Slightly Gravelly Sand |
| Mean | Medium Sand | Fine Sand | Fine Sand |
| Skewness | Coarse Skewed | Fine Skewed | Fine Skewed |
| Kurtosis | Mesokurtic | Very Leptokurtic | Platykurtic |
| Mineralogy | 80% Quartz 15% Feldspar 5% Clasts | 75% Quartz 15% Feldspar 10% Clasts | 50% Quartz 10% Feldspar 40% Clasts |
| Rounding | Well Rounded | Sub Angular | Sub Angular-Ang. |

Table 8 describes the statistical and lab analysis of sediment samples from terrace

Sample 2-4

This layer consisted of very coarse sand deposited in small (cm scale) cross beds. Small pebbles were common throughout this sample; it was poorly sorted. Statistically, this sample is classified as poorly sorted, slightly gravelly sand. The majority (% mass) of sediment lies in grains at -1Φ . The mean grain size and rounding classified as sub-rounded medium sand. Kurtosis was mesokurtic, indicating a slight concentration of mass in the middle grain sizes, but

overall the mass is spread throughout different grain sizes. Further analysis of sediment can be seen in Table 9 and Figure 12.

Sample 2-5 (Uppermost Waterfall Sample)

The uppermost sample was taken in a layer of coarse, massive material, identified visually as very coarse sand. Small pebbles were common, indicating poor sorting. Statistically, the sample is classified as poorly sorted sandy gravel. Percent mass of this sample fell in grain sizes between 0Φ to 3Φ . The mean grain size and rounding classified as sub-rounded to sub-angular very coarse sand. Kurtosis was leptokurtic, indicating a concentration of mass near the middle of the grain size scale. Further analysis can be seen in Table 9 and Figure 11.

Site 2: Tube Samples

Statistically, all sediments from this sample classified as poorly sorted, slightly gravelly sand. The majority (% mass) of sediment lies between 0Φ to 4Φ . The mean grain size and rounding was classified as sub-rounded to sub-angular medium sand. Variation within this sample was surprisingly small; more was expected due to splitting. Further analysis can be seen in Table 9, as well as in Figures 10 and 11.

| Table 9 | Site 2.4 | Site 2.5 | Site 2 Tube |
|--------------------|--|--|--|
| Sieveing Error (%) | 2.2% | .6% | 1.2% (average) |
| Sorting | Poorly | Poorly | Poorly (all) |
| Textural Group | Slightly Gravelly Sand | Sandy Gravel | Slightly Gravelly Sand |
| Mean | Medium Sand | Very Coarse Sand | Medium Sand |
| Skewness | | Fine Skewed | Symmetrical(except ¹ / ₄) |
| Kurtosis | Mesokurtic | Leptokurtic | Mesokurtic (all) |
| Mineralogy | 70% Quartz 15% Feldspar 15% Clasts | 80% Quartz 10% Feldspar 10% Clasts | 75-80% Quartz 10-15% Feldspar 5-15% Clasts |
| Rounding | Sub Rounded | Sub Round.-Sub Ang. | Sub Round.-Sub Ang. |

Table 9 describes the statistical and lab analysis of sediment samples from terrace

FINAL OSL AGE REPORT

Project: 7-mile Creek

Project #: 139

Scientists: Laura Triplett and Jake Bruhler

Report by: Tammy Rittenour

Report Date: March 28, 2013

OSL Age Information¹

| USU num. | Sample num. | Num. of aliquots ² | Equivalent Dose, De (Gy) ³ | Overdispersion (%) ⁴ | Dose Rate (Gy/ka) | OSL Age (ka) ⁵ |
|----------|-------------|-------------------------------|---------------------------------------|---------------------------------|-------------------|---------------------------|
| USU-1165 | JB 12-01 | 20 (60) | 79.64 ± 16.15 | 27.1 ± 5.9 | 2.29 ± 0.10 | 34.8 ± 7.8 |
| USU-1166 | JB 12-02 | 36 (53) | 23.10 ± 3.44 | 37.0 ± 4.9 | 1.67 ± 0.08 | 13.8 ± 2.5 |

¹Age analysis using the single-aliquot regenerative-dose procedure of Murray and Wintle (2000) on 1-mm small-aliquots of quartz sand. Preheat and cut heat temperatures were 240°C and 160°C, respectively and held over 10 seconds.

²Number of aliquots used for age calculation, number of aliquots measured in parentheses. Rejection of aliquots follows standard rejection criteria (see Rittenour 2005 for example).

³De calculated using the Minimum Age Model of Galbraith et al (1999), error on De is 2-sigma standard error.

⁴Overdispersion represents scatter in De beyond calculated uncertainties in data, OD >20% is considered significant.

⁵Error on age is 2-sigma standard error; ages are expected to be overestimates due to extreme partial bleaching.

Figure 13. Final OSL Age Report

Discussion

Site 1 Interpretations

The lower locality of Site 1 consisted of a massive, approximately meter thick, unstratified sand lens. Analysis of this sample did not correlate with any standards of fluvial sediment, alluvium, or colluvium materials collected by Lund (2013) (Figure 12). Deposition of this sediment is interpreted to have happened quite quickly, possibly in one event. I have interpreted this as a single large event because the lens is relatively homogenous, non-bedded, and has no characteristics of a long period of deposition. Transport distance was likely quite short, based on the angularity and sorting of the sediment (Twenhofel, 1945). The deposition is certainly not fluvial in origin; it is different from all other sediments in the terrace. These

characteristics indicate that the lens is colluvium, a gravity driven deposition from a destabilized slope.

OSL dating of Site 1.1 (USU 1165) supports interpretation as colluvium. The sample was partially bleached, meaning that quartz crystals in the sediment were not fully exposed to sunlight prior to burial. There are a variety of reasons for the partial bleaching, but it fits well with a colluvial deposit. Colluvium essentially slides down a slope; this would not necessarily expose all of the sediment to light.

The upper locality of Site 1 was much different than the lower unit of the same site. Small scale (centimeter scale) graded bedding was present, which is a strong indication of fluvial deposition and constant flow in one direction (Trommelen, 2008). Sediment analyzed here was moderately sorted; much of the bulk was between 500 and 125 μm (1 to 3 Φ scale). This sample visually correlated to the colluvial standard collected by Lund (2013), indicating fluvial origins (Figure 10). Sand grains are sub-rounded, indicating that transportation distances were moderate, or the grains had high levels of impaction during transportation. The Seven Mile Creek system is not likely to round grains to this degree- rounding requires impacts with other grains of hard minerals. While there are other sand grains being transported, there are too many soft minerals that decrease impacts, and reduce amounts of rounding in quartz grains (Twenhofel, 1945). Also, Seven Mile Creek is not long enough for this degree of rounding to occur solely in the Creek. Much of the rounding likely occurred previously- likely from glacial transport of previously-rounded materials such as the Jordan Sandstones common throughout the area.

Analysis of the tube of sediment that was collected at the upper locality of Site 1 was also characterized as alluvially deposited sediment. Similarly to the upper locality at site 1, rounding probably occurred before the grains entered Seven Mile Creek. Samples 2/4 and 3/4 visually correlated quite well with the fluvial standard (Lund, 2013), while samples 1/4 and 4/4 also correlated, though not as well (see Figures 10 and 11). This is also open to other interpretations- more standard samples are needed for accurate correlation.

Site 2 Interpretations

Site 2 is interpreted to be mostly colluvial sediments deposited by slope destabilization; presence of water likely played a role in these mass wasting events. There are many small, intermittent layers of graded sand beds. The best interpretation for this sequence is deposition of thick colluvial layers, intermittently eroded by Seven Mile Creek. Following the erosive events, the bedded layers were likely deposited. This sequence repeated itself over time, leaving the alternating thick colluvial layers cut by thin layers of fluvial deposits.

Individual samples support this interpretation. The lowermost sample (2.1) was sub-rounded, indicative of long transportation distances (Twenhofel, 1945). It also had low visual correlation to the fluvial standard when plotted in a histogram. This sample is interpreted as a fluvial deposit. This sediment sits on top of a sediment layer appearing to have colluvial origins, and it is possible that fine grains from that layer may be skewing of the curve towards the fine-grained end of the curve. The next sample upwards (2.2) had no bedding or other signs of fluvial deposition. The layer the sample was collected from was massive and poorly sorted. Grains were sub-angular. Sample 2.2 is interpreted to as colluvial sediment.

OSL dating of sample 2.2 (USU 1166) was badly ‘partly bleached,’ indicating that the crystals were not exposed to full sunlight before deposition. Unfortunately, partial bleaching also means that deposition dating is not accurate. The OSL dates for this sample are too old; Seven Mile Creek was still glaciated at the time the OSL dates suggest sediment was buried.

Continuing upwards, sample 2.3 was a thin layer (10cm) of very poorly sorted material. Grains were angular, and no bedding was present; there were no indications of fluvial deposition. This sample is also interpreted to be colluvial material. Sample 2.4 was a small layer of cross-laminated sediment approximately 5cm thick. Grains were sub-rounded to sub-angular, indicating short transportation distances and little re-working (Twenhofel, 1945). Based on the slight correlation to the fluvial standard, this sample is interpreted as fluvial deposition shortly following the deposition of the underlying colluvial material (sample 2-3). The Uppermost sample collected at Site 2 (2.5) from a massive (½ meter thick), poorly sorted, layer. No bedding planes or other characteristics of fluvially deposited sediment were present. This unit is interpreted as colluvial sediment.

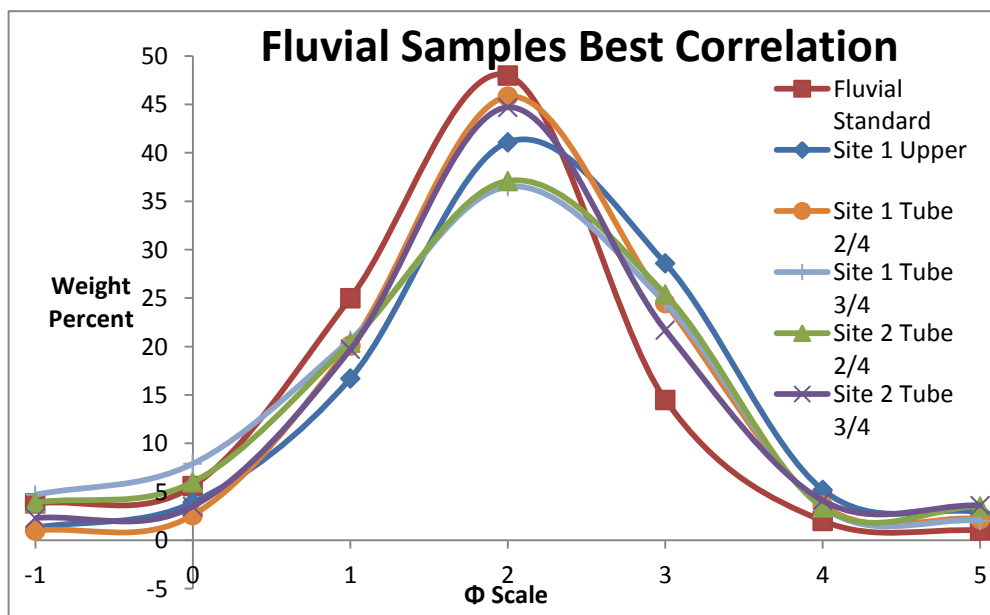


Figure 10: Best fitting curves of samples compared to Fluvial Standard (Lund, 2013)

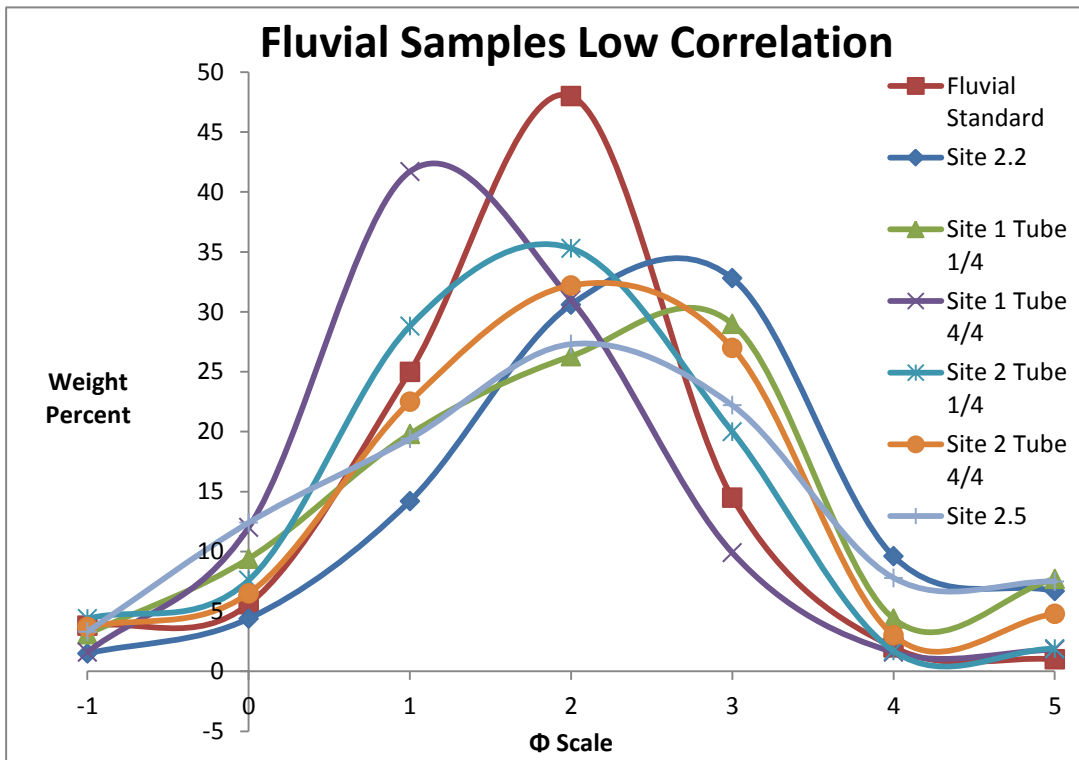


Figure 11:
Low-
correlation
curves
plotted with
Fluvial
Standard
(Lund, 2013)

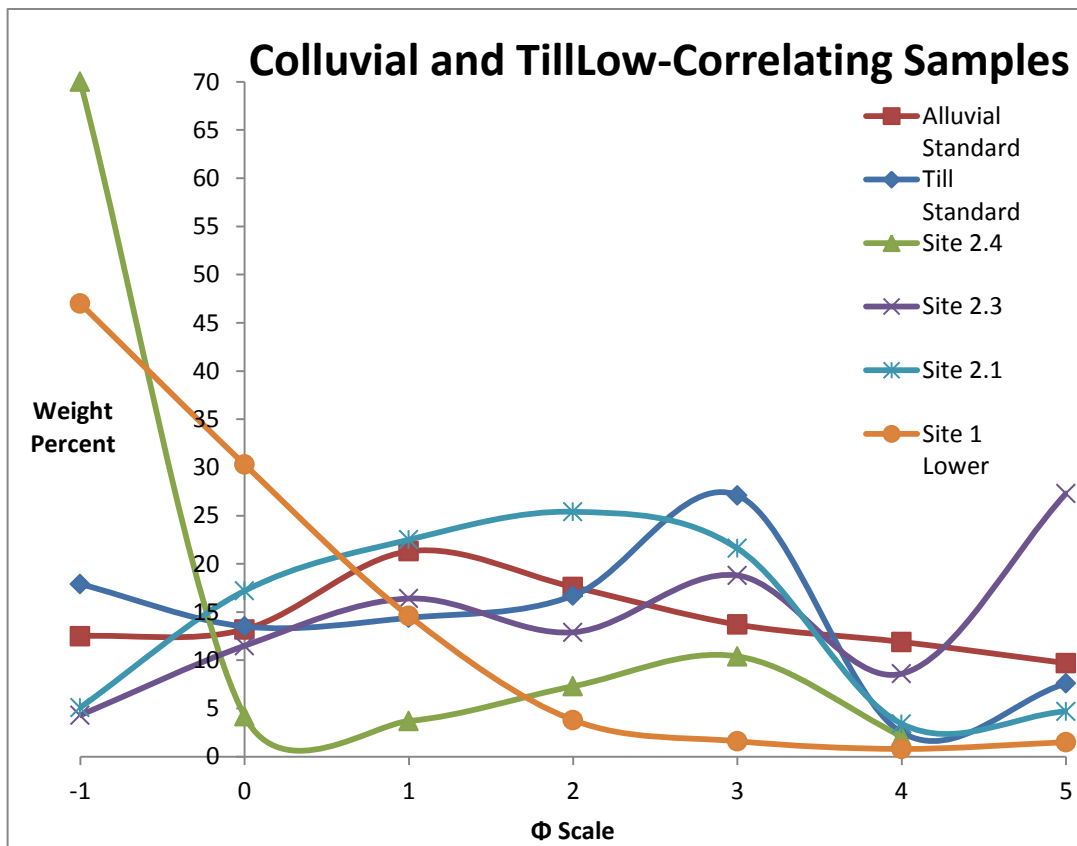


Figure 12:
Low-
correlation
curves plotted
with Colluvial
and Till
Standards
(Lund, 2013)

Overall, the terrace is interpreted to have formed through both colluvial (gravity & non-constant water flow) and fluvial (strictly stream/water-lain) deposition. Sediment deposition in the terrace appears to be mainly colluvial, with occasional fluvial deposition events. Fluvial layers tend to be thin, bedded, and medium grained; these are separated by much thicker layers of coarse grained, un-bedded massive colluvial layers. Massive, poorly sorted layers with a lot of variation in grain size are much more prevalent than fluvial deposits. Rain events, freeze-thaw cycles, and slope over-steepening likely led to colluvial deposition occurring intermittently. It is assumed that the ancestral Seven Mile Creek was not powerful enough to wash away the entirety of these sediments, with intermittent fluvial deposition atop the colluvial deposits.

The main till units in the park are the Upper and Lower Haiberg Members (Meyer et. al, 2012), and are the source unit for most of the sediments in the terrace. The ravines within Seven Mile Creek Park are quite steep, meaning that energy rates of the flow are high (Monegato, 2011; Trommelen, 2008), as is the erosive power. After Glacial River Warren lowered local base level dramatically, Seven Mile Creek down-cut to re-gain equilibrium, while depositing beds of medium-poorly sorted medium sand. As the channel incised through the glacial till, over-steepening of ravines likely occurred, leading to mass wasting events flowing into the Seven Mile Creek. Also, during periods of high water flows (summer storms, spring melt), the weakened ravine edges would have slumped towards the stream, forming the thick, poorly sorted layers seen in the terrace outcrop today. Fluvial deposition would have continued atop the slumped material, creating the oscillating pattern between fluvial and colluvial deposits. If the creek was roughly the same size in the past as it is now, there may have not been enough erosive energy to wash away all of the sediment deposited by these colluvial events. This pattern of fluvial beds lying between colluvial layers occurs at each of the sampling sites, and is also

observed (although not formally discussed) at other localities along the terrace. This process occurred over thousands of years following the last glacial maximum.

In comparison, the two sites are both similar and different. Because of differences in elevation, I do not believe that any two samples come from a single stratigraphic layer. The sediment source comes from two different ravines; though they both cut through the same till packages, the ravine above Site 2 is much larger than the ravine above Site 1. None of the samples were statistically well sorted; this was also expected because of a few different factors; the largest being that Seven Mile is not a very long nor high energy stream, which is likely a factor in the poor sorting. The Creek likely does not have the time (distance) or energy to sort sediment very well. Also, if high volumes of colluvium were entering the stream system, it is even less likely that the Creek would have the ability to sort it effectively within its entire length. However, if the entire face of the terrace was exposed, I suspect that a portion of the layers would extend across much of the length.

Conclusion

The terrace feature studied in this thesis has been interpreted to have originated from both colluvial and fluvial modes of deposition. There is solid evidence for each, both of which are backed up by thorough field mapping and statistical analysis. This conclusion fits very well with knowledge of local geology and the impressive geomorphic changes that are happening in Seven Mile Creek Park at present. Because the stream was forced to incise through 100+ feet of till to regain equilibrium following Glacial River Warren, it makes sense that the slopes would be significantly destabilized, especially in periods of high precipitation. However, during these

periods of high precipitation, it can also be assumed that flow rates in Seven Mile Creek would be high, leaving behind fluvially deposited materials.

There is potential for future work in Seven Mile Creek Park. I would be very interested to see if there is correlation between terrace levels in Seven Mile Creek Park and those in the Minnesota River Valley. Another idea that has potential is ground-penetrating radar analysis of the terraces and floodplains within Seven Mile Creek Park. This could also be expanded to some of the larger tributaries in the area- the Le Sueur & Blue Earth Rivers would potentially have left behind terraces during periods of rapid down-cutting due to changing base level and equilibrium in the post-glacial era.

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