A Stratigraphic and Sedimentological Study of Cretaceous Strata at Flandrau State Park, New Ulm, Minnesota

By: Dylan Blumentritt
Advisor: Julie Maxson
Gustavus Adolphus College

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ABSTRACT

Cretaceous sandstone and shale were deposited on the Cretaceous Interior Seaway margin in the New Ulm, Minnesota area. Outcrops of Cretaceous sediment in this area are not common, and subsequently are not well understood. Two outcrops near Flandrau State Park were measured, and the sediments were described through the aid sieve analysis and thin sections. Stratigraphic columns depicting distribution and lithology of Cretaceous sediment were correlated with other recent studies of the area, and give further evidence towards deposition processes.

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FIGURES

INTRODUCTION

Cretaceous deposits formed when the eastern edge of the Cretaceous Western Interior Sea covered the western portion of what is now Minnesota (Figure 1). The outcrops in Flandrau State Park, along the Cottonwood River (Figure 2), consist primarily of sandstone, shale, and conglomerate, and were most likely deposited in the late Cretaceous period during the Cenomanian age (Setterholm, 1994). The rocks in the study area are hypothesized to show a trend of marine deposits to the west, to more non-marine deposits to the east, indicating a depositional environment at the margin of this sea (Setterholm, 1994). The purpose of this study was to investigate the outcrops of Cretaceous sandstone, shale, and conglomerate in Flandrau State Park on the Cottonwood River to better understand the nature of deposition. The outcrops were described and analyzed in detail in order to correlate them with sections described by Blaha (1996) and Joslin (2001).

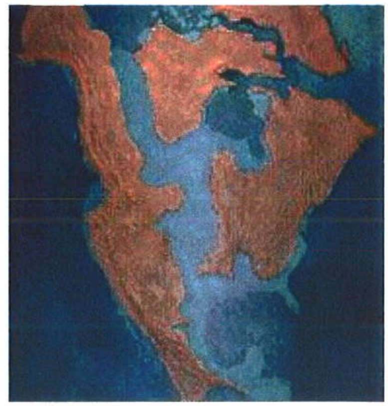

Figure 1. Model of the extent of the Cretaceous Interior Seaway. Notice Minnesota on the eastern margin of the seaway (Univ. of Nebraska State Museum, 2001).

Research Site Location

Flandrau State Park, New Ulm, Minnesota

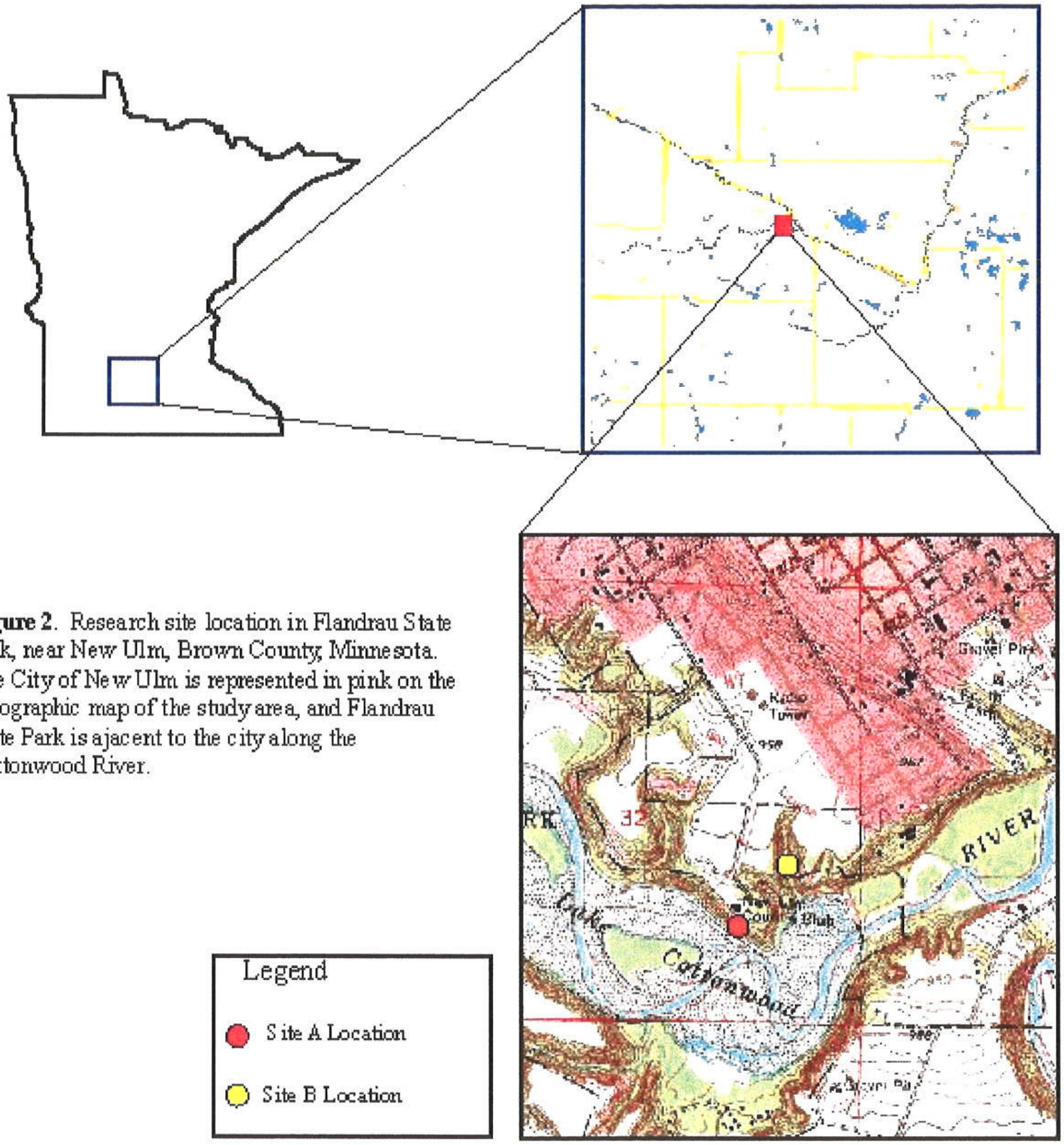

Figure 2. Research site location in Flandrau State Park, near New Ulm, Brown County, Minnesota. The City of New Ulm is represented in pink on the topographic map of the study area, and Flandrau State Park is ajacent to the city along the Cottonwood River.

Source: MN DNR, 2002

GEOLOGIC SETTING

Flandrau State Park is located on the southern edge of the city of New Ulm, Minnesota, on the banks of the Cottonwood River, approximately 2.5 miles before it joins the Minnesota River (Figure 2).

During the Cenomanian Age of the Cretaceous Period the epicontinental seas were invading North America, depositing the Zuni sequence of sediments. Western Minnesota is thought to be on the margin of this great interior seaway, and the Cretaceous sediments show a transition between marine environments to the west, and non-marine to the east.

In the New Ulm area deposits of sandstone, shale, and conglomerates represent this sequence. The Cretaceous sediments in this area are overlain unconformably by Pleistocene glacial drift and underlain unconformably by a Precambrian bedrock surface.

PREVIOUS WORK

Study of these Cretaceous sedimentary rocks began over a hundred years ago when Kloos (1872) described clay sediments in Stearns County. Sardeson (1908) named the Cottonwood River Valley Cretaceous rocks 'The Big Cottonwood Formation'. This nomenclature was later changed by Stauffer and Theil (1941) who correlated them to the Ostrander Member of the Windrow Formation. The assignment of the Windrow Formation to the Ostrander Member was later confirmed by an extensive study of the Cretaceous system in Minnesota by Sloan (1964). Setterholm (1990) compiled a map of Cretaceous rocks in western Minnesota, and later (Setterholm, 1994) did more studies on the transition between marine and non-marine depositional environments. Most recently studies by Blaha (1996) and Joslin (2001) focused specifically on outcrops in the New Ulm and Courtland areas with emphasis on sediment analysis and correlation of deposits. Blaha (1996) and Joslin (2001) both agreed, based on grain size analysis and relationships, that the Cretaceous strata were a result of a river delta that formed when a river emptied into the Cretaceous Western Interior Seaway. Blaha (1996) attributed the variations in the rock sequences to fluctuations in sea level.

METHODS

Both field and lab techniques were applied, and were equally important to this study. Field data was obtained from two selected outcrops at Flandrau State Park during the spring of 2002. Outcrops along the Cottonwood River were located with the aid of a USGS 7.5 Minute Series Topographic map. The elevations of outcrops, and thickness of units were determined using a Jacob's Staff in conjunction with a Brunton Compass. Accuracy in elevation measurements for bedding is critical for correlation to other studies and the methods used here have an estimated error of +/- five feet. Each outcrop was described by unit layers according to height, color, dominant grain size, lithology, and thickness. From this data a composite stratigraphic column was constructed.

In the lab, further analysis of color, composition, grain shape (rounded/angular) and fossil content was done using a binocular microscope. Grain size and sorting were determined using dry sieving techniques, where each sample was placed in a sieve set and then clamped to a sieve shaker for approximately 15 minutes. The material collected was sufficiently disaggregated by weathering at outcrop A to use sieving analysis and outcrop B was poorly cemented and easily broken apart. Histograms were constructed from the sieve data for a more detailed analysis of the sediments collected at Flandrau State Park. These analyses provided an instrument for better understanding sedimentation assemblages and trends. Histograms also aided in assigning names to each unit because of differences and in correlating them with the other outcrops. It should be noted that grain size percentages were obtained as a function of mass and assumes that all grains have the same density. Petrographic thin sections were made of the fine sand in the inter-bedded sand and clay unit, and of the coarse conglomeratic unit to aid in determination of mineralogy, and interpretation of the origin of sediments. The samples were poorly cemented, and had to be impregnated with epoxy before the thin sections were made. Field and lab data obtained aided in comparing with the data presented from other Cretaceous sandstone, shale, and conglomerate outcrops studied near New Ulm.

DISCUSSION

Three discrete lithological units were recognized and described at outcrops A and B in Flandrau State Park. The units are inter-bedded sand and clay, conglomeratic coarse sand, and fine sand units, and are based on lithological characteristics obtained through field interpretation and lab analysis. An attempt was made to correlate these units with other studies in the area to provide further insight as to the nature of deposition.

Inter-bedded Sand and Clay

The inter-bedded sand and clay unit (Figure 3) was the lower most unit, and only observed at outcrop A. The elevation of the upper contact is approximately 842 feet

Figure 3. The lower most inter-bedded sand and clay unit found at outcrop A.

above sea level, whereas the lowest observable elevation was at 831 feet above sea level. The observed thickness was 11 feet, though the exposure of the base of this unit is limited. A similar unit was observed by Joslin (2001) where drill rig information from the Minnesota Valley Minerals Inc. obtained by Joslin (2001) indicated that the inter-bedded sand and clay unit had a thickness of up to 20 feet in the Courtland area. Particles in the sand portion of the unit are very fine, according to sieve analysis, and sub-rounded. The sand is well sorted and bone white in color with some yellow to orange staining. Histogram 1 (Figure 4) is the sand portion of the inter-

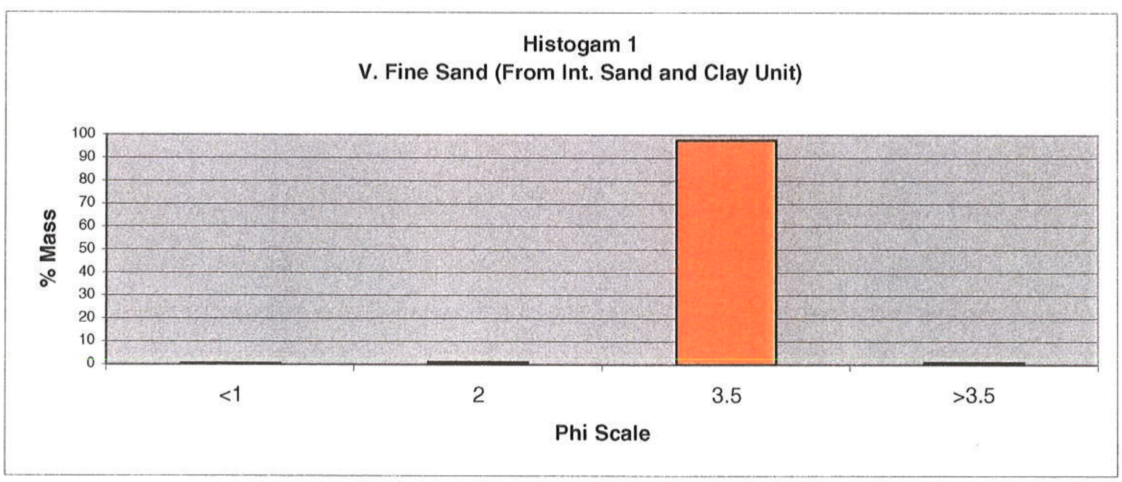

Figure 4. Extremely well sorted very fine sand, also see Figures 3, 5, and 13

bedded sand and clay unit. This unit is very well sorted and equigranular. The composition of the sand is >99% quartz. Traces of tourmaline and Fe-oxides, probably magnetite, were identified. The clay fractions of the unit are in horizontal beds ranging from 1/8 to 3 inches thick with an average of approximately 1 inch, and occur in relative bedding pairs, which are two clay layers of similar thickness occurring close together (Figure 5). The clay beds contain a significant amount of vertical bioturbation that was in-filled with the quartz fine sand, which was stained around the perimeter of the burrow. The burrows are perpendicular to the bedding and ranged in diameter from 1/8 to 3/8 inches. Carbonized wood fragments were recovered from the clay layers of the inter-bedded sand and clay unit, although they are not very abundant. One carbonized leaf was found. A layer of flat hematite concretions up to 13 inches in diameter was observed in abundance on the upper contact of the inter-bedded sand and clay unit.

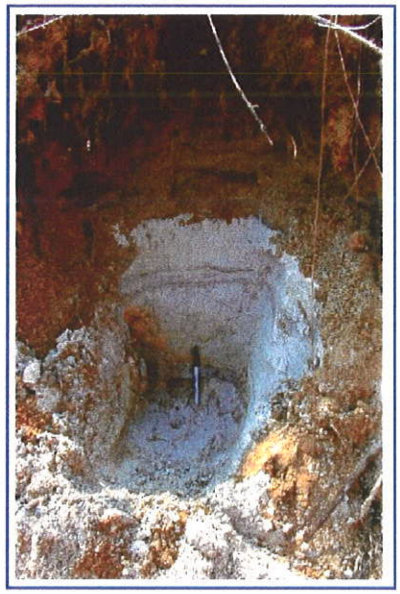

Figure 5. Distinct contact between the inter-bedded sand and clay unit and the Conglomeratic coarse sand unit at outcrop A. The coarse sand is poorly cemented and unconsolidated here due to weathering. Notice the pair of clay layers, in the inter bedded sand and clay unit.

Conglomeratic Coarse Sand

The conglomeratic coarse sand occurs at locations A and B, above the inter-bedded sand and clay unit (Figure 5) and below the fine sand unit at outcrop A. The upper contact is approximately 853 feet above sea level, with the lower contact at 842 feet, which gives a thickness of 11 feet at outcrop A. The exposure at outcrop B has a measured thickness of approximately 10 feet, although the lower contact is not well exposed (Figure 6). The grain sizes range from medium size sand to larger pebbles, and are poorly sorted (Figure 7). Histograms 2, 3, and 4 all represent the conglomeratic coarse sand unit. Histogram 2 (Figure 8) is the lower contact of this unit at outcrop A; histogram 3 (Figure 9) is the upper portion of this unit at outcrop A; histogram 4 (Figure 10) is the conglomeratic coarse sand from outcrop B. All three distributions are bimodal and virtually identical with the exception of histogram 4, which has larger clasts than the

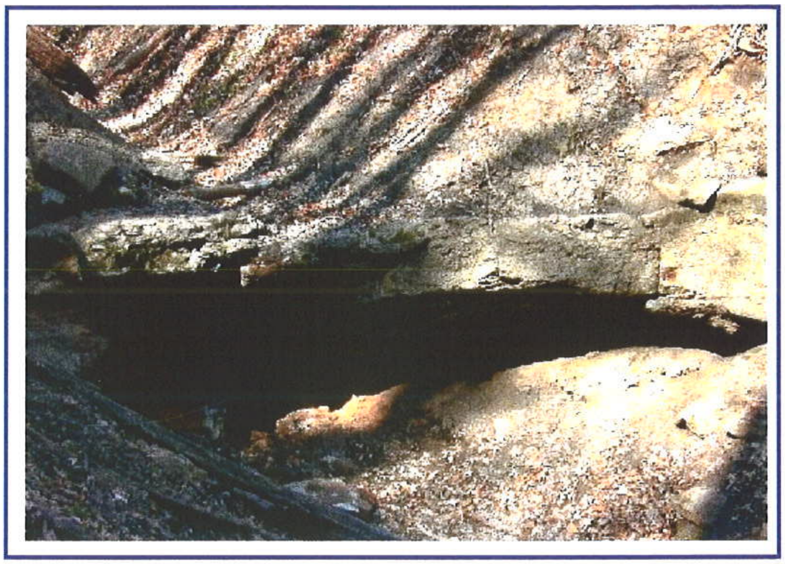

Figure 6. Outcrop B exposing the conglomeratic coarse sand unit which is cemented fairly well. The area in the photograph is approximately 20 feet wide.

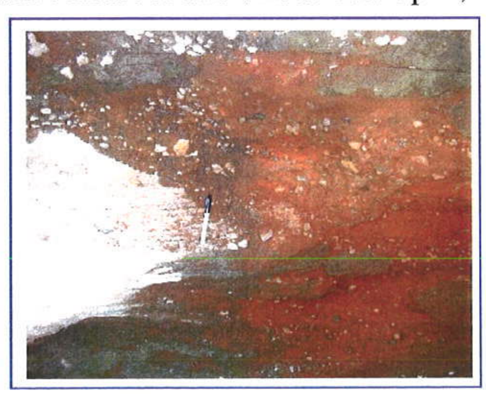

Figure 7. Close-up of conglomeratic coarse sand unit at outcrop B. Notice the faint structural crossbedding on the left side of the photo and the larger pebbles suspended in the sand.

other two. The difference seen in histogram 4 may be attributed to the sampling method, because in this case samples were taken from the sandstone rock face where the smaller grains were weathered away first, leaving the larger pebbles behind. The beds show some grading, fining upward, at both outcrops. At outcrop B there are noticeable trough cross beds in the sandstone. The conglomeratic coarse sand is not well lithified at the surface at outcrop A. However, it is lithified at outcrop B, and therefore and trough cross bedding could be easily observed. The sand and pebble-sized grains are rounded to angular. Composition is 70% to 80% quartz with the remaining grains being feldspars and lithic (rock fragment) material. Lithic pebbles were determined to be composed of granites, clastic sandstone grains and quartzite. The color of the conglomeratic coarse sand is deep to light orange created by a coating of iron oxide.

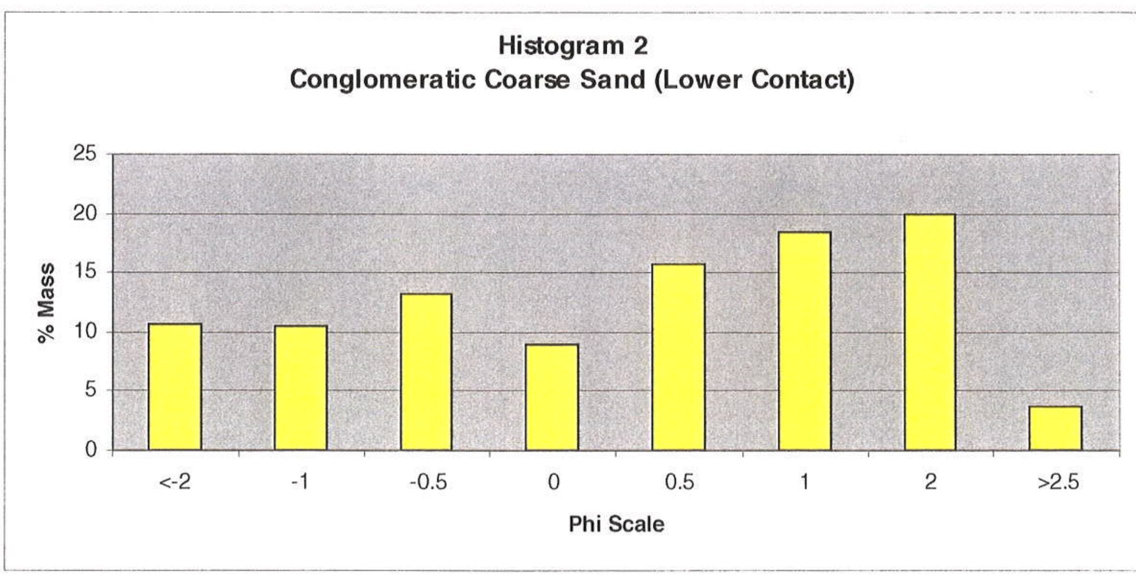

Figure 8. Poorly sorted conglomeratic coarse sand, also see Figures 5 and 13.

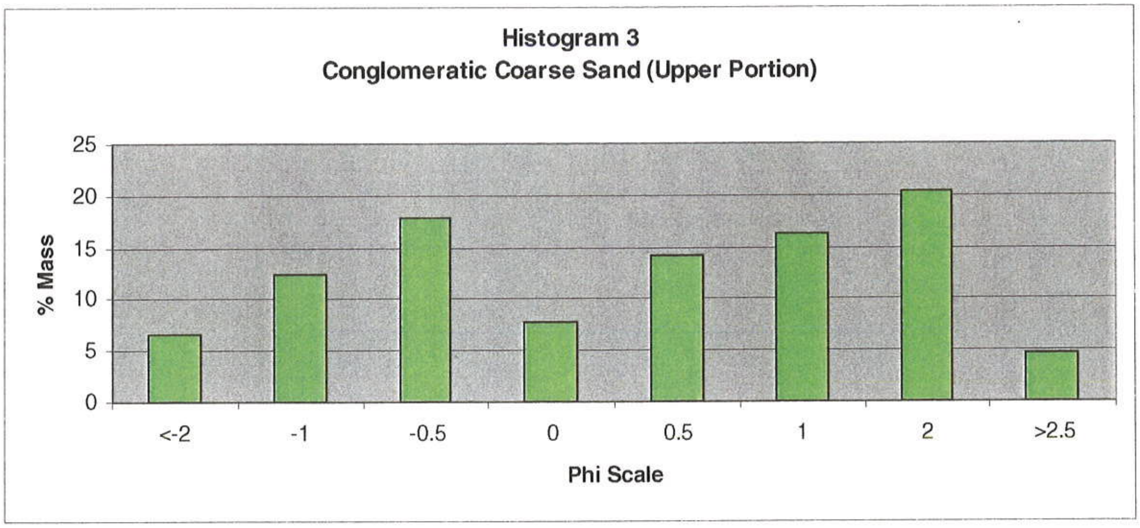

Figure 9. Bimodal distribution of poorly sorted conglomeratic coarse sand.

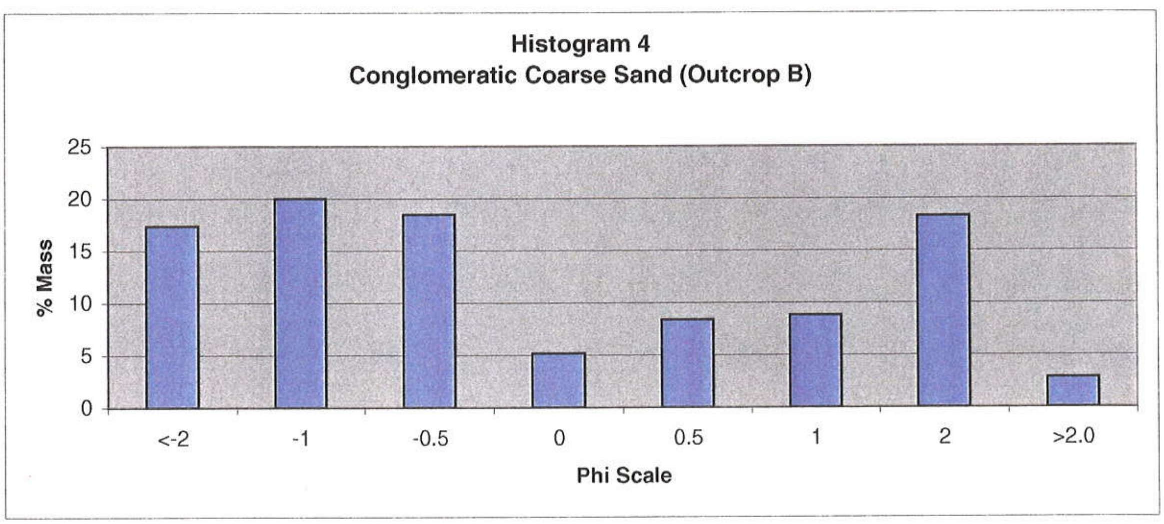

Figure 10. Bimodal poorly sorted conglomeratic coarse sand unit at outcrop B. Notice the high amount of large pebbles (low phi number) in this sample. Also see Figures 6 and 7.

Fine Sand

The upper most observed layer, found at outcrop A, is the fine sand unit (Figure 11) overlying the conglomerate coarse sand unit. The lower contact is at approximately 853 feet above sea level and the unconformable upper contact with glacial till is at 859 feet making the observed thickness 6 feet. The sand is pale yellow to white, unconsolidated fine sand and is well to moderately well sorted. Histogram 5 (Figure 12) represents the grain size distribution of the cross-bedded fine sand unit. This distribution is interesting because the majority of sand grains have a phi size of 2.0, and then get finer in an almost linear way to less than 3.5 phi. The grains are mostly rounded to sub-angular quartz with some feldspars and traces of black silicates and micas. Sand is relatively clean with little oxide coating. There is very noticeable trough cross bedding of 1-2 feet wide and some orange staining.

Figure 11. Fine sand unit, the upper most layer at outcrop A. Notice the trough cross bedding all throughout the exposure.

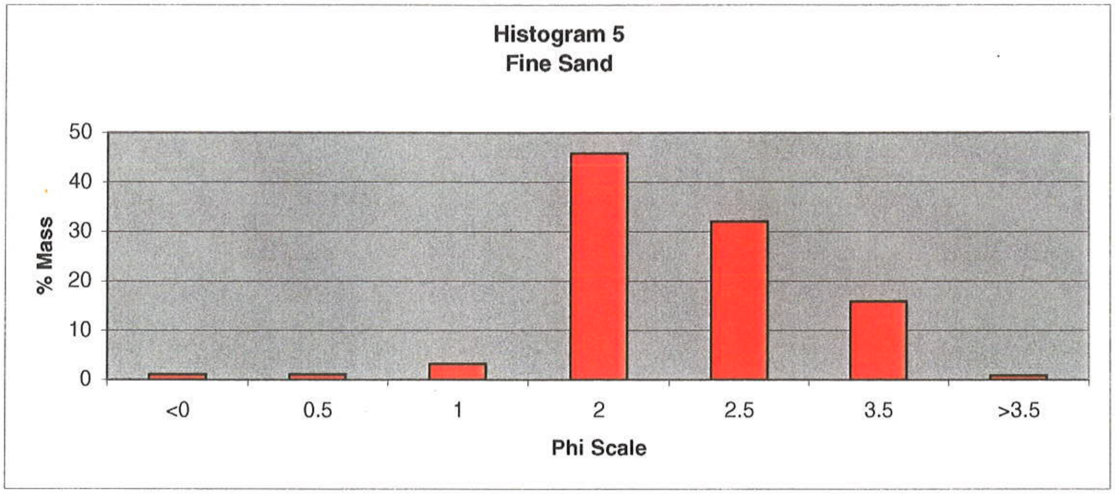

Figure 12. Moderate to well sorted sample of fine sand unit (cross-bedded), see Figures 11 and 13.

INTERPRETATIONS AND CORRELATIONS

A composite stratigraphic column was constructed from observations made and data taken from the Flandrau State Park (FSP) Site based on differences in grain sizes and sediment composition (Figure 13) and was compared with the stratigraphic columns constructed in Blaha (1996) and Joslin's (2001) studies (Figure 14). The inter-bedded sand and clay unit, at FSP site A correlates in elevation and description very well with the K1 unit at Joslin's Courtland Clay Mine site. However, this unit was missing at all of Blaha's sites, which are geographically located between FSP and the Courtland Clay Mine. Just above the inter-bedded sand and clay unit at FSP site A is the conglomeratic coarse sand, which resembles sand sediments described by Blaha.

A model based on these composite sections was constructed and is shown in Figure 15. This linear cross section model from FSP site A to the Courtland Clay Mine

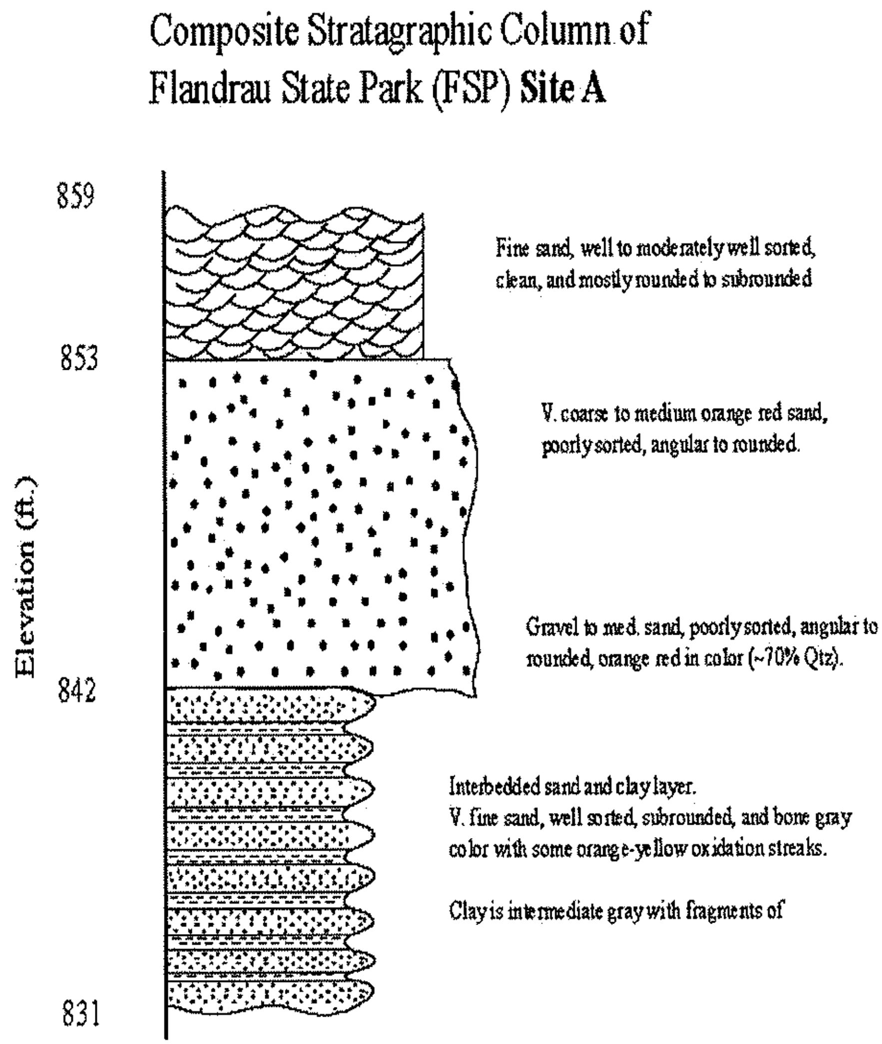

Figure 13. Composite stratigraphic column of Flandrau State Park at Site A locality. Column shows the three distinct units present at FSP site A as determined by lithology and grain size analysis.

Suggests that inter-bedded sand and clay unit is a pro delta deposit with periodic energy surges. The pro delta environment is proposed because it is a fine-grained unit that is laterally extensive over approximately four miles. This pro delta deposit must have been shallow marine environment because the pairing of clay layers with the inter bedded sand

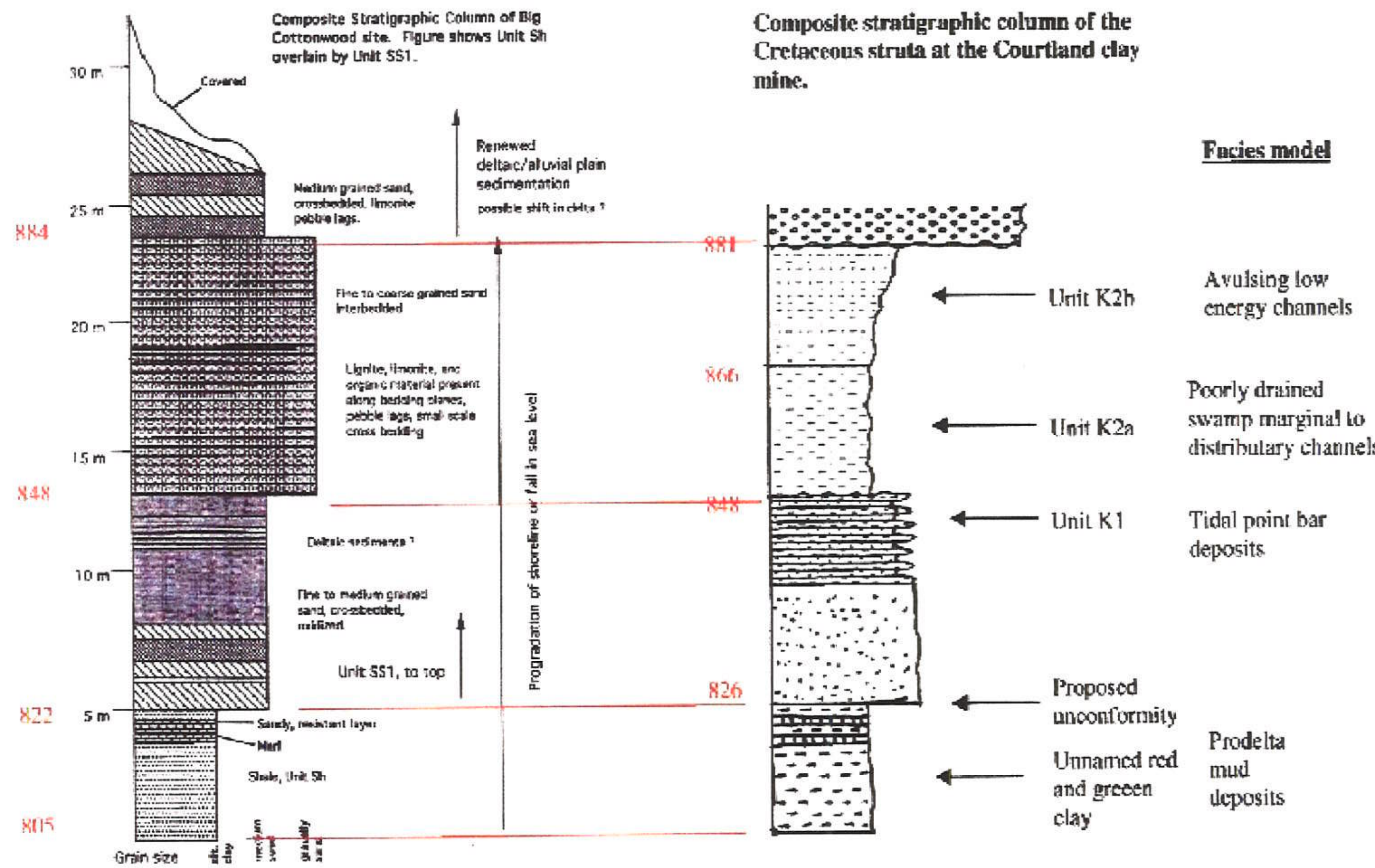

Figure 14. Correlation between Blaha's (1996) "Big Cottonwood" site and Joslin's (2001) Courtland clay mine site. Numbers in red indicate elevation above sea level (feet). Adapted from Joslin (2001)

and clay unit suggest strong tidal influence. The coarser sand units, characteristic of Blaha's sites and the FSP sites, are interpreted as being deposited by higher energy deltaic or stream channels, as shown in the model (Figure 15). As these fluvial channel sediments were being deposited, clay sediments were also accumulating as over-bank deposits. As the delta aged, sediments were reworked many times by avulsing streams. One line of evidence for the reworking of the deltaic sediments is the hematite concretions. Joslin (2001) discovered these concretions randomly throughout his K2a clay unit at the Courtland Clay Mine. But at FSP site A, concretions fitting the same description were found as a layer above the inter bedded sand and clay unit. They are interpreted to have formed in situ in the K2a clay unit, which was reworked by avulsing stream channels in the FSP vicinity and were set down at the bottom of the channel, which formed the concretion layer. I am proposing that the economic grade clay deposits in the New Ulm/Courtland area are simply over bank deposits that have not been reworked by fluvial processes in an active delta environment. Flandrau State Park (FSP) outcrops correlate very well with the other strata studied in the area by Blaha (1996) and Joslin (2001). Most of these sediments are fluvial and/or deltaic in origin, and therefore part of an ever-changing system that may vary widely within a small area. The many locations examined in the New Ulm/Courtland area aid in providing a "larger picture" of what happened in the late Cretaceous on the eastern boundary of the interior seaway.

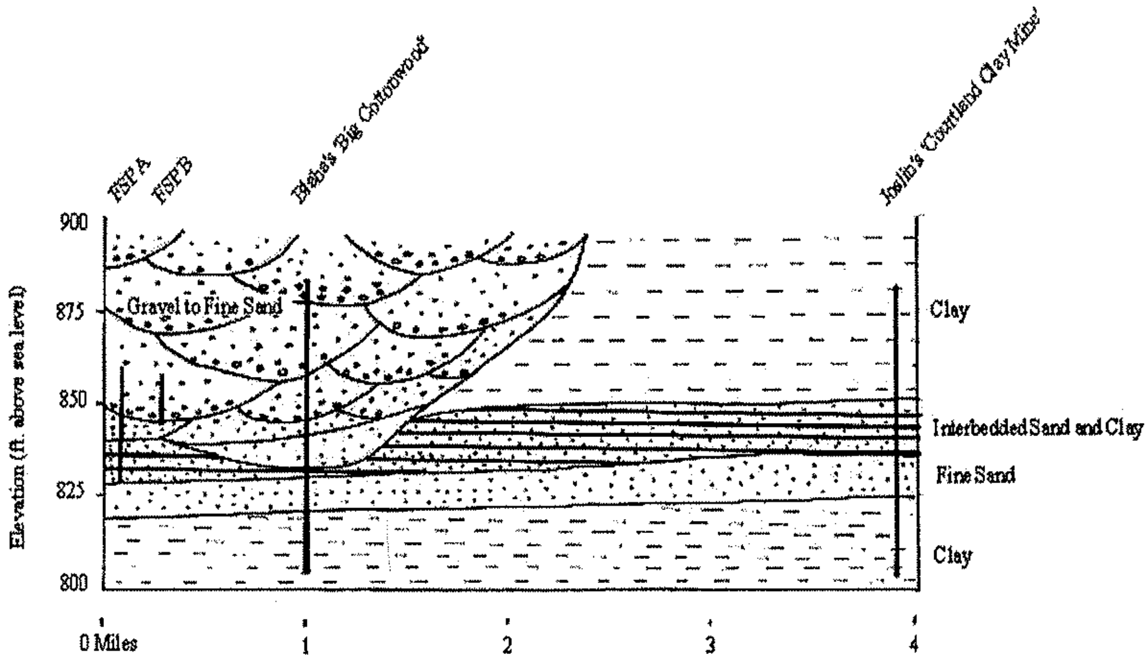

Figure 15. Proposed cross section accross the current Minnesota River Valley from Flandrau State Park (FSP) site A to Joslin's Courtland clay mine. Based on compostie stratigraphic columns of all three studies.

CONCLUSIONS

This study concludes that Cretaceous deposits in the New Ulm area are the result of a river dominated deltaic environment. The lower most inter bedded sand and clay unit is thought to be deposited in a pro delta environment, with the two sand units above being formed by an avulsing river system. These sedimentary units, correlated with other studies in the area by Blaha (1996) and Joslin (2001), suggest a river dominated deltaic sedimentary environment. Sediments in the area prove to be variable due to the character of avulsing river channels, but are still correlative and instrumental in understanding the nature of this environment.

ACKNOWLEDGEMENTS

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