APPENDIX K

GEOLOGIC REPORT

DELAWARE PARK SITE

The Geology of the Sediments Along the White Clay Creek in the Vicinity of the Proposed Route #7 Bridge

by

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Introduction

In order to interpret the geology of the sediments bordering the White Clay Creek near the site of the proposed Route #7 bridge, three trenches were dug at varying distances from the creek on topographic highs. These locations were chosen on the premise that paleo-occupational sites would be located on elevated areas along the creek. The lithologies were examined to determine the structure and geologic history of these highs. Digging was discontinued at the depth where water was reached, since the water would only obscure any deeper lithologies.

The sediments from each of these trenches are described below with respect to their locations, lithologies, and interpreted conditions of deposition. From the examination of these trenches, the recent depositional history of the creek valley can be interpreted.

Site 1

At the first site, Site 1, (figure 1), a trench was dug into a topographic high located approximately meters southeast of the White Clay Creek on the west side of the present Route #7. The trench was approximately 15.2 meters in length and water was reached at about 2.7 meters below the surface. Other than the soil horizon which makes up the top 20.0 centimeters, the trench exhibited two basic lithologies which separately show various textures and structures.

Unit 1. The basal lithology, designated 1, (figure 2), consists primarily of very coarse, poorly sorted clastic material which shows multiple layering, some of which exhibits well developed cross-bedding. Thin, better sorted coarse sand and gravel layers are present, but the bulk of the sediments is very poorly sorted, very coarse, muddy sands, gravels, cobbles and even boulders. The sandy layers have abundant mica and magnetite, and are cross-bedded and banded.

The magnetite and mica are concentrated and accentuate the bands and cross-bed forsets. These sands are fairly clean and only show orange clay staining. They generally exhibit poor sorting, and angular to subangular quartz grains. The feldspars are usually more well rounded.

Compositionally, Unit 1 basically consists of: quartz, about 75%, feldspar only about 2%, mica 10-20%, with the rest being assorted metamorphic rock fragments of varying sizes including medium sand sized magnetite grains.

The position of the basal contact of this coarse sand and cobble unit was not reached. The upper boundary is sharp, and Unit 1 is overlain by a much finer lithology, Unit 2. This upper contact is not a conformable one and dips slightly toward the creek to the west. At this site, the upper contact is located approximately 1.6 meters below the ground surface.

Unit 2. Unit 2, (fig. 2), is primarily of a much finer grade than Unit 1. The sorting and roundness of the grains has increased as does the quartz and mica components. At this site, this upper unit shows laminated coarse to fine sands, silts, and clays. Ripple cross-laminations are visible and abundant throughout. Unit 2 is itself subdivided into three basic subunits, the lowermost two only differing in their clay contents, and the upper being the soil horizon.

The thin basal sub-unit of Unit 2 is composed of laminated buff, brown, and orange fine grained sediments which are more clay rich, hence the lighter color, than the sediments overlying them. They also contain less mica. This clayey layer is approximately 20.0 centimeters thick in this trench, but appears to thin away from the creek.

The overlying brown medium grained sands are, with the exception of the amounts of mica and clay, compositionally the same as those below. They are: quartz 80%, feldspar 1%, mica 10-15%, magnetite less than or equal to 3%. and other metamorphic rock fragments 4-6%. The amount of clay varies. The top of Unit 2 is at the surface, and is a 20.0 centimeter thick, bioturbated and rooted horizon which represents the soil zone.

Interpretation of Lithologies. At Site I, Unit 1,(fig.2), is the basal unit and is a very coarse, poorly sorted, fluvial alluvium derived from the erosion of the nearby metamorphic Piedmont rocks. Their cross-bedding, sorting and coarseness are characteristic of alluvial sediments deposited under a braided type of river system of high energy, and only a short distance from the source. They were probably deposited as a result of the increased outwash associated with the presence of glacial ice during the Pleistocene, and correspond to the Columbia Formation which is laterally extensive over most of the state of Delaware.(Jordan, 1964)

The nearby source is reflected in the high amounts of metamorphic rock fragments, very poor sorting, and angularity of the grains. Much of the interstitial clays within these coarse fluvial sediments is probably secondary and the result of the breakdown of feldspars and other less stable minerals. This would also account for the low amounts of feldspar present. Channel lags and bar deposits indicate the braided fluvial environment which deposited these sediments.

The unconformable sharp contact between these coarse sediments of Unit 1 and the younger fine grained sediments of Unit 2,(fig. 2), is interpreted as an erosional surface and suggests that perhaps some reworking of the topmost portion of Unit 1 has taken place. The extent of the loss or reworking of Unit 1 sediments is not known, but conditions of deposition had changed to a much lower energy fluvial system. This is evidenced by the thick sequence of multiple, laminated sands, silts, and clays. With each flooding of the creek, thin layers of fine sand, silt, and clay are deposited overbank. The higher concentrations of clay at the base of Unit 2, in the thin laminated layer, indicate low velocity flow, or near standing water conditions. Since the differences between this basal laminated clayey layer and those laminated sands and silts above can be attributed to minor changes in the energy of flow of the water that deposited them, these two sub-units are considered not only to represent basically the same conditions with respect to each other, but also the same conditions operating in the present White Clay Creek. The thin soil layer at the surface has been bioturbated by plant roots, and probably also by man, (ie. a Plow Zone).

Site II

The second trench dug, (fig. 1), was located approximately 150 meters from the creek on the north side, and paralleled the present highway, which is located 25 meters to the east. The trench was 19.7 meters in length and 1.2-1.8 meters in depth. In this trench, two basic lithologies, Units 3 and 4,(fig. 3), are present, separated by an erosional boundary, but appear to differ from the two lithologies exposed in the trench at Site I on the other side of the creek. Both of these units can be subdivided into sub-units of varying composition and structure, but with gradational contacts.

Unit 3. Unit 3, (fig. 3), is located at the base of the trench at Site II, and is composed of fine grained sand, silt, and clay with abundant mica. The sand is clay supported, buff to variegated in color, and very high in its mica content. Much of the clay may be the result of the breakdown of feldspars and micas. Approximately 15% of this sediment is mud, with detridal quartz making up almost 80% of the clastics. The grains are very poorly sorted and angular. Gravels and cobbles are found throughout. Above this very clay rich, sandy sub-unit is another mica rich sand, which is compositionally the same as the sub-unit below, but containing less clay and more coarse sands. Both of these sands show well developed cross-bedded structures.

The lower boundary of these micaceous sands of Unit 3 is located below the bottom of the trench, the water table being reached at approximately 2.2 meters. The lateral extent of the more clay rich basal sand layer is uncertain, as it was exposed in only a small section of the trench. The upper cross-bedded sands are much more extensive, outcropping over most of the trench length. The upper contact of these sands is irregular, and extends as shallow as 1.0 meters toward the north end of the trench and plunges gradually below the water level toward the creek to the south. It appears to be an erosional surface, probably the result of scouring.

Unit 4. The base of Unit 4, (fig. 3), is a coarse gravel and cobble lag deposit of quartz and metamorphic rock fragments, which lies unconformably on the sediments of Unit 3. In the north end of the trench, this lag is channeled and immediately overlain by two white clay lenses with included cobbles of quartz and metamorphic rock fragments. These clays grade upward into very poorly sorted, yellow-brown alluvium above. This alluvium also has cobbles and gravels throughout. Toward the south, away from the clay lenses, this gravel lag is not as pronounced, but still grades upward into the same yellow-brown alluvium. This alluvial layer appears to plunge toward the creek, and is overlain by a silty brownish-grey alluvium. These two sub-units of Unit 4 have a similar composition, but the lighter color of the basal sub-unit reflects the greater amount of interstitial clay. Both of these represent similar depositional conditions, and their mutual contact appears gradational. Neither shows any visible internal structures. The sediments of Unit 4 extend over most of the trench length, but the top 20.0 centimeters at the south end of the trench is a mixed fill deposit of recent origin.

Interpretation of Lithologies. Although it is clear that the Holocene overbank sands and muds overlie the Pleistocene Columbia Formation at Site I, (fig. 2), and as will be seen at Site III, (fig. 4), this transition was not exposed in the sediments examined at Site II, (fig. 3). Even though the Pleistocene gravels are probably present below the level to which the trench at Site II was dug, they were not present except as reworked material in the deposits examined. The sediments examined at Site II are interpreted as point bar deposits of the Holocene and present day meandering White Clay Creek, and were deposited as the channel migrated across the valley. The trench at Site II was not dug deep enough to reach the coarse lag at the base of the lower point bar, which probably overlies the Pleistocene gravels, but did reach the coarse cross-bedded sands. These are represented by the cross-bedded micaceous sands of Unit 3, (fig. 3). The large amounts of clay within these sands may be at least partially due to the breakdown of feldspars, micas, and other metamorphic rock fragments.

The clay lenses and gravel lags of Unit 4, (fig. 3), probably represent local scouring as chutes which were abandoned, leaving the clays to settle out from suspension. The lag and the clay lenses were in turn covered by the overbank material of Unit 4.

The lateral plunge of these sediments toward the creek as well as the cross-bedded sands overlain by overbank muds, and the presence of chute fill deposits indicate that the meandering creek has migrated over this area, leaving point bar deposits. This process is still continuing.

Site III

The trenches at Site III are located near, and on the same side of the creek as Site I, (fig. 1). This site, although showing some minor differences, has essentially the same two lithologies as described above for the sediments exposed in the trench at Site I.

Initially, a 2.3 meter deep trench was dug at Site III, (fig. 1), which revealed the two basic lithologies, (fig. 4). The unconformable boundary, also present here, between the older coarse and the younger finer units, Units 5 and 6 respectively, is erosional and seems to gradually dip down in a direction approximately normal to the line of the first trench. In order to determine whether this was a real plunge or just a local phenomenon, another trench was dug at right angles to the first. This new cut confirmed the gradual plunge of the erosional boundary toward the creek, a condition also seen at Site I.

The trenches at Site III, (fig. 1), are located approximately 120 meters from the creek on the southeast side, and 120 meters to the west of the present highway. As was noted, these trenches show two basic lithologies, a very coarse unit below, and a younger, finer unit above; Units 5 and 6 respectively, (fig. 4). As exhibited by the coarse sediments of Unit 1, these coarse sands, gravels, cobbles, and boulders show variations in structure throughout.

Unit 5. Unit 5, (fig. 4), is a basal, very coarse unit which extends from slightly less than 1.0 meter below the surface, (depth varying with plunge), to an undeterminable depth below the bottom of the trench. The entire unit is composed of alternating, cross-bedded coarse sands (rich in mica and magnetite), and very coarse gravel and cobble lags. These sediments are primarily quartz, feldspar, metamorphic rock fragments and muds. Near the bottom of the trench, a thicker, 30.0 centimeter local lense of cross-bedded very clean, micaceous sands is present, and below that, another gravel layer. Near the top of Unit 5, the alternating, cross-bedded, mica rich sands show high concentrations of magnetite accentuating the cross-bed forsets.

The depth of the lower boundary of this unit is unknown. The upper boundary is sharp and unconformable with the overlying Unit 6, (fig. 4), at approximately 1.0 meter, and plunges slightly westward toward the creek. This upper boundary is interpreted as an erosional surface.

Unit 6. Unit 6, (fig. 4), the youngest unit at Site III, is approximately 1.0 meter thick, but in contrast to the comparable Unit 2, (fig. 2), at Site I, shows no discernable internal structures. Compositionally, these fine sediments are very muddy, poorly sorted fine to medium sized sands of quartz 80%, feldspar 2%, mica 15%, and other metamorphic rock fragments including magnetite, 3%. Some of the quartz grains appear to be subrounded, but others are still angular. Gravel grade material is also present throughout.

The upper boundary of Unit 6 is at the surface and has been bioturbated by root action into a soil zone. Both of these two units, Units 5 and 6, (fig. 4), extend over the lengths of the trenches and appear to correlate with those at Site I, (fig. 2).

Interpretation of Lithologies. The lack of visible structure within the sediments of Unit 6, is probably due to its greater distance from the creek than those comparable sediments of Unit 2. The basal coarse unit at Site III, (Unit 5, fig. 4), still shows the characteristic poorly sorted alluvium and braided fluvial types of sedimentary structures characteristic of the Columbia Formation in northern Delaware. (Jordan, 1964) The composition, as at Site I, reflects the proximity to the metamorphic rocks of the Piedmont source, and much of the clay here is also probably diagenetic.

Conclusions

During the Late Pleistocene, as a result of the increased outwash and erosion associated with the glacial ice and the accompanying low stand of the sea, a period of massive erosion, transportation and deposition of coarse sediments in the form of braided rivers was occuring in northern Delaware. (Kraft, et al.,1975) The sediments are very coarse, very poorly sorted, and primarily of metamorphic origin. These braided fluvial deposits of the Columbia Formation reflect the outwash nature and the proximity to the metamorphic Piedmont source.(Jordan, 1964)

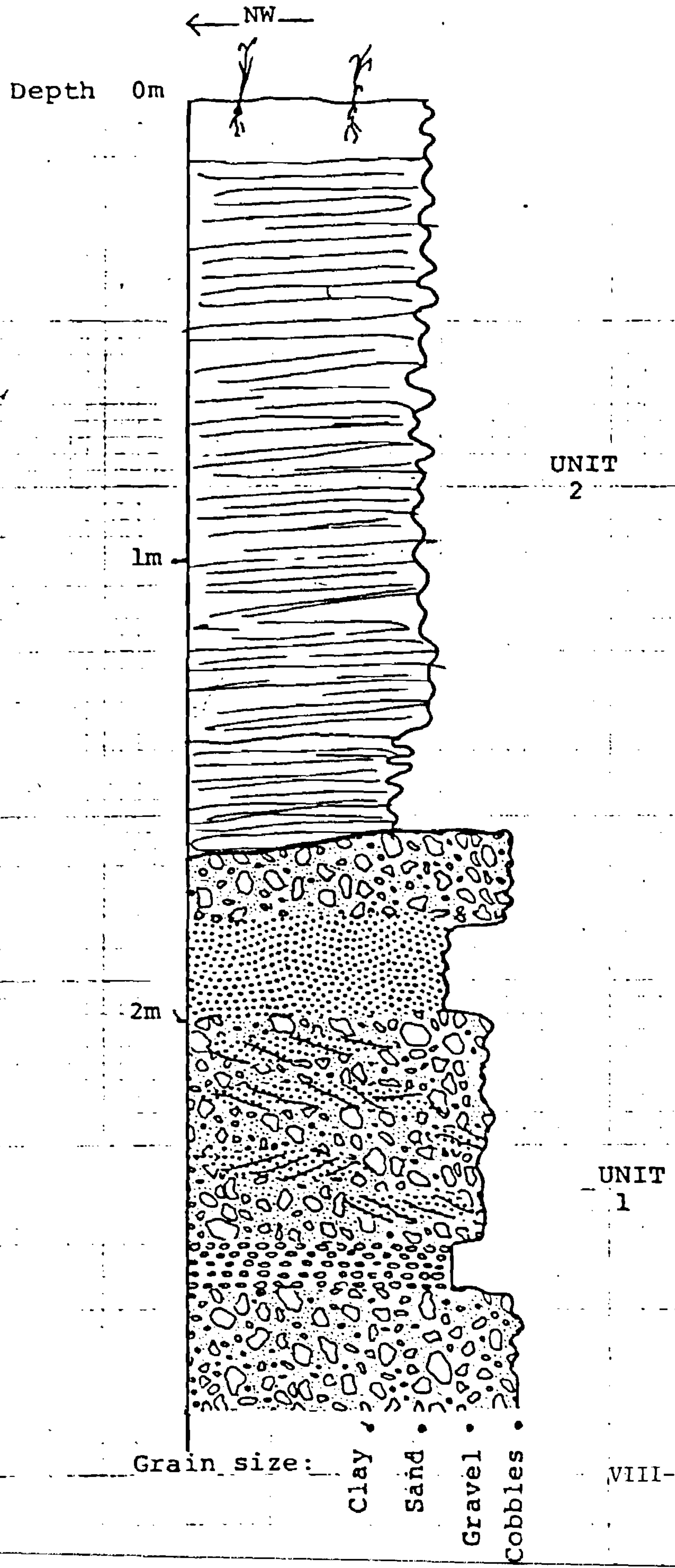
When the glacially affected conditions moderated, the outwash streams were no longer competent enough to move the coarse material. Drainage was of much lower energy, only much finer material was being moved, and the streams became meandering. The depositional conditions along the White Clay Creek during the Holocene were probably very much what they are today. Flooding conditions caused laminated overbank deposition of sands and silts which can be seen clearly in Unit 1, (fig. 2), Site I, due to its proximity to the stream (fig. 1). Further away from the creek, these overbank deposits are not as frequent and are therefore subject to increased bioturbation with its resulting loss of internal structure. This can be seen in the sediments of Unit 6, (fig. 4), at Site III.

Migration of the meandering channels over the flood plain through time, eroded into, reworked and redistributed the existing sediments into point bars. These point bar type deposits, including abandoned chute scours, cross-bedded sands, and overbank accumulations are evident in the trench at Site II,(fig. 3). The thin upper surfaces show both the effects of bioturbation by man and by plants. Frequent present day floods still erode into and deposit overbank accumulations of sand, silt, and mud. A gravel lag, the reworked Pleistocene gravels, can also be seen within the present day channel.

The top of the Pleistocene gravels has been eroded, but how much has been eroded off and reworked is uncertain. It is for this reason that no accurate age can be placed on the unconformable boundary between the Pleistocene braided fluvial sands and gravels and the Holocene flood plain deposits. The ages, and also any determination of the rates of deposition represented by these deposits, any finer than just Pleistocene or Holocene, is not possible without other controlls.

The deposits at Site I and III, (figs. 2 and 4), appear to have been untouched by the meandering channels for some time if at all, as they only show thick accumulations of the thin laminated overbank flood plain deposits. This is in contrast to the sediments observed in the trenches at Site II, (fig. 3), which show the point bar types of deposits indicative of recent reworking of previous sediments. Whether these previous sediments were the Pleistocene gravels, overbank muds, or earlier point bars is uncertain, as is the rate of the reworking. The area around Site II,(fig. 1), appears then to be the least likely to yield occupational sites. The areas around Sites I and III however, (fig. 1), show only overbank accumulations, and no recent reworking in the form of point bars could be observed at these two sites. The durations of the intervals represented by these flood plain deposits however are unknown.

SITE I



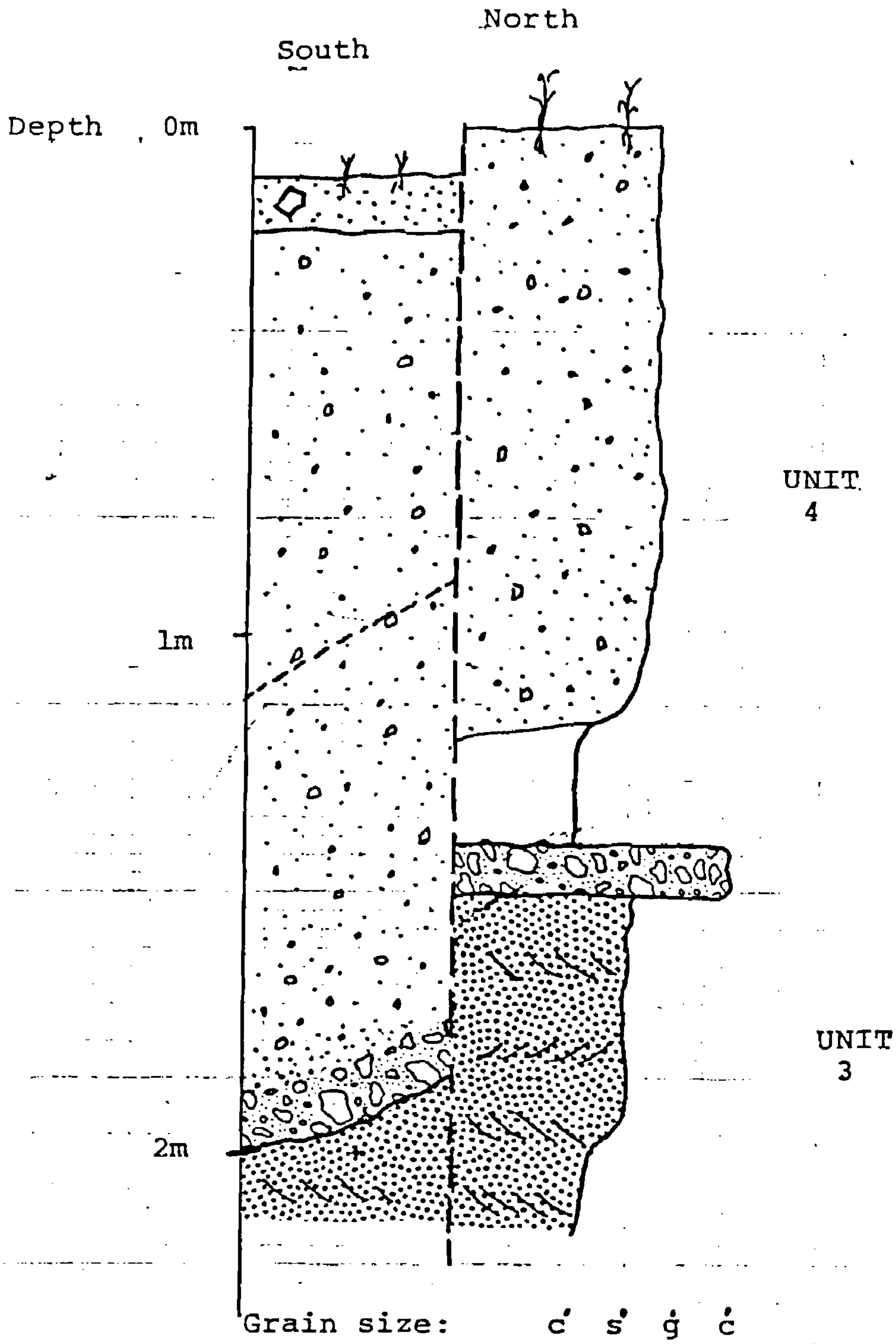
Bioturbated "Plow Zone"

Laminated, Sands, Silts, and Muds. Brown

Laminated, Clay-rich, Sands and Silts. Buff, Orange, Brown

Very Coarse, Sands, Gravels, Cobbles and Boulders with layers of Well Sorted Gravel and X-bedded Sands. Abundant Mica and Magnetite.

SITE II



Recent fill at south end of trench.

Unstructured, brownish-yellow, sandy muds. Overlain at the south end by brown-grey, sandy muds.

Local white clay lenses at north end. Underlain by gravel and cobble lag.

Fine to coarse, X-bedded micaceous sands. Increase in mica and clay below. Variegated.

(FIGURE 3)