APPENDIX D

Physical Environment and Geologic History

at the

Delaware Park Site

by

Dr. Robert Doyle

INTRODUCTION

The following report describes the physical environment and geologic history at the Delaware Park Archaeological Site in Stanton, New Castle County, Delaware. Included is a discussion of the geologic history, stratigraphy, drainage, and physiography of the site, which are all necessary to a description of the geologic setting and paleo-environment in the area during the span of Indian occupation. The geologic descriptions and conclusions presented have derived from several weeks of field investigation on and near the site, review of the available literature, and subsurface boring data. Staff geologists from the Delaware Geological Survey contributed discussion and field observation which were of assistance to the author.

It should be noted that not all time-stratigraphic relations for the Pleistocene and Holocene periods in Delaware have been confirmed by absolute dating methods. Within this constraint, however, the conclusions reached by the author represent the most accurate and logical interpretation available.

SUMMARY STATEMENT

The Delaware Park Archaeological Site is located approximately one mile south of the Fall Line. This line marks a geologic and topographic break between ridge-forming Paleozoic crystalline rocks of the Piedmont to the north, and younger unconsolidated sediments that form the flat surface of the low-lying Coastal Plain. The site itself is underlain by three geologic units of the Coastal Plain stratigraphic sequence. These are, from top to bottom, recent flood plain silt deposits, late (or post) Pleistocene alluvial fan deposits, and the Potomac Formation. The coarse sands and gravels of the Columbia Formation are not present at the site proper. All of the archaeological features are found within the flood plain silt unit or in feature pits dug into the underlying alluvial fan unit.

Although there is no definitive geochronological evidence to date the geologic units, and thus the cultural period, information available from field investigations and literature review provides a reasonable estimate of the historical setting of the site. This evidence, discussed in a latter section of this report, indicates that the cultural age of the site is 1) post-18,000 years b.p., and 2) there is no evidence that the site was inhabited during the deposition of the younger Quaternary alluvial fan deposits, which are presumed to be 18,000 to 24,000 years b.p. in age. Stated another way, the site was inhabited after the end of the Pleistocene, probably during the last 10,000 years, which is the assumed date of deposition of flood plain sedimentation related to the flooding episodes on White Clay Creek.

The present drainage and topography patterns at the site have not changed significantly during the last 10,000 to 15,000 years. The course of White Clay Creek has been stable, with minor northside meandering, during that time. The accumulation of flood plain silt deposits has raised the

height of the knoll at the site slightly. This increase in height probably continued during the time of occupation. However, the site is assumed to have been a positive topographic feature prior to occupation. Marsh (or swamp) existed at a lower elevation south of the site, under the present rail lines and for a few hundred feet to the south and east of them.

Geological investigations indicate that the physical environment at the site during occupation was a northeast trending knoll one-half mile long, paralleling the south bank of White Clay Creek. The top of the knoll was 5 to 10 meters above the non-flood level of the creek. It was bounded on the south by a brackish (?) marsh and on the east by a wide channel flood plain at the confluence of White Clay and Mill Creeks. Periodic flooding of White Clay Creek would have covered the site with water. Silt deposits from each flood have also covered the site, making it uninhabitable for short periods of time.

The flood plain silt deposit at the site does not have an extensive soil profile developed; although near White Clay Creek a strata cut has an extensive 0.5 meter soil zone present. This indicates that there may have been considerable erosion or historical removal of at least 0.5 meter of surface. Some archeological and geological evidence had, therefore, been removed prior to excavation of the site.

GEOLOGIC SETTING

The site is located near the northern limits of the Coastal Plain Province, one mile from the crystalline rocks of the upland Piedmont (Figgure 1). It is underlain by a series of coastal plain sedimentary units ranging in age from Cretaceous (65 m.y.) to Recent. The geologic history of the area defines the physical environment into which the site is emplaced.

Stratigraphy: There are three coastal plain units which underlie the site:

1) Flood plain deposits 18,000 (est.) to Recent
2) Alluvial fan deposits 25,000 to 18,000 (est.)
3) Potomac Formation 65 m.y., and older

1) Flood plain deposits: This unit is composed of buff to light brown, non-bedded, homogeneous fine grained silts, and minor poorly bedded sand wedges related to overbank flooding episodes on White Clay Creek. Included within this unit are randomly deposited accumulations of coarse gravel and cobbles which were laid down as cobble flush material during very active flooding periods. These flush cobble deposits are present at the southwest end of the excvations area and in two of the five pits dug around the site to the east and north.

2) Alluvial fan deposits: These are well bedded flat-lying layers of sand and fine gravel, along with rarely occuring associated coarse sand wedges. The wedges are composed of steeply dipping foreset fan structures.

The flat-lying bedded sequence is made up of alternating layers, 5 to 15 cm. thick, of dark brown, micaceous, magnetite-rich coarse sand, gravel and silt; interbedded with finer sand, silt, clay and minor fine gravels that are yellow-brown to red-brown in color. The finer unit contains less than 20% magnetite and mica. This unit is one to 5 meters thick on the average, with a thicker section at the center of the site. At the northwest end of the site this unit is less than one-half meter thick. The steeply dipping foreset beds of the fan features are present in only one place within the site proper, at feature no. F 39. Other exposures are present in the storm drain pits 100-200 meters southeast of the site. These fans contain steeply ($\pm$ 40°) dipping coarse buff to yellow-brown coarse sand and gravel. They are well bedded and contain structures similar to those found in modern alluvial fans.

3) Potomac Formation: This unit crops out in various parts of the study area. It occurs in both the east and west ends of the site, and in construction pits just north of the railway tracks. It is composed of pink and white silts and clays, often with varicolored red, black, and red-grey bands of clay and silt. The sandier portions are present as discontinous patches throughout the exposure. The formation is characterized by durable "hard" clay and silt which is usually impermeable and resistant to erosion. Exposures of the unit have been mapped in the bottom and lower parts of the existing White Clay Creek channel. It is presumed to occur beneath the bedded alluvial fan unit on the site proper. although no evidence of its presence was found in a 10 meter deep auger hole at the center of the site. At one pit south of the railroad tracks, Foss (personal communication, 1980) noted a one half meter "marshy" soil horizon present at the top of the Potomac unit.

Logs of Highway Division borings taken 50 feet north of the railroad tracks noted weathered Piedmont bedrock at 25 feet below the land surface, or, approximately 10 feet below the deepest coring intersection at the site itself.

Geologic History: Lack of definitive geochronological data at and near this site places constraints upon the interpretation of local geologic history. However, correlation with well documented stratigraphic information from elsewhere in the state plus available field mapping data near the site permits the development of an acceptable chronology. This chronology explicates the development of the physical environment of the site both before and during the time of occupation.

The initial geologic event that affected the site environment occurred during the Late Cretaceous Period (65 m.y) and continued into the Tertiary Era, when the Atlantic margin was compressed and the crust was deformed by folding and faulting. Several northeast and east trending faults were developed in the coastal plain near the Fall Line. These faults formed minor (15-60 meters) elongate depressions and ridges in the Potomac Formation surface, changing the course of the streams draining the Piedmont from a southerly trend to a new northeast to east direction. White Clay Creek and Christiana Creek are two of these structurally subsequent streams which began to flow into the depressions formed by the aforementioned compression. A long period of erosion followed this event but these two anomalous stream channels and the related fault block ridges persisted, and still remain today.

During the late (or early post) Pleistocene, a major flooding in the region covered the Potomac pediment surface with sand and gravel in the form of alluvial fan deposits (Spoljaric, 1972), near the Fall Line boundary, including that of White Clay Creek, with sediments. The layered micaceous sand unit found at the site is representative of these deposits. Due to the blocking effect of a high (20-30 m.) faulted ridge south of White Clay Creek, alluvial fan sediments continued to build up. The sediments filled the depression containing the stream channel and formed a low, wedge-shaped ridge just south of the main channel of the creek. This ridge persists today as the base of the knoll on which the site is located.

After cessation of alluvial fan deposition in early post-Pleistocene time, the White Clay Creek drainage was re-established and downcutting stream erosion north of the site resumed. The size and volume of the creek was larger at that time ($\pm$ 18,000 yrs. b.p.), and erosion of the pre-existing alluvial fan deposits was extensive. The steep 5 m. south "bluff" near the site marks the maximum flood stage erosion line of the early Holocene White Clay Creek.

The present 50 m. wide channel flood plain of the creek represents the normal channel fill of the stream. Major periodic flooding during the Holocene, which is still continuing at the present, began some time after 18,000 yrs. b.p., presumably from 10,000 years ago to the present. This flooding created the flood plain sediments which covered the pre-existing alluvial fan unit, draping over the top of the knoll that bordered the south bank of the creek. At the time that habitation of the knoll commenced, this process had further raised the elevation of the knoll to two or more meters above its present level (Figure 4).

Geologic history at the site during the Holocene (the last 10,000 yrs.) was marked by periodic flooding and overbank deposition along the creek, development of a marsh or swamp on the south side of the site in the depression now covered by the rail right-of-way, and partial and periodic erosion of the knoll by sub-aerial weathering sheet-wash which carried sediment off the knoll to the north and east as a thin veneer of silt. This silt veneer is localized in the swamp lands east of Highway 7. The amount of water and size of White Clay and Mill Creeks was sharply reduced as shifts in Peidmont feeder drainage resulted from a combination of lowered volumes of water, tectonic shifting, and stream piracy at the headwaters of the creeks. At this same time, a steadily rising sea level combined with reduced drainage volume acted from about 8,000 years ago onward to alter the courses of the outflow channels east of the site across Bread and Cheese Island.

The impact of colonization cannot be assessed, although evidences of colonial farming of the site for 200 years certainly accellerated erosion and weathering of the knoll.

Physiography and Drainage: The site is located in the Atlantic Coastal Plain Province, but is only one mile south of the Appalachian Piedmont Highlands. The proximity of the site to the Fall Line contact between these two provinces is reflected in the unique topography associated with this geographic position all along the Piedmont Front. The site is on a knoll along the south bank of White Clay Creek. It is 30 to 70 meters wide at and near the excavation area, and is at least one mile long. It starts

at an elevation of 22 feet above MSL, 8 to 10 meters above the recent flood plain meadows and swamps surrounding it. The knoll ridge line surface dips gradually to the northeast, ending at the north side of the old railroad spur near Route 7. The southeast side of the knoll dips gently into a partially dessicated swamp near the main rail line. Its north and east slope is steeper; at 50 meters from the site the knoll is incised into a steep 5 meter erosion bank above the present flood plain of White Clay Creek. The knoll is surrounded on the west, north, and east by flat featureless meadows established on the flood plains of White Clay and Mill Creeks.

Northwest of these flood plain meadows, the land rises slowly across the ancient Cretaceous pediment surface to an evelation of 300 to 400 feet at the Hockessin Plateau. South of the site, the land rises again to an elevation of 100 feet. This elevation, one mile south of the site, is the drainage divide between the two main east-west flowing streams in the area - White Clay and Christiana Creeks. The divide is part of the presumed fault block structure developed during Late Cretaceous tectonic compression.

With regard to drainage patterns, this site is located at the major confluence of the two dominant stream systems in the area. Mill Creek has retained the south-flowing pattern typical of the pre-Tertiary drainage of the area, and drains Piedmont terrane. The pattern followed by White Clay Creek is influenced by the post-Cretaceous fault depressions discussed earlier. This younger drainage pattern pirated streams and changed the major flow directions from north-south to a northeasterly trend. The establishment of this pattern must have occurred about 50-60 m.y. ago. Surface and subsurface mapping indicates that this pattern has not changed significantly since that time.

There have been minor changes in the drainage patterns since the end of the Pleistocene which have occurred near the site itself (Figure 3). The present course of White Clay Creek close to the margin of the site knoll probably represents Recent (post-10,000 years) southeastern movement of a meander in the creek. This southward movement is still going on today. At some undefined time since the Pliestocene the stream was several hundred meters north of its present channel, probably downcutting into the alluvial fan unit. With the beginning of significant relative sea level rise 8,000 years ago, the downcutting process changed to sidecutting and the meander assumed a southward course. At this same time, the southernmost portion of Mill Creek began to cut laterally to the northeast, forming the meander which is present in the creek today. The result of this sidecutting meander pattern on the part of both streams was a relocation of their confluence point eastward from its previous position near the east gate of Delaware Park to where it is today. As this process occurred, the northeast point of the site knoll was eroded both in terms of elevation and lateral extent. This erosion caused a reduction in size and height of the knoll both before and during occupation.

Post-Pleistocene sea level rise also affected the courses of all the major streams in the area. As sea level rose, the New Castle marsh became clogged with sediment, the channels of major creeks were blocked off, and the complicated drainage pattern around Bread and Cheese Island was developed.

These changes were further enhanced by a probably major reduction in water volume and erosional competence in the major streams, particularly

White Clay Creek. The principal effect of this reduction in volume was a stabilization of the stream channels over the last few thousand years. The lower volume of water also contributed to the shift in channel locations in the streams around Bread and Cheese Island.

It may be concluded that there has been no significant change in the drainage pattern of White Clay and Mill Creeks during the last two or three thousand years. Prior to that time the sidecutting meander process and higher water volumes would have had a more serious impact on the physical environment of the site.

There are two other factors which require discussion and explanation. One of these is the timing and physical extent of the deposition of the overbank floodplain unit within which all archaeological features were found. The second factor concerns the possibility that the low area south and east of the site along the course of the old mill race was a previously existing east-flowing channel of White Clay Creek.

Deposition of overbank sediments by flood waters of White Clay Creek is presumed to be an active geologic process today. Calculations for at least the 100-year flood levels would indicate flooding and silt deposition over the top of the knoll. Given the assumption of greater water volume in the creek several thousand years ago, overbank flooding and deposition would have been more frequent and extensive. Flood plain silts have been mapped one-quarter mile away on both sides of the creek. Because there is no evidence to provide an accurate date for the flood plain silt unit, or the top of the alluvial fan unit, it can only be assumed that the silt unit is post-Pleistocene in age. There is no information available on the rate of sedimentation, the frequency of flood water depositional events, or the rate of erosion of the sediment layer by normal processes of weathering and erosion. Field evidence and soil studies indicate that some erosion, either natural or historical, has occurred. However, the presence of a relatively undisturbed marsh or swamp soil profile of "young" age at the rail right-of-way pit, and the development of an extensive soil profile in the silt unit exposed at the strata cut near the creek suggest that recent erosion has not been extensive. As noted in the summary, the site may have been periodically untenable during periods of major flooding, but generally the site has existed in its present form and environment for the last 10,000 years.

Detailed mapping at and near the site did not uncover any evidence for the existence of a pre-existing east-flowing oxbow cutoff channel of White Clay Creek along the old mill race. A 30 meter strata cut at the extreme southeast end of the site through part of the depression near the mill race exposed a wedge of coarse cobble and gravel material which the author assumes to be in place. However, the lack of other evidence for a stream channel, including channel walls, layered fluvial deposits, combined with the presence of Potomac Formation clay at the south end of the cut, as well as the morphology of the cobble zone with its scattering of cobbles up into the feature cuts FE50 and FE51 adjacent to the wedge, all indicate that this sedimentary feature is a flush deposit related to a major flood episode. The presence of a marsh of swamp soil horizon in the nearby railroad right-of-way pit, which is probably related in time to the silt overbank deposition unit, indicates that the mill race channel is, and has been, a natural low area. Major flooding of high energy flood water

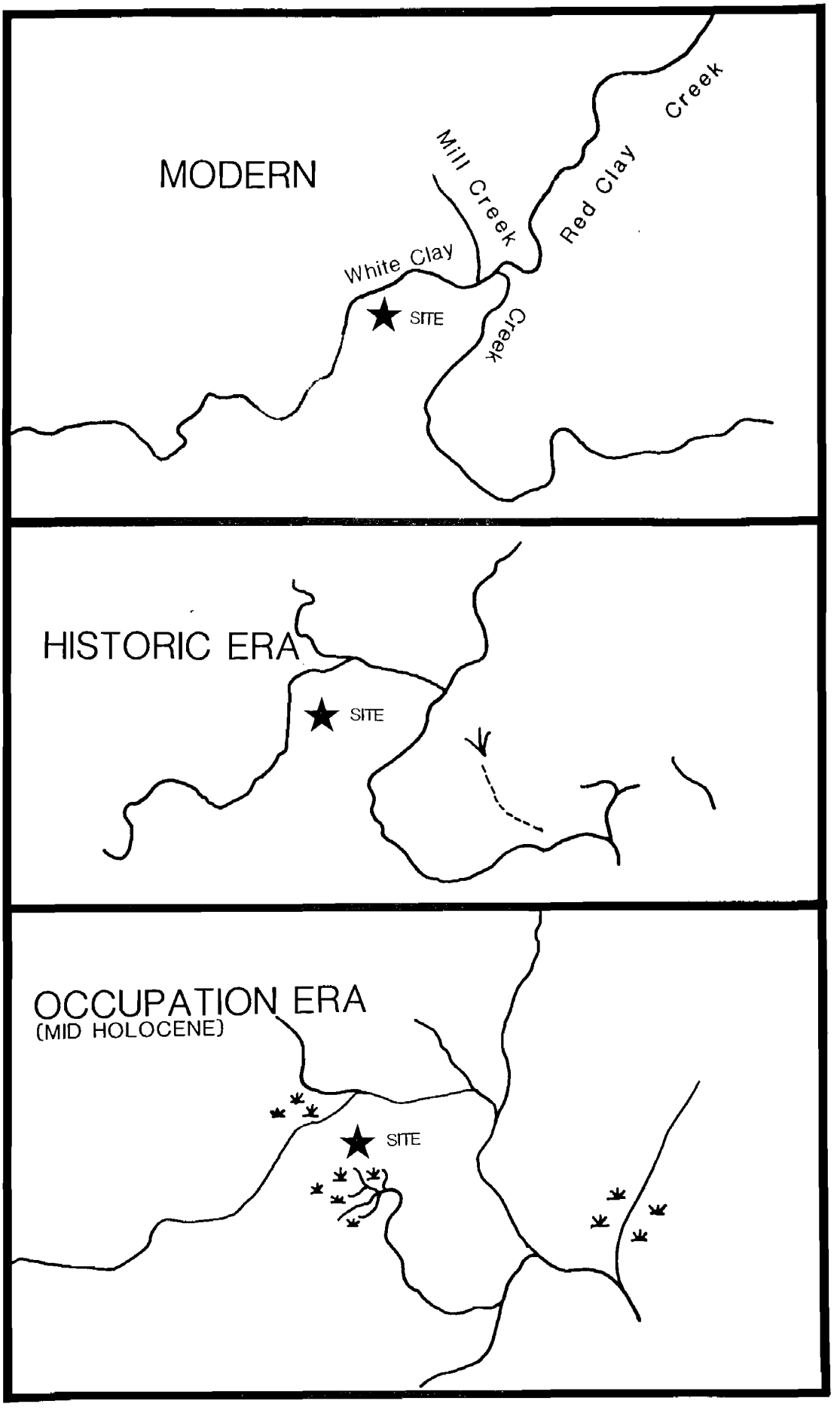

Figure 3 Maps showing presumed channels of White Clay and Mill Creeks at various times in the past.

would have occurred in this low area, but the actual presence of the swamp profile, plus all other observations, rules out the possibility of a major post-Pleistocene channel at that locality.

Physical environment: Based on observations of the geology of the site as discussed above, the following description of the physical environment has been compiled. This description consists of three parts, following the outline provided the auther concerning the "scope of work" for this project.

1) Reconstruction of drainage patterns: White Clay, Red Clay and Mill Creeks have been essentially in their present channel courses for a very long time. Pleistocene and post-Pleistocene geologic activity, however, has caused minor but important changes in both the regime and courses of these streams.

Shortly after the end of the Pleistocene and subsequent to the deposition of the alluvial fan unit, White Clay Creek cut a deep channel down into the sediments of the alluvial fan unit. The channel was near or slightly to the north of its present location. At about 10,000 years ago, post-Pleistocene relative sea level rise began to affect local drainage patterns. The most significant of these effects was a change from a downcutting to a sidecutting regime for both White Clay and Mill Creeks. The channel of White Clay Creek migrated southward for a distance of a few hundred meters. A meander developed which cut into the south bank of the creek, eventually forming the steep scarp at the north side of the site. This process narrowed the width of the site knoll by as much as 50 meters.

A sidecutting meander was also developed on Mill Creek, moving that channel to the east. The interaction of these two meander patterns was the dislocation of the confluence of the two streams southeastward, where a wider flood plain developed and the northeast end of the knoll was eroded into the steep cutbnak near the old railway abutment.

A second change in drainage was a reduction in the water volume of White Clay Creek during the last 10,000 years. There is no direct evidence to date this reduction exactly, but pollen analyses at the site and data from other places in the Delmarva Penninsula yield a data of a few thousand years ago, probably during the period of early occupation of the site. This decreased water volume, combined with a steadily rising relative sea level caused a major alteration to the downstream section of White Clay Creek, relocating it to its present position around the south side of Bread and Cheese Island.

These changes, if they occurrred during occupation as presumed would have altered both the physical environment and resource base at the site, particularly during the earlier period of occupation.

3) Geologic history and stratigraphy: The knoll upon which the site is located was formed by the rapid buildup of various types of layered sediments, deposited during a period of great flooding. Beginning at the end of the Pleistocene Ear (or shortly thereafter) sufficient sediment was

deposited in the valley of White Clay Creek to create a positive topographic element which persists, in altered form, today. Subsequent to the initial deposition which created the knoll, White Clay Creek re-established a channel near the location of its former course. Periodic flooding of the creek during the last 10,000 years has deposited overbank flood plain silt on and around the knoll. These silts probably reached a maximum thickness of 2 to 3 meters on the knoll proper. Sheet wash erosion and weathering processes since the onset of silt deposition have homogenized the silts, destroying any evidence of layering and probably removing as much as one meter of material from the knoll. There is evidence northeast of reworked silts being deposited quite recently. This reworked material was derived from erosion of the knoll. Recent agricultural activity is largely responsible for this erosion, since at the undisturbed creek bank strata cut an uneroded, deep, and strongly weathered soil horizon in the silt unit has been exposed.

There is very little overbank silt deposition southeast of the knoll (away from the creek). Pits at the rail right-of-way exposed only 10 to 20 cm. of the silt unit. In this location, the silt overlies and is interbedded with a swamp or marsh horizon one-half meter thick. This horizon is probably equivalent in time to the deposition of the silt unit and represents a swamp environment in the depression that still exists today. The swamp soil horizon lies directly on the Potomac Formation surface, or, in some cases, a thin wedge of reworked micaceous sandy sediment derived from erosion of the alluvial fan unit present on the knoll. This erosion took place in the early Holocene (Figure 4).

Concerning the possibility of an older (early Holocene) channel south and behind the site knoll, there is no positive field evidence to support such a thesis. Mapping information does indicate that there was a swamp in the millrace cut region. The presence of a cobble flush wedge at the south strata cut indicates that the present day low area has been a flood water course; characteristically, during the time of occupation probably containing a low-lying swamp with some standing water. An "island knoll" of sorts might have existed, but a thesis proposing major changes in the course of the creek is not compatible with field evidence.

3) Paleoenvironment of the site: Paleoenvironmental data has been derived from pollen studies conducted on a series of the grab samples taken in archaeologic features on the knoll. The total pollen profile from the combined feature counts appears to be consistent with individual feature analyses, and indicates an environment similar to that prevailing near the site today. Three dominant elements may be recognized in the pollen "rain" at this site: a mixed deciduous forest, open meadowland or forest opening, and an aquatic-swamp element. Pollen from plants typical of each of these environments has been recovered.

A) Mixed deciduous forest: This assemblage is dominated by oak and elm, with minor elements of other hardwoods. Pine and hemlock pollen is present in a restricted sense, comprising less than 20% of the total count. Juniper and Taxodium complex pollen comprise less than 5% of the total. The percentage of gymnosperm pollens present (pine, hemlock, etc.) is undoubtedly higher than the actual percentage of plants in the immediate area, as the bisaccate nature of gymnosperm pollens permits a much wider

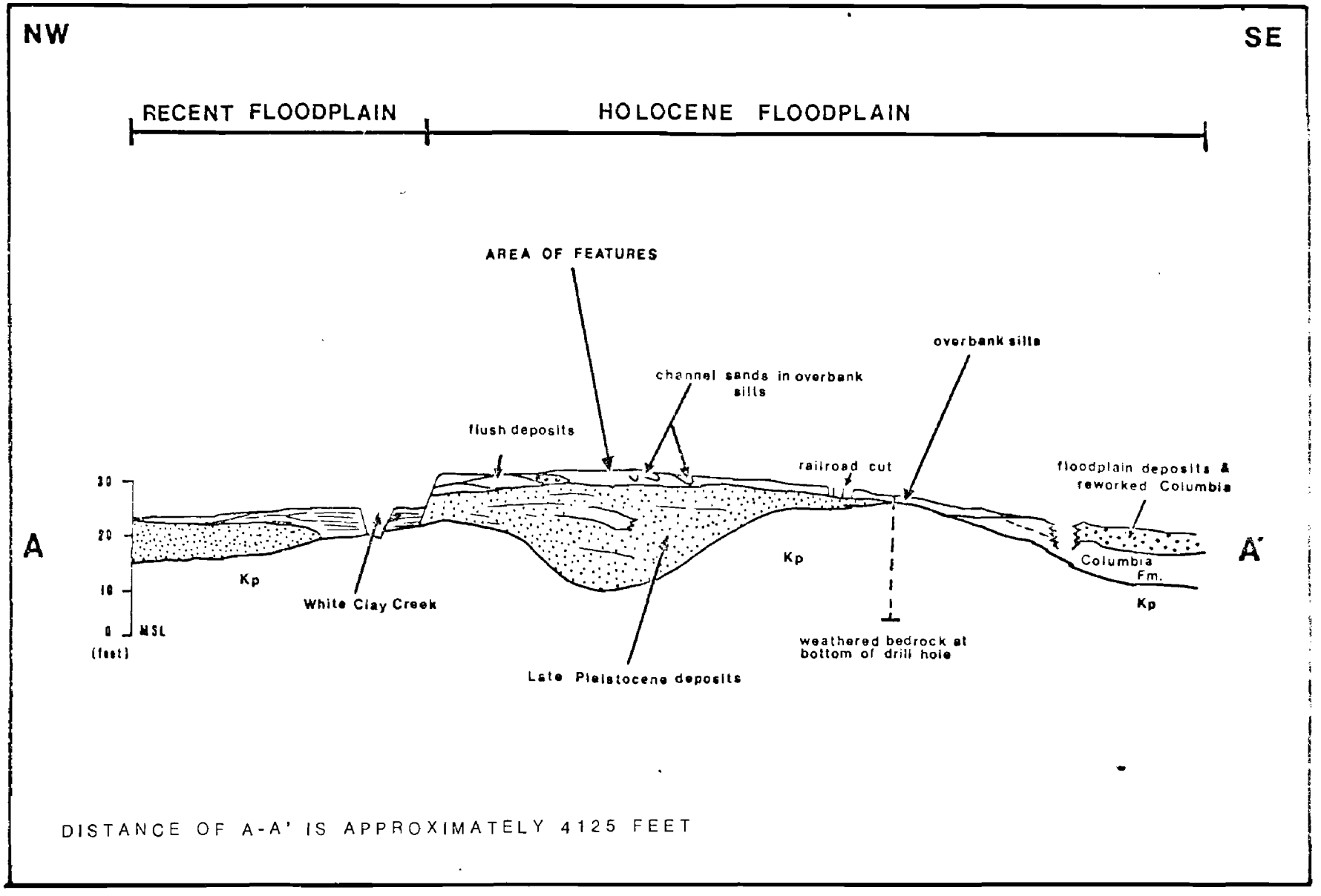

Figure 4 GEOLOGIC CROSS-SECTION THROUGH SITE

dispersal than that of angiosperm pollen. The majority of the gymnosperms in a mixed deciduous forest are confined to well-drained, often sandy slopes that are somewhat drier than the ground on which the oak and elm grow. The relative lower elevation of the site knoll compared to the landscape both to the north and south of the area probably created a "sink" for the pollen of gymnosperms growing on the higher ridges surrounding it.

2) Forest openings or meadows: This assemblage is dominated by the monosulcate, elongated and simple pollen grains typical of grasses. Due to their extremely simple structure, generic determination of most grass pollens is not possible except through electron microscopic photography. However, the simple grass pollens are nearly as abundant in the total count from the site as are the deciduous tree pollens, indicating the presence of broad meadows or open forest glades nearby. Other genera typical of this environment include Frageria, Rumex, Plantago, and members of the Campanulacea, Roseacea, and phlox family. These are all herbaceous flowering types which grow in open grassy spaces. The additional presence of Ambrosia, or ragweed is a sure indicator of open areas.

3) Aquatic and swamp areas: The most persuasive argument for the presence of fresh or very slightly brackish swamps in the area close to the site is the presence in the pollen assemblage of Typha (cattail), Carex (sedge), and members of the suborder Cheopodiineae (amaranth, etc.). These three types are marker genera for swampy conditions, especially Carex, which is important in the formation of the swamp soil horizons. Carex also, given sufficient accumulation, is a primary component in fresh-water peats. Although no true peats were reported at or near the site, the richly organic swamp soil horizon described from the rail right-of-way pit is the initial stage of peat formation.

Several aspects of the site today are quite altered from its probable appearance during occupation. First, the swampy areas have essentially dried, and are currently covered with grasses and scrub. Second, the original forested area has long since been cut over. The trees surrounding the site today are secondary growth, and, while there are still elements of the original forest composition present, the community also contains willow, poplar, and other trees typical of regrown areas. Finally, there has been a sufficient rise in relative sea level over the last 8,000 years to create a brackish marsh in the area of Bread and Cheese Island. Plants growing in this area today would include Salicornia and related genera, which are suited to brackish water, as well as cattail and sedge on higher areas of the marsh.

Pollen from a strata cut was analyzed separately to examine the profile for significant changes in the composition of the flora with time. Of particular interest were the boundary areas between the units described earlier as underlying the site. Potomac Formation material was not exposed on the knoll itself, but samples were taken at 2-inch intervals throughout the exposure of both the flood plain silts and the underlying alluvial fan unit. A gradual increase in the relative percentage of grass and herbaceous plant pollen was noted from the bottom of the flood plain silt unit towards the surface. This indicates a concommitant increase in the areal extent of the meadow type of environment. It has been suggested that the presumed reduction in the volume of water in the streams of this area may

account for this trend. A decrease in water volume would expose a greater area of the flood plain to consistent colonization by grasses and other non-woody plants, and increase their contribution to the total pollen count. No significant changes in profile were noted across the boundary between the alluvial fan unit and the silt unit. Actual numbers of pollen were much lower in the alluvial fan unit, but percentages of the various types of pollen grains remained essentially stable.

CONCLUSIONS

1) The drainage patterns, topographic configuration and paleoenvironment at the site have not changed significantly since before the time of occupation. Changes in vegetation have been primarily the result of the post-contact agricultural activity.

2) The overbank flood plain silt unit within which all the cultural material was found was first deposited on the site knoll at plus 10,000 years ago. The underlying alluvial fan unit was deposited in a very short period of time at about 18,000 years ago. If, after deposition of this unit, it was used as an occupation site prior to 10,000 years ago, erosion has removed any evidence of habitation.

3) There has been erosion of the silt unit, estimated to be a maximum of one meter. However, most of the erosion has occurred since contact, and the integrity of the site from a geological standpoint has not been harmed. Turbation by sheet wash and weathering may have homogonized the silt and cultural strata, but feature material has probably not been moved from the knoll.

4) There is no positive evidence for a change in the course of White Clay Creek to a southern oxbow loop during the Holocene.

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