Geology of the Cactus Hill Archaeological Site (44SX202), Sussex County, Virginia

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GEOLOGY OF THE CACTUS HILL ARCHAEOLOGICAL SITE (44SX202),
SUSSEX COUNTY, VIRGINIA

A thesis submitted in partial fulfillment of the requirements for the degree of
Bachelor of Science with Honors in Geology

from the
College of William and Mary in Virginia

by
Kevin B. Jones

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Table 1. Aeolian sand accretion rates for time intervals based on radiocarbon dates on carbonized wood found at the Cactus Hill Site ............................................. 32
Cactus Hill Archaeological Site (44SX202), located just east of the Nottoway River in Sussex County, Virginia, contains a nearly complete stratified archaeological sequence that has been radiocarbon dated to 11,000 or possibly 15,000 B.P. Geologically, the site is underlain by a surficial aeolian sand, a basal silty clay, and a fluvial sand and gravel. The fluvial sand and gravel is inset against the silty clay.

Aeolian deposition was initiated during the late Wisconsinan full or late glacial interval, when the climate in the southeastern United States was colder and windier than at present. Aeolian sand accretion rates fluctuated from a maximum of 4.6 cm (1.8 in.) per 100 years at approximately 9,000 B.P. to essentially no accretion at present.

Prior to aeolian deposition, the Cactus Hill landscape consisted of an approximately 2 m (7 ft.) high north-facing paleoscarp separating a silty clay upland to the south from fluvial sand and gravel deposits to the north and west. During the late Wisconsinan full or late glacial, deflation of the fluvial sand and gravel blanket by northwest winds began. Aeolian sand accreted against and eventually overtopped the paleoscarp. Aeolian activity probably ceased between 6,000 and 3,000 B.P.

Human occupation of Cactus Hill began approximately halfway through the period of aeolian deposition. The occupation of Cactus Hill was centered on the well drained aeolian sand.
INTRODUCTION

Many Paleoindian archaeological sites have been identified along the Nottoway River in Sussex County, Virginia. Here, the river meanders northeast through the Fall Zone and inner Coastal Plain for 27 km (17 mi.). The bed of the Nottoway in Sussex County is covered with quartz and quartzite cobbles, which were used extensively by early inhabitants of the area as raw material for stone tools (Egloff, 1989).

Cactus Hill Archaeological Site (44SX202) is located on a terrace east of the Nottoway River 8 km (5 mi.) northeast of the town of Stony Creek, Sussex County, Virginia (Figure 1). The site has yielded abundant Paleoindian cultural material, including projectile points, ubiquitous debitage, and fire-cracked rocks. Most importantly, it contains a virtually complete, stratified archaeological sequence that has been radiocarbon dated on charred wood by J.M. McAvoy (in press) to at least 11,000 and possibly 15,000 years before present (B.P.). Based on these dates, Cactus Hill is one of the earliest sites of human occupation identified on the east coast of the United States.
Sand and gravel is mined at Cactus Hill. As of October 1995, this mining had produced a pit measuring approximately 180 by 75 m (600 by 250 ft.) and up to 4 m (13 ft.) deep. Most of the artifacts from the mined land have been lost. Some remaining areas of high artifact density have been looted, resulting in extensive disturbance of the upper 1 m (3 ft.) of sediment over much of the southern half of the site.

Figure 2. Cactus Hill Archaeological Site, looking north across mined area, showing outcrop of surficial aeolian sand underlain by fluvial sand and gravel. Scarp at edge of mined area is approximately 2.4 m (8 ft.) high.

Cactus Hill consists of three stratigraphic units: a silty clay unit, a bedded sand and gravel unit, and a surficial, stratified, artifact-bearing medium sand unit which overlies the first two. The sand and gravel unit is fluvial and is inset against the silty clay unit. The surficial sand is an aeolian dune deposit which mantled the paleotopography
reflected by the contacts between the surficial sand unit and the underlying units. The dune sand was probably deflated from the fluvial sand and gravel unit to the northwest.

PURPOSE

The primary purpose of this study was to construct a geologic history of the Cactus Hill Site. The secondary, related goals of this study were to determine the origin and age of the surficial sand, to determine what the geologic reasons were for the early human occupation of Cactus Hill, and to investigate the effects that human activity and climatic and vegetative changes during and prior to human occupation had on the Cactus Hill geologic record.

METHODS

A combination of topographic surveying, hand augering, vibracoring, ground-penetrating radar (GPR), and textural and mineralogical laboratory analyses were used to determine the configuration, distribution, and origin of the surficial sand.

Sediment samples were obtained by hand auger and vibracore and from pit bank exposures. The grain size and sorting of the samples were analyzed using the Rapid Sediment Analyzer settling tube at the Virginia Institute of Marine Science and by sieving using $\frac{1}{2}-\phi$ intervals. The mineralogy of the samples was analyzed by point counting and visual estimation in the laboratory. Sample rounding was analyzed visually in the laboratory. The goal of this analysis was to determine how the characteristics of
the surficial sand and underlying units change across the site. Samples taken at depth
were analyzed in order to understand the nature of the contact between the surficial sand
and the underlying units. The soil profiles of the surficial sand and silty clay units were
also examined.

The topography of Cactus Hill and the locations of borings were surveyed with a
theodolite. A GPR survey was made along a transect crossing the western part of the
Cactus Hill Site and on a small site north of the pit. Four vibracores were taken along the
GPR transect to provide undisturbed ground truth for the GPR data. The GPR and core
data has not yet been evaluated.

PALEOENVIRONMENT

During the late Wisconsinan full glacial (23,000 to 16,500 B.P.) and late glacial
(16,500 to 12,500 B.P.) intervals, the Coastal Plain of Virginia was covered by a boreal
forest of mostly jack pine (*Pinus banksiana*), with lesser amounts of spruce (*Picea*) and
fir (*Abies*), similar to the forests now found in the maritime provinces of eastern Canada
(Figure 3) (Delcourt and Delcourt, 1985 and 1986).
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Figure 3. Paleovegetation maps for the southeastern United States (Delcourt and Delcourt, 1985)

Throughout this time period, the atmospheric Polar Frontal Zone, the boundary between the Pacific and Maritime Tropical Airmasses, had a mean winter position along latitude 33°N (Figure 4). North of the Polar Frontal Zone, winds were dominantly the Prevailing Westerlies of the Pacific Airmass (Delcourt and Delcourt, 1985). Whitehead (1973) and Barry (1983) suggest that the late Wisconsinan full and late glacial time intervals were at least seasonally drier along the Atlantic Coastal Plain, including the...
Cactus Hill region, than at present. The summer temperatures in the region probably averaged 20°C (68°F), or 7°C (13°F) less than at present, and winter temperatures probably averaged -10°C (14°F), or 18°C (32°F) less than at present (Barry, 1983). According to Whitehead (1973), the winds in the region may have been more intense and directional than at present.

Figure 4  Paleoclimatic reconstructions of predominant airmasses of eastern North America (Delcourt and Delcourt, 1984).
These westerly winds in combination with the cold, dry climatic conditions in the rain shadow of the Appalachian Mountains caused extensive aeolian activity along the Atlantic Coastal Plain during the late Wisconsinan full and late glacial intervals. Based on mean grain sizes of sand dunes which formed during this period, winds may have been 1.4 times stronger than current coastal dune-forming winds (Carver and Brook, 1989). Migrating sand dunes probably produced gaps in the boreal forest and maintained an open taiga in areas across the region (Delcourt and Delcourt, 1986; Whitehead, 1973).

The vegetation in the Coastal Plain of Virginia changed from a boreal pine-spruce taiga to a mixed deciduous and evergreen forest of oak (*Quercus*), pine (*Pinus*), hemlock (*Tsuga*), and hickory (*Carya*) during the latest Pleistocene and early Holocene (12,500 to 8,500 B.P.) (Delcourt and Delcourt, 1986 and 1991). In the Atlantic Coastal Plain of Virginia, the climate began to warm by about 10,500 B.P. The climate of other unglaciated areas of the eastern United States began to moderate thousands of years earlier, but a glacial climate persisted along the Atlantic Coastal Plain north of South Carolina because the area was cooled by the cold Atlantic Labrador Current (Delcourt and Delcourt, 1986). The Labrador Current was positioned between the shoreline and the warm Gulf Stream farther offshore until northward migration of the Gulf Stream shifted the Labrador Current northward and away from the central Atlantic Coast by about 10,500 B.P. (Delcourt and Delcourt, 1986).

Oak probably dominated the Cactus Hill region during the middle Holocene (8,500 to 4,000 B.P.). At 8,000 B.P., oak comprised about 60 percent of the trees in the area (Delcourt and Delcourt, 1986 and 1991). By 5,000 B.P., oak domination had decreased and the floral assemblage had shifted toward the mixed deciduous and
southeastern evergreen forest vegetation currently found in the region. This vegetational shift may reflect an increase in fire frequency brought about by the increasing influence of the Maritime Tropical Airmass and by human inhabitation of the area. Humans may have set fires which maintained tracts of open pine forest and increased the carrying capacity of faunal resources, such as white-tailed deer (Delcourt and Delcourt, 1985).

The present temperate climate and mixed deciduous and southeastern evergreen forest vegetation were maintained in southeastern Virginia through the late Holocene (4,000 B.P. to present).

AEOLIAN DUNES IN THE SOUTHEASTERN UNITED STATES

On the Coastal Plain of Georgia, unstratified inland dunes occur to the east of major rivers, such as the Altamaha, Canoochee, Ogeechee, Ohoopee, and Savannah, and to the east of Carolina bays. Markewich and Markewich (1993) identified stream channel, floodplain, and Carolina bay deposits as the source areas for these dunes, and concluded that the dunes were formed by persistent west or west-southwest winds. They also identified at least two sets of dunes of different ages at several localities on the Georgia Coastal Plain. Stratigraphically, they found all inland dunes to be younger than 500,000 B.P., and many to be younger than 250,000 to 40,000 B.P. A set of dunes along the Altamaha River (Figure 5) formed more recently than 15,000 B.P., based on a radiocarbon date on the river terrace underlying the dunes. Along the Ogeechee River, another set of dunes became inactive before 3,000 B.P., based on a radiocarbon-dated terrace geomorphically younger than the dunes (Markewich and Markewich, 1993).
Thom (1967) established the presence of southwest-northeast trending dune fields north of the Great and Little Pee Dee Rivers in South Carolina formed during the Wisconsinan full glacial interval. One radiocarbon date indicates that one of these dune fields is less than 36,000 years old. Another radiocarbon date, in combination with stratigraphic dating based on past elevations of sea level, suggests that another dune sheet began forming about 17,000 B.P. and became inactive about 6,000 B.P. These dune fields developed during low stands of sea level when, because of the lower base level, the Great and Little Pee Dee Rivers were braided and incised. The trends of these dune fields indicate formation by west-southwest winds.

Daniels et al. (1969) showed with a radiocarbon date on an underlying soil that aeolian sands at Toisnot Swamp, on the North Carolina Coastal Plain, were deposited after 10,700 B.P.

In the Cape Fear River valley, North Carolina, Soller (1988) dated sand dunes to the east of the Cape Fear River and to the northeast of nearby Carolina bays. Several radiocarbon dates on peat and wood at the bases of these dunes reflect at least two dune-
forming events. Five dates indicate dune formation beginning more than 35,000 B.P., whereas two dates point to dunes forming at 8,000 and 6,000 B.P. Soller (1988) also shows mineralogically that the Cape Fear River valley dunes were derived from Cape Fear River sediments. He suggests that during a low stand of sea level, the exposed, incised Cape Fear River channel was deflated and the sand was transported a short distance by southwest winds to form dunes on the northeast side of the river. Dune formation ceased approximately 3,500 B.P., when backfilling of the Cape Fear River channel began.

Whitehead (1973) cited examples of Carolina bay localities in Bladen County, North Carolina where aeolian activity occurred during the Wisconsinan full glacial interval. The Carolina bay deposits contain increased sand fractions during the full glacial, as well as broken diatoms, sponge spicules, and pine pollen grains which were probably caused by increased sand deposition and wind agitation of the lake bottom sediments. Carver and Brook (1989) found that parabolic dunes northeast of Carolina bays near Elizabethtown, Bladen County, North Carolina, were also formed by southwest winds.

On the Delmarva Peninsula of Maryland and Delaware, low, inconspicuous parabolic sand dunes of the Parsonsburg Sand cap terraces to the southeast of major rivers and mantle uplands. Peat lenses at the base of the upland dunes have radiocarbon ages of between 30,000 and 13,000 B.P. (Denny et al., 1979), indicating that the dunes began forming during the late Wisconsinan. Microfloral assemblages in these peat lenses indicate a climate at the onset of aeolian deposition cooler and drier than at present (Sirkin et al., 1977). The Parsonsburg Sand dunes which cover terraces to the east of the
Chicamacomico, Nanticoke, Wicomico, and Pocomoke Rivers generally have no dateable organic material at their bases, but Denny and Owens (1979) consider these dunes either late Wisconsinan or Holocene. Based on parabolic dune axis directions, the Delmarva Peninsula dunes were formed by northwest winds (Denny and Owens, 1979).

Late Pleistocene and Holocene dunes on the upper Coastal Plain of southern Virginia were recognized by archaeologists at least as early as 1967, when the Turner Site on Assamoosick Swamp in Sussex County was identified as aeolian in an Archaeological Society of Virginia site report (McAvoy, in press). By 1983, the Nottoway River Survey of the Archaeological Society of Virginia had identified eight probable aeolian deposits containing cultural material, including the Cactus Hill Site, along a 16-km (10-mi) course of the Nottoway River (Figure 6).

The Slade North Site, one of these aeolian dune locations, was excavated archaeologically and examined geologically between 1983 and 1994. This site is located 5 km (3 mi) upstream from the Cactus Hill Site, and like Cactus Hill, is located on a low terrace to the east of and adjacent to the Nottoway River. G.H. Johnson, College of William and Mary, (in McAvoy, in press) found the Slade North Site sand to be quartzose with trace amounts of mica and heavy minerals, moderately to well sorted, subangular to well rounded, and to contain more spherical and more frosted grains than nearby modern fluvial and Pleistocene fluvial-estuarine sands. Sediment grain size histograms of the Slade North Site sand closely matched those from an aeolian dune above the east bank of the Chowan River at Gatlington Landing, Gates County, North Carolina.
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Figure 6. Aeolian archaeological sites identified along the Nottoway River by the Nottoway River Survey by 1983 (McAvoy, in press).

**PHYSIOGRAPHIC SETTING**

The Nottoway River heads in the Piedmont and flows through the Fall Zone into the upper and middle Coastal Plain. The Nottoway is a major tributary of the Chowan River which flows into Albemarle Sound in eastern North Carolina. The Nottoway flows about 250 km (155 mi.) from its headwaters near Green Bay, Prince Edward County, Virginia to its confluence with the Blackwater River to form the Chowan River at the
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Virginia-North Carolina state line. The drainage basin of the Nottoway River above Cactus Hill encompasses about 2,600 km² (1,000 mi²) (Figure 8). Near Cactus Hill, the Nottoway River has a gradient of approximately 0.6 m/km (3.1 ft./mi.) and a low flow elevation of approximately 13 m (44 ft.) above sea level.

A hydrologic gage on the Nottoway River at Stony Creek, ten miles upstream from Cactus Hill, has been in continuous operation since 1929. The highest measured flow at Stony Creek, 714 m³/s (25,200 ft.³/s), occurred in 1940. This flood had a recurrence interval of about 100 years and produced a gage height of 7.3 m (24 ft.). A 10-year flood at Stony Creek corresponds to a flow of 345 m³/s (12,200 ft.³/s) and a gage height of 5.8 m (19 ft.) (C. Bell, pers. comm.). Based on this river flow data and an analysis of topographic cross-sections of the Nottoway River floodplain at the gaging station and at Cactus Hill, during a 100-year flood, water at Cactus Hill would rise to a level of approximately 19.8 m (65 ft.) above sea level (Figure 7). A 100-year flood, then, would leave Cactus Hill above water, but would flood the swales adjacent to Cactus Hill. During a 10-year flood, water would rise to approximately 18.0 m (59 ft.) above sea level, flooding some swales on the terrace upon which Cactus Hill is located, but leaving the Cactus Hill area above water.
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Figure 7. Topographic cross-sections of Nottoway River floodplain at Cactus Hill and Stony Creek gaging station. Topographic data from Stony Creek and Sussex, Virginia 7.5-minute quadrangles. Vertical exaggeration 25x
Figure 8  Geologic map showing the Nottoway River drainage basin above Cactus Hill (modified from Virginia Division of Mineral Resources, 1993).
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Figure 9  Topographic map showing Cactus Hill Archaeological Site (44SX202) and surroundings (from Sussex, Virginia 7 5-minute quadrangle). Contour interval 10 feet  Dotted lines represent 5-foot contours
In the upper and middle Coastal Plain, the Nottoway River flows through a terraced landscape (Figure 9). A discontinuous, low floodplain exists on the inside of meanders and locally along straight reaches of the river. The first terrace above the river, on which the lower part of the Cactus Hill Site is located, exhibits ridge and swale topography (Figure 10). The linear ridges and swales trend east-west and have a relief of about 3 m (10 ft.). The elevations of the swales on this terrace range from 15 to 18 m (50 to 60 ft.) above sea level.

This terrace upon which Cactus Hill is located is the equivalent of the Grafton Plain and is bounded on the north and south by the Lee Hall Scarp. A succession of terraces with tread elevations of about 23 m (75 ft.) and 27 m (90 ft.) above sea level lie above the Lee Hall Scarp.

Topographically, the Cactus Hill site can be divided into at least two parts with different morphological characteristics (Figure 11). The topography of the western part
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of Cactus Hill is asymmetric; the ridge slopes gently (about 1°) to the north and more steeply (more than 4°) to the south. The central part of the ridge is more topographically symmetric, sloping to the north and south at about 1°. Surveying and sampling have not been completed on the eastern part of Cactus Hill.

Figure 11  Topographic map of Cactus Hill showing area of sand and gravel mining  Contour interval 1 foot  Stratigraphic cross-sections shown in Figure 13.
GEOLOGIC SETTING

The lithic materials found in the bed of the Nottoway River were exploited by early inhabitants of the Cactus Hill area for the manufacture of tools and weapons. The source of these river gravels is the Piedmont rocks to the west and coarse sediments at the base of discontinuous deposits of the upper Coastal Plain along the Fall Zone. Approximately one-quarter of the drainage basin of the Nottoway River above Cactus Hill is located in the Coastal Plain and three-quarters is located in the Piedmont. The Piedmont rocks of the Nottoway drainage basin include granites, gneisses, schists, slates, abundant quartz veins, and a variety of other igneous and metamorphic rocks (Figure 8). The weathered mantle on the Piedmont contains abundant quartz clasts, which over time are introduced into the Nottoway drainage system.

The sediments of the upper Coastal Plain contain coarse clasts derived not only from the Piedmont but also from the mountains to the west of the Piedmont. Principal among these clasts are the quartzites of the west flank of the Blue Ridge and adjacent Valley and Ridge. The present drainage basin of the Nottoway River does not reach the Blue Ridge or Valley and Ridge, however. Initially, these quartzites were probably eroded from the ancestral Appalachian Mountains, and have been moved eastward during repeated cycles of transportation throughout the Mesozoic and Cenozoic.

The bed of the Nottoway River is mantled with pebbly and cobbly sandy alluvium. The base of this alluvium rests on coarse sediments of the Cretaceous Potomac
Group (Weems et al., in preparation). Near Cactus Hill, the Nottoway channel walls are cut into the lower Pleistocene(?) Charles City Formation.

SEDIMENTOLOGY AND STRATIGRAPHY

Three stratigraphic units are recognized at Cactus Hill: an older basal silty clay capped by a probable paleosol, a fluvial sand and gravel, and a surficial aeolian sand (Figure 12).

The basal silty clay unit, which crops out to the south of Cactus Hill, is typically a mottled light grey (N7) and dark yellowish orange (10 YR 6/6) compact silty clay containing scattered sand grains. The sand grains are rounded and range in size from fine to coarse. This silty and fine sandy stream terrace soil has been mapped as the Tomotley sandy loam, a poorly drained soil of moderately slow permeability, derived from loamy marine or fluvial sediments (McEachern, unpublished).

The fluvial unit is usually a moderate yellowish-brown (10 YR 5/4), very poorly sorted, pebbly coarse sand, with a maximum thickness of more than 3 m (10 ft.). The sand grains are mostly angular, whereas the pebbles and scattered cobbles are well rounded. Mineralogically, the unit is about 91 percent quartz, 4 percent feldspar, 4
percent lithic fragments, and 1 percent carbonized wood and heavy minerals. The fluvial unit is inset against the silty clay unit.

The surficial aeolian sand mantles only part of the Cactus Hill Site and contains the stratified sequence of archaeological artifacts in its upper part. The aeolian sand covers much of the fluvial sand and gravel unit, thickens southeastward to a maximum thickness of approximately 2 m (7 ft.) where it laps onto the silty clay unit, and then thins southeastward across the silty clay unit. The stratified archaeological sequence is up to 0.7 m (2.3 ft.) thick. The aeolian sand is typically a moderate yellowish-brown (10 YR 5/4), moderately sorted, subrounded medium sand. It contains about 93 percent quartz, 3 percent feldspar, 3 percent lithic fragments including numerous mica flakes, and 1 percent carbonized wood. The aeolian sand has been mapped as the Buncombe loamy sand, an excessively drained, rapidly permeable soil derived from sandy alluvium (McEachern, unpublished).

Auger samples show that the central and northern parts of Cactus Hill consist of the aeolian sand underlain by only the fluvial sand and gravel unit (Figure 13). In the western part of Cactus Hill, the surficial sand is underlain by the sand and gravel unit on the gentle north slope and by the clay unit on the steeper south slope.

Auger sampling also shows that the topography of the central part of Cactus Hill reflects the contact between the aeolian sand and the fluvial sand and gravel unit. The sand unit in the central part of Cactus Hill is about 1.5 m (5 ft.) thick, although it thins to less than 0.5 m (1.6 ft.) at the northwestern end of section B-B'.
The grain size of the aeolian sand remains nearly constant across Cactus Hill. A textural analysis of a single vertical sequence of surficial sand from central Cactus Hill shows a slight variation in grain size with depth (Figure 14). Overall, the sequence fines
upward from a mean grain size of about 1.30 $\phi$ at the base of the surficial sand to approximately 1.75 $\phi$ near the surface.

Sorting of the surficial sand is greatest, well to moderately well sorted, at the crest of Cactus Hill and is generally moderate elsewhere. No obvious variations in surficial sand grain rounding were observed across the site; the grains were generally subrounded to subangular.

**ORIGIN OF THE SURFICIAL SAND**

McAvoy (in press) believes that the sand features found close to the Nottoway River, including Cactus Hill, are not dunes, but are features produced in part by large flood eddy currents of the Nottoway River. The location, age, texture, and mineralogy of Cactus Hill as determined by this study, however,
indicate that Cactus Hill is indeed a dune deposit.

Cactus Hill is located on the Atlantic Coastal Plain in Virginia. The Coastal Plain from Georgia to Delaware contains many areas of inland dunes. Additionally, Cactus Hill is located just above the east bank of a north-south trending reach of the Nottoway River. Most inland dunes that are associated with rivers are found on the east sides of north-south trending reaches.

Radiocarbon dates on carbonized wood found about halfway through the stratified surficial sand at Cactus Hill indicate that deposition of the sand began prior to 15,000 B.P. At that time, the climate in Virginia was cooler, windier, and possibly drier than at present, favoring aeolian activity. Along the Atlantic Coastal Plain, most inland aeolian dunes have been dated to the late Pleistocene or Holocene, as has Cactus Hill.

The almost exclusively sandy nature of the surficial sand indicates that its depositional process must have been very selective. Most upland sediments on the upper and middle Coastal Plain are poorly sorted mixtures of sand, silt, and clay containing some coarser clasts. The process which deposited the surficial sand selectively separated out particles which were coarser and finer than sand (Daniels et al., 1969). Aeolian activity is the only process that is this selective, commonly producing deposits of well to moderately sorted sand.

The surficial sand at Cactus Hill is texturally similar to aeolian sands found at the Slade North Site, Virginia and Gatlington Landing, North Carolina. A plot of mean grain size vs. standard deviation (sorting) (Figure 15) shows the similarity between the Cactus Hill surficial sand and the two aeolian dune sands. This plot also shows the textural
differences between the aeolian sands and nearby fluvial sands from Cactus Hill and Gatlington Landing.

In a study to determine which textural parameters are most effective in differentiating several types of aeolian and fluvial sands, Moiola and Weiser (1968) found that inland aeolian sands and fluvial sands could not be differentiated very effectively using textural parameters. Figure 15 shows that plotting mean grain size vs. standard deviation is, in fact, an effective way to differentiate late Pleistocene and early Holocene inland aeolian sands of the Atlantic Coastal Plain from fluvial sands. The inland dune sands used by Moiola and Weiser were collected from active dune fields, but the inland dunes of the Atlantic Coastal Plain are no longer active. Because present winds are not as intense and directional as those which produced the Atlantic Coastal Plain dunes, sands in currently active dunes are finer than those which were deposited by the stronger winds of the late Pleistocene and early Holocene. The inland dune sands of Moiola and Weiser, then, are not texturally comparable to the Atlantic Coastal Plain inland dune sands, such as those found at Cactus Hill.

The source area of the aeolian sand at Cactus Hill was probably the nearby fluvial sand and gravel unit to the northwest. The fining of the aeolian sand to the east supports an aeolian mode of deposition with a source area to the west or northwest. The accretion of aeolian sand against a north-facing paleoscarp indicates a source area to the north or northwest. The mineralogical similarity of the fluvial sand and gravel unit and the aeolian sand unit, both of which consist of 91 to 93 percent quartz, 3 to 4 percent feldspar, and 3 to 4 percent lithic fragments, also substantiates the fluvial sand and gravel source area.
The generally moderate sorting and subrounded to subangular grains are not typical of dunes whose sediments have been transported long distances. At Cactus Hill, the source area was less than 1 km (0.6 mi.) away. Because the grains were not transported a great distance, the resulting accumulation of sediment is neither as well sorted nor as well rounded as it would have been otherwise.
The part of the aeolian sand unit below the stratified archaeological sequence has similar textural and mineralogical properties to the sand containing the archaeological sequence, and there is no obvious stratigraphic break between the sterile and artifact-bearing sections of the aeolian sand. Therefore, the entire aeolian sand unit, including the stratified archaeological sequence and its underlying sterile sands, was probably deposited during the same extended period of aeolian deposition. This indicates that aeolian deposition must have begun well before 11,000 or possibly 15,000 B.P., the date obtained for the base of the archaeological sequence by McAvoy (in press). No dates have been obtained for the sand below the archaeological sequence because significant amounts of organic material have not been recovered.

Assuming that the rate of aeolian deposition of the sterile sand was comparable to that of the artifact-bearing sand, aeolian deposition may have begun 25,000 to 30,000 B.P. If, however, the rate of aeolian deposition peaked prior to the human occupation of the site and deposition of artifacts, the onset of aeolian deposition at Cactus Hill would have been more recent.

Parts of the Cactus Hill Site have been carefully excavated and dated by McAvoy (pers. comm.). Dates for horizons in the aeolian sand were initially determined on projectile points and were later confirmed by radiocarbon dates on carbonized wood. Based on these dates, accretion rates were found to have been variable but generally
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decreased from as much as 4.6 cm (1.8 in.) per 100 years from 8,900 to 9,100 B.P. to zero at present (Figure 16 and Table 1).

![Graph of aeolian sand accretion rate as a function of time.](image)

*Figure 16. Graph of aeolian sand accretion rate as a function of time. Sand accretion rate intervals are based on radiocarbon dates on carbonized wood found at several locations on the Cactus Hill Site (McAvoy, pers. comm.).*

<table>
<thead>
<tr>
<th>Time span (B.P.)</th>
<th>Average accretion rate (per 100 years)</th>
<th>Number of samples used in calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>6,500-7,000</td>
<td>1.5 cm (0.58 in.)</td>
<td>2</td>
</tr>
<tr>
<td>7,800-8,700</td>
<td>0.43 cm (0.17 in.)</td>
<td>3</td>
</tr>
<tr>
<td>8,300-8,700</td>
<td>0.64 cm (0.25 in.)</td>
<td>1</td>
</tr>
<tr>
<td>8,300-8,900</td>
<td>1.8 cm (0.7 in.)</td>
<td>1</td>
</tr>
<tr>
<td>8,300-9,100</td>
<td>2.9 cm (1.13 in.)</td>
<td>1</td>
</tr>
<tr>
<td>8,900-9,100</td>
<td>4.6 cm (1.8 in.)</td>
<td>4</td>
</tr>
<tr>
<td>9,100-9,400</td>
<td>2.5 cm (1.0 in.)</td>
<td>1</td>
</tr>
</tbody>
</table>

*Table 1. Aeolian sand accretion rates for time intervals based on radiocarbon dates on carbonized wood found at several locations on the Cactus Hill Site (McAvoy, pers. comm.).*

McAvoy (pers. comm.) does not feel that any of his radiocarbon dates more recent than 6,500 B.P. are valid indicators of sand accretion rates, possibly because of bioturbation by humans. The accretion rate curve shown in Figure 16 for dates more recent than 6,500 B.P. is speculative. This curve is based on the approximately 0.5 m
(1.6 ft.) depth of aeolian sand above the 6,500 B.P. horizon at a carefully excavated section of the Cactus Hill Site, the observation that aeolian deposition is not currently active at Cactus Hill, and the evidence elsewhere along the Atlantic Coastal Plain that aeolian activity ceased by between 6,000 and 3,000 B.P. (Thom, 1967; Soller, 1988; Markewich and Markewich, 1993). If aeolian deposition at Cactus Hill continued until more recently than 6,000 to 3,000 B.P., the speculative peak in sand accretion rate would be wider and not as high.

The sand accretion rate curve (Figure 16) is similar to the plot of mean grain sizes with depth in a carefully excavated section of surficial sand (Figure 14). Based on projectile point and radiocarbon dating of horizons in this section by McAvoy (pers. comm.), the sand accretion rate curve can be adjusted to show accretion rates as a function of depth in this section. Side-by-side plots of mean grain size and sand accretion rate as a function of depth (Figure 17) show that sand accretion rate maxima and minima correspond to mean grain size maxima and minima. Stronger winds may have produced higher sand accretion rates and may have been able to transport larger sand grains, resulting in the deposition of coarser sediments during periods of more rapid sand accretion. The similarity between the mean grain size and sand accretion rate plots supports the general shape and amplitude of the conjectural (dotted) portion of the sand accretion rate curve, as well as an aeolian method of deposition.

The variable accretion rate of sand probably reflects several different natural and anthropogenic causes. Among potential variables affecting the accretion rate are the availability of sand, climatic conditions, intensity of local winds, changes in vegetative cover, frequency of fire, and intensity of human activity on the site.
Because the sandy fluvial deposits immediately to the north and west of Cactus Hill were available for deflation throughout the period of aeolian accretion, the availability of sand for aeolian transport would have been constant and would probably not have been an important variable. However, episodic major floods may have supplied additional sand for deflation and reduced local vegetative cover.

With the onset of glaciation, both climatic and vegetative changes occurred along the Atlantic Coastal Plain. Although it is impossible to prove that these conditions initiated aeolian deposition at Cactus Hill, their timing coincides with the probable onset of aeolian deposition. Stronger, more directional, and possibly drier winds present during glaciation would probably have produced higher rates of aeolian deposition than during the post-glacial period. These high rates of deposition decreased with the retreat of glaciers and establishment of deciduous and later a mixed forest cover.

Natural and man-made fires and intensive human occupation of the site would have reduced or removed surface cover, allowing for the rapid deflation of barren sand. Such a removal of surface cover by fire may have been responsible for the high sand accretion rate noted at about 9,000 B.P.

Based on the thicknesses of the sterile and artifact-bearing sections of aeolian sand, human occupation began midway through the period of deposition of aeolian sand at Cactus Hill. Although human occupation of the Cactus Hill Site may have increased the rate of sand accretion, this occupation could not have initiated aeolian deposition.
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Figure 17. Mean grain size and rate of sand accretion with depth in a single excavated section in the surficial sand near central Cactus Hill.
GEOLOGIC RECONSTRUCTION

Before the onset of aeolian activity at Cactus Hill, a low, east-west trending scarp separated an upland to the south underlain by silty clay and a lower area to the north underlain by sandy fluvial deposits (Figure 18, a, b, and c). The scarp was located near the southern edge of present-day Cactus Hill. Well before 15,000 B.P., and possibly as early as 25,000 to 30,000 B.P., aeolian activity began. The fluvial sand and gravel blanket to the north and west was deflated as medium and fine sands were blown southwestward and accreted along the northern edge of the scarp (Figure 18, d). Aperiodic flooding may have allowed deflation to continue by replenishing the fluvial sand and gravel blanket and reducing vegetative cover. Shifting sand and gravel bars in a braided Nottoway River may have also replenished the fluvial sand source area. As deflation of the fluvial sediments continued, the accreting aeolian sand eventually overtopped the scarp, capping the silty clay south of the scarp with aeolian sand (Figure 18, e). Thereafter, the earliest human inhabitants migrated to the area, occupied the locally high sandy areas, and utilized the lithic resources found in the bed of the nearby Nottoway River.

The main part of the Cactus Hill Site was, even at the time of earliest occupancy, a well drained area. The highest part of Cactus Hill would have remained barely above water during even a 100-year flood of the Nottoway River. By contrast, the linear trough to the south, underlain by clayey soils, was poorly drained and subject to flooding. This trough was apparently also less inhabited—few artifacts have been found there. The
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The occupation of Cactus Hill was centered on the well drained area underlain by aeolian sands and fluvial sands and gravels.

Figure 18. Schematic geologic reconstruction of the Cactus Hill Site. North is to the left.
CONCLUSIONS

The location, topography, texture, and relationship to underlying units of the surficial sand indicate that this sand is aeolian. Cactus Hill is located on the southeastern Atlantic Coastal Plain, an area dotted with late Pleistocene and Holocene aeolian dune localities. Like most aeolian dunes in the Southeast, Cactus Hill is on the east bank of a north-south trending reach of a river. The topography of Cactus Hill from north to south is asymmetrical. The surficial sand is medium grained and finer, decreases in grain size to the east, and is generally moderately to well sorted. The mean grain size and sorting of the surficial sand at Cactus Hill are similar to those of aeolian sands at the Slade North Site, Virginia, and Gatlington Landing, North Carolina. Typical aeolian sorting and grain rounding are not present in the aeolian sand at Cactus Hill because the sand was transported less than a few hundred meters from its fluvial source deposits located to the northwest. This distance was insufficient to produce typical aeolian sorting and rounding characteristics in the sediment. The aeolian sand migrated across a fluvial surface, accreted against a north-facing paleoscarp, and spilled onto the edge of the adjacent upland.

Sand accretion rates varied, decreasing from 4.6 cm (1.8 in.) per 100 years at about 9,000 B.P. to essentially no accretion at present. These rates were strongly influenced by late Pleistocene and early Holocene climatic and vegetative conditions and may have been affected later by human occupation.
Based on paleowind directions from several late Pleistocene aeolian dunes throughout the Atlantic Coastal Plain, winds in the Southeast during the late Pleistocene were dominantly from the west-southwest in Georgia, rotating toward the southwest through the Carolinas (Carver and Brook, 1989). On the Delmarva Peninsula, however, winds were from the northwest. If the aeolian sand at Cactus Hill did accrete against a north-facing paleoscarp, late Pleistocene winds at Cactus Hill were also out of the northwest, suggesting that the northwest paleowind directions found on the Delmarva Peninsula may be part of a large region of northwest winds, rather than a local anomaly.

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