APPENDIX H:

GEOARCHAEOLOGICAL INVESTIGATIONS

Geoarcheological Research Associates

GEOARCHEOLOGICAL INVESTIGATIONS AT THE SANDOM BRANCH SITE COMPLEX (7NC-J-227/228), SR 1 SMYRNA TO PINE TREE CORNERS, NEW CASTLE COUNTY DELAWARE

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Table of Contents

Introduction H-5
Research Design and Field Methods H-7
Geoarcheological Approach to Sites in the Delaware Coastal Plain H-10
Laboratory Analyses H-12
7NC-J-227 Stratigraphy and Depositional Chronology H-15
7NC-J-228 Stratigraphy and Depositional Chronology H-19
Chemistry of Cultural and Noncultural Sediments H-24
Stratigraphic Framework and Evidence for Environmental Change H-30
- Origins and Age of the Columbia Formation (Base of Sandom Sequence; pre-cultural) H-30
- Origins and Age of the Late Quaternary Deposits (Top of Sandom Sequence; artifact bearing) H-32

Modeling Site Formation at Sandom Branch H-33
Summary and Discussion of Research Significance H-35
References Cited H-36

List of Figures and Drawings

Figure H-1. Site Locations for 7NC-J-227 and 7NC-J-228 along Sandom Branch depicted on Clayton 7.5' USGS Quadrangle Map H-6
Figure H-2. 7NC-J-227 and 7NC-J-228 showing geoarcheological transects..... H-9
Figure H-3. Photo of 7NC-J-227 facing unnamed tributary of Sandom Branch..... H-15
Figure H-4. Generic Stratigraphy of 7NC-J-227, Column at N68/E466..... H-16
Figure H-5. Schematic Stratigraphy of 7NC-J-227 along transect 2 (NE-SW)..... H-18
Figure H-6. Photo of Gravel Splay at N65-66 on the Site 7NC-J-227 Grid..... H-18
Figure H-7. Generic Stratigraphy of 7NC-J-228, Column at N226.5/E451..... H-20
Figure H-8. Schematic Stratigraphy of 7NC-J-228 along transect 3 (N-S)..... H-20
Figure H-9. Photo of basin-shaped stain probably caused by tree throw, 7NC-J-7NC-J-228..... H-21
Figure H-10. Photo of large burrow feature at N236/E449 on the 7NC-J-228 Grid..... H-21
Figure H-11. Laboratory Results for Stratigraphic Column at N237/E446.5, 7NC-J-7NC-J-228..... H-23
Figure H-12. Schematic Stratigraphy along transect 4 across Holocene floodplain of Sandom Branch west of 7NC-J-7NC-J-228..... H-24
Figure H-13. Bivariat Plot of silts and clays vs. organic matter for 19 samples H-26
Figure H-14. Bivariat Plot of silts and clays vs. total phosphates for 19 samples..... H-27
Figure H-15. Phosphate fractionation results for 24 samples..... H-28
Figure H-16. Comparison of the chemistry of sediments analyzed for non-cultural and prehistoric features from 7NC-J-7NC-J-228..... H-29

List of Tables

Table H-1. Geoarcheological Samples collected from the Sandom Branch Sites..... H-14
Table H-2. Samples of Organic Sediment collected from Stratigraphic Profiles..... H-16
Table H-3. Possible Cultural Sediments selected for sedimentological and geochemical analysis..... H-25

Introduction

The following report summarizes the results of geoarcheological investigations at the Sandom Branch Site Complex (7NC-J-227 and 7NC-J-228). These investigations were performed under contract to Parsons Engineering Science, Inc. as part of the DelDOT SR 1 project. Phase II investigations, completed in the fall of 1999, identified the key environmental and site formation problems at the two sites (Schuldenrein 1999a). A detailed research design was then prepared for the Phase III investigations (Schuldenrein 1999b), with the following general objectives now having been satisfied through preparation of the present final report:

- A review of the regional stratigraphic framework for the Delaware Coastal Plain, including what is known about the distribution, age, and genesis of Holocene deposits.

- A locally derived depositional chronology based on field observations, sampling, and radiocarbon dating of stratigraphic columns along a series of five (5) transects across the Sandom Branch Site Complex.

- Testing of specific hypotheses about the genesis of the sandy matrices in which the cultural materials occur, including colluvial, alluvial, and aeolian deposition as well as in-place weathering or "pedoturbation" of the parent Pleistocene deposits.

- Testing of hypotheses bearing on the cultural versus natural genesis and function of a sample of the pit features at 7NC-J-228.

Archeological sites 7NC-J-227 and 7NC-J-228 occupy adjacent topographic highs flanking Sandom Branch, a minor stream which has incised headward into Pleistocene sand and gravel deposits of the Delaware Coastal Plain (Figure H-1). Prehistoric cultural material and activity areas were found primarily on interfluve surfaces, and the archeological sequence was arranged laterally as well as vertically within the relatively shallow sandy deposits. Pits and areas of staining were the result of geogenic or biogenic as well as anthropogenic site formation processes. Charcoal was poorly preserved and did not always provide reliable radiocarbon dates for the artifact-bearing deposits. Analysis of the archeological assemblages and site stratigraphies has nonetheless provided results which can be used to test hypotheses about Holocene landscape evolution and regional environmental change as well as the specific history of geogenic and anthropogenic events at each site.

0 1000 2000 3000 4000 F

Figure H-1. Site Locations for 7NC-J-227 and 7NC-J-228 along Sandom Branch on the Delaware Coastal Plain, depicted on Clayton 7.5' USGS Quadrangle Map.

Research Design and Field Methods

Field investigations at the Sandom Branch Site Complex were performed concurrently with the Phase III excavations in December through January of 2000. The analysis phase has continued through the submission of the present report. The specific field and laboratory tasks performed in these investigations were as follows:

(1) Description of approximately 50 stratigraphic exposures along five transects crossing the interfluvial landforms at both sites and extending down onto the alluvial floodplain of Sandom Branch in the vicinity of 7NC-J-228. The transects provide a landscape and chronological context for the prehistoric features and artifact concentrations for both sites.

(2) Radiometric sampling to provide absolute dates.

(3) Sediment and soil sampling and laboratory analysis to identify primary depositional (alluvial, colluvial, aeolian, etc.) and soil environments as well as post-depositional perturbation mechanisms by living organisms and soil processes.

(4) Chemical analysis to identify cultural features and to improve the archeological interpretation of the prehistoric activities which may have produced them.

The five (5) transects examined are plotted in Figure H-2 and represent an adjustment to the original set of three (3) transects prepared by Schuldenrein (1999b) due to field conditions. The transects were oriented as follows with respect to the site grid:

(1) A central north-south transect at approximately E470 spans both 7NC-J-227 and 7NC-J-228.

(2) An east-west transect "staggered" across the highest portion of the 7NC-J-227 terrain from N67/E467 east to N90/E510 and up to the ridge crest at 12 m amsl.

(3) A north-south transect at E450 on 7NC-J-228.

(4) An east-west transect at N237 running across the center of 7NC-J-228 then downslope across the T-0 landform flanking the Sandom Branch tributary.

(5) A north-south transect at E398 on the T-0 paralleling the Sandom Branch tributary.

The discussion of stratigraphic profiles in the present report will focus on three of the five transects, transects (2), (3), and (4). A schematic cross-section has been prepared for each of these transects, linking from three to five stratigraphic profiles. All of the profiles were partitioned into soil horizons in the field, according to the criteria in Soil Survey Staff (1951, 1975, 1994). The sediment texture of each horizon was recorded in classes such as silt loam, fine sandy loam, silty clay loam, etc. (Birkeland 1999:10-11; Soil Survey Staff 1975). Color was recorded moist using the Munsell chart.

The structure of each soil horizon was characterized in terms of the shape and size of its "peds" (Birkeland 1999:12). Where structure was poorly developed or not present, more attention was paid to sedimentological attributes such as bedforms and depositional sorting within a horizon (Reineck and Singh 1986). Boundaries between horizons were characterized in terms of both distinctness and topography (Birkeland 1999:356), with particular attention being paid to boundaries which define the tops of buried soils in each profile.

The profiles sampled for sedimentological and geochemical analyses were in upper landscape positions (i.e. interfluves) where the cover sands were thickest and the archeological contexts better preserved. The initial proposal to sample two (2) locations intensively at 10 cm intervals was modified since no individual columns reached the two meter desired depth. Profiles were sampled from Pleistocene sand and gravel beds upward through all of the natural soil horizons on the sites. The maximum interval between samples was 30 cm, so that horizons thicker than that were split (e.g., 2AB1, 2AB2).

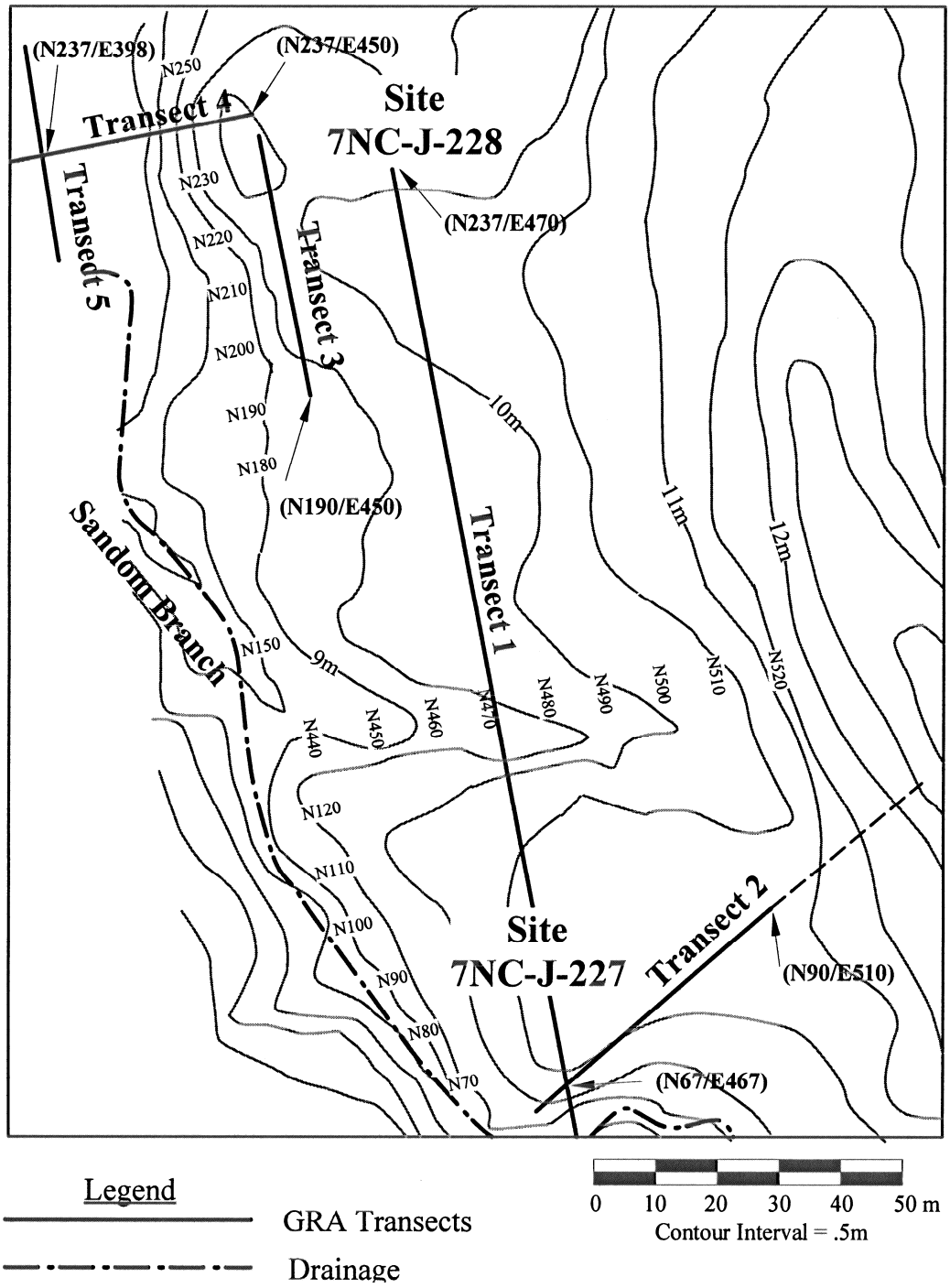

Figure H-2. Sites 7NC-J-227 and 7NC-J-228 showing the layout of geoarcheological transects.

Geoarcheological Approach to Sites in the Delaware Coastal Plain

Geoarcheology, as defined by Butzer (1982), is the application of earth science methods to archeological research problems. As an approach to the stratigraphy and physical setting of archeological sites, geoarcheology has, in many respects, been incorporated into the recent developments in the analysis of site formation processes (e.g., Nash and Petraglia 1987; Schiffer 1987). Previous geoarcheological studies in the Delaware Coastal Plain (Custer 1999; Kellogg and Custer 1994) have explored issues of environmental change, which are addressed to the extent possible with the data from the Sandom Branch Site Complex. What is most unique about the present study, however, is the analysis of how site formation processes varied across the landscape preserving the archeological contexts. Coastal plain settings are particularly suited to such an analysis.

Some site formation processes are clearly unique to the archeological record. Significant examples include trampling (Nielsen 1991; Schiffer 1987:126-129) and scavenging (Schiffer 1987:106-11) as well as discard in general. Site formation is also governed by the principles of sediment transport (Bagnold 1941; Middleton 1976; Middleton and Southard 1977), however. Sediments are found where they are because of the balance of driving and resisting forces operating in the site's physical setting. Many events of sediment transport which are essential to understanding the archeological record cannot be immediately inferred from the deposits on site. It is consequently necessary to examine, sample, and analyze sediments collected off site and to review what is already known about Quaternary stratigraphy in the region.

This history of site formation along the Delaware Coastal Plain is long and extensive. Some studies of archeological sites have interpreted the sandy mantle at the land surface as a product of aeolian deposition (Custer 1989, 1994, 1999; Custer and Watson 1987; Ward and Bachman 1987). These deposits have been cited as evidence for the mid-postglacial xerothermic (warm, dry) climatic interval proposed by Carbone (1976, 1982), although in some cases they overlie archeological contexts which are Early Woodland or younger. The proposed correlation with large-scale climatic change was questioned by Joyce (1988) on the grounds that summer drought conditions or human activities could have disrupted the vegetation sufficiently to mobilize sand. More recently, Leigh (1998, 2001) has explained cover sands overlying prehistoric archeological contexts in the Coastal Plain of South Carolina by pedoturbation of preexisting shoreface marine sands.

The data from the Sandom Branch sites presented below record the types of localized and time-transgressive aeolian deposition attributed by Joyce to be have resulted by human impact. Regional environmental change cannot be ruled out, however. A likely process which is rarely discussed would be high winds generated by the thermal gradient associated with forest fires. Unfortunately, there is no record of significant burning episodes during the late Holocene in any of the regional proxy records. Watts (1979) suggested that the increase in pine at the expense of oak in Coastal Plain pollen from New Jersey may have been due to frequent forest fires.

The best evidence in the Delaware Coastal Plain for drier regional climate would appear to date to the late Pleistocene, possibly extending into the early Holocene (Ramsey 1998; Webb et al. 1994). At the Pollack Farm site, sand was mobilized by the reduced vegetation and increased wind strength. Dry climate may also have played a role in the formation of the "undrained depressions" which postdate the last interglacial. Sediments within these depressions are "a combination of sands locally reworked by seasonally ponded water and wind-blown material (Ramsey 1998:30)." Webb et al. (1994) cored several ponds and closed depressions near the SR 1 Project to reconstruct local paleohydrology and vegetation change. They obtained twelve radiocarbon dates spanning 14.2-2.65 ka and inferred that a dry period occurred from 11-6 ka BP based on intervals of mud cracks bracketed by radiocarbon-dated mud. The limited paleoenvironmental proxy records therefore appear to accord best with a late Pleistocene or early Holocene age for deflation of closed depression features and sand deposition downwind.

Site formation processes which occur within the general rubrics of "biomantle" or "pedoturbation" processes have attracted considerable interest in recent years (Johnson 1990; Johnson and Watson-Stengner 1990; Leigh 1998, 2001; Michie 1990; Mueller and Cavallo 1995; Stein 1983), at Coastal Plain sites. Such processes were very evident in the stratigraphy of both of the Sandom Branch sites. Tree throw was particularly prevalent at 7NC-J-228. At 7NC-J-227, root disturbance and translocation of organic matter resulted in several erroneous radiocarbon dates, even for plant macrofossils identified to species. Faunal turbation was also extensive, with burrows ranging from less than a centimeter in diameter up to those of marmots and other medium-sized mammals.

Tree throw disturbance is a particularly sensitive issue for Delaware archeology, since it has been argued that many "pithouse" structures identified on Coastal Plain sites are actually tree throws as opposed to cultural features (Mueller and Cavallo 1995). One of the disturbed areas at 7NC-J-228, Feature 3, was initially identified as a large pit structure. Results of laboratory grain size and soil chemical analyses are compatible with Feature 3 being a product of natural disturbance, although it is possible this feature was nonetheless used at some point for storage or refuse disposal. In general, tree throw, burrowing by rodents and frost-heaving are all mechanisms which must be considered in accounting for the distribution of artifacts and sediments in Coastal Plain sandy sites.

While the present study will show how site formation processes varied across the Sandom Branch biophysical landscape, it must ultimately reject the biomantle model (Johnson 1990; Michie 1990) as a comprehensive explanation for Holocene deposition and archeological site formation. Downward migration of artifacts within the "cover sands" undoubtedly occurred at both locations, but there is also evidence for net accretion of the interfluve surfaces within the Holocene epoch. All five of the stratigraphic columns for which grain size analysis was conducted show an increase in silt in the upper part of the profile. Two profiles show the fining-upward trend which would be expected in either an alluvial floodplain or wind-born dust deposit (Allen 1977; Glennie 1970; Reineck and Singh 1986). Alluvial deposition appears unlikely given that both profiles are on interfluve surfaces at least two meters above the Sandom Branch channel.

In two of the other three stratigraphic columns for which grain sizes were analyzed, the percent sand actually increases near the surface. The coarsening upward in these profiles is a phenomenon which has not been widely reported for the Delaware Coastal Plain. Explanations entertained in the conclusion of this report include wind deflation, colluviation, and finally some combination of soil processes analogous to the "desert pavement" model recently proposed for the western United States (McFadden et al. 1987, 1998; Wells et al. 1995).

While the observed stratigraphy indicates a varied depositional history and extensive bioturbation, there were intact, buried cultural features found at both sites. Sedimentological and geochemical analyses summarized in this report help to differentiate these cultural features from areas of non-cultural disturbance. Ultimately, it is hoped that such analyses can be used diagnostically. They may be able to "fingerprint" features and activity areas. Only limited inferences are possible based on the 19 samples of possible cultural sediment analyzed from 7NC-J-227 and 7NC-J-228. The anthropogenic contributions to the parent sediment or soil matrix do appear comparable to those observed in our previous study of the Lums Pond prehistoric site (7NC-F-18) in northern Delaware (Petraglia et al. 1998:251-265). In general, numerous pit features of diverse sizes and shapes were found at 7NC-J-228, while the cultural activities at 7NC-J-227 resulted primarily in shallow features such as hearths and clusters of fire-cracked rock.

Laboratory Analyses

A total of 146 samples of soil and sediment were collected during the investigations at the Sandom Branch sites (Table H-1). Particle size analyses were performed on columns from both sites to test for anthropogenic and natural depositional contexts (Folk 1974; Friedman and Sanders 1978; Inman 1949, 1952). Sands were sieved at half phi (0.5 ø) intervals for a column of eleven (11) samples from the north end (N237/E 446.5) of 7NC-J-228. Tripartite (sand-silt-clay) grain size analyses were then performed on four (4) additional stratigraphic columns of from four (4) to six (6) samples each. Two of these columns were from 7NC-J-227 and two were from 7NC-J-228. The total of 31 samples from these five stratigraphic columns serve as "control" samples, since they record the sedimentological and geochemical "background" with which to compare possible cultural sediments at the Sandom Branch sites.

Samples of bulk sediment were collected for radiocarbon dating of humic acids. As discussed below, the results for these samples are generally consistent with the archeological stratigraphy. While the dates were critical in synthesizing the landscape history of the Sandom Branch site environment, contamination by modern organic matter was also a problem. The primary contamination mechanisms were lateral and vertical mobility of soil organics through the loose cover sands. This is more pervasive in soil humin than for charcoal specimens selected from pit features and other archeological proveniences.

Sedimentological and geochemical samples were selected from collections taken by project geoarcheologists and archeological field crews. Nineteen (19) samples were tested for tripartite grain-size analysis, soil pH, organic matter, available P, exchangeable Ca, Mg, and K, and citrate-dithionite extractable iron (Fe). These included recognized features or

areas of natural disturbance initially identified as features. The soil phosphate (PO3) was fractionated for a total of 24 samples, of which seven (7) were from 7NC-J-227 features, twelve (12) were from 7NC-J-228 features, and the remaining five (5) were control samples from non-cultural contexts. The fractionation patterns, plotted on a ternary diagram, are often directly correlated with specific activities on both prehistoric and historical archeological sites (Eidt 1977; Schuldenrein 1995).

Table H-1. Geoarcheological Samples collected from the Sandom Branch sites (7NC-J-227 and 7NC-J-228)

SITE	North	East	Trans	Feature Fill Samples	Geochem Controls	Sedimentology Samples	Radiocarbon Bulk Samples	Other Samples	Total
7NC-J-227	N68	E466	1,2		6	6			12
7NC-J-227	N71	E463	1				1		1
7NC-J-227	N72	E462	NA		3	3			6
7NC-J-227	N76	E488	NA					1	1
7NC-J-227	N77	E476	2		4	4			8
7NC-J-227	N81	E470	2		5	5	1		11
7NC-J-227	N105	E466	1						0
7NC-J-227/8	N130	E470	1			1		2	3
7NC-J-227/8	N150	E470	1			1		1	2
7NC-J-227/8	N190	E471	1			1		1	2
7NC-J-228	N207	E456	3		5	4			9
7NC-J-228	N209	E456	NA	F#28(1)*					1
7NC-J-228	N216	E451	NA	F#29(1)	1				2
7NC-J-228	N220	E455	NA	F#13(1)					1
7NC-J-228	N220	E456	3		1				1
7NC-J-228	N221	E448	NA	F#18(1)*	1				2
7NC-J-228	N221	E454	3		4	4			8
7NC-J-228	N224	E451	3		2	2	1		5
7NC-J-228	N225	E446		F#34(1)					1
7NC-J-228	N226.5	E445		F#39(1)					1
7NC-J-228	N226	E453	3		7	7	1		15
7NC-J-228	N228.5	E451	3		6	6			12
7NC-J-228	N230-231	E445	3	F#8(1)*	4	4			9
7NC-J-228	N231	E446.5	NA	F#3(2)*					2
7NC-J-228	N236	E445	NA	F#27(2)*					2
7NC-J-228	N237	E446.5	3		11	11			22
7NC-J-228	N222	E398	5				1		1
7NC-J-228	N227	E398	5				1		1
7NC-J-228	N237	E388	5			1		1	2
7NC-J-228	N237	E403	5			1		1	2
7NC-J-228	N237	E498	5				1		1
Total				**11**	**60**	**61**	**7**	**7**	**146**

*Archaeological Analyses: Determined Non-Cultural

7NC-J-227: Stratigraphy and Depositional Chronology

Site 7NC-J-227 is at the southern end of the Sandom Branch Site Complex on an undulating landform which slopes gradually toward a small unnamed tributary (Figure H-3). The tributary is fed both by groundwater seeping from the Pleistocene sand and gravel beds and by runoff from agricultural fields to the south and east. Its narrow (1-2 m wide) and shallow (<50 cm deep) channel currently traverses arcuate meanders downslope toward its juncture with Sandom Branch on the valley floor below 7NC-J-228. The most direct path downslope crosses 7NC-J-227 and follows the linear channels filled with gravelly sands.

Figure H-3. Photograph of 7NC-J-227 facing north across the unnamed tributary of Sandom Branch.

Figure H-4 is a composite section based on the sediment column sampled at N68/E466. The archeological materials are of Woodland age and are contained with the 30 cm of capping sediment that has buried a preexisting soil (2Bt-2BC-2C soil horizons). The buried soil formed in Pleistocene sand of the Columbia formation (Groot and Jordan 1999:6-8; Jordan 1964). The soil is very poorly developed, particularly when compared with the degree of weathering evident in the 7NC-J-228 profiles. Field observations indicated a very weak subangular blocky ped structure and a minimum of translocated clay. Nonetheless, increases in clay, iron, and potassium shown in Figure H-4 clearly identify the Pleistocene-age sediments and distinguish them from the Holocene-age surface veneer. It is noted that substantial clay translocation is not common in sandy soils because of the permeability of the sand matrix. Accordingly, the Bt designation was made on the strength of the antiquity of the Columbia formation and the local expression of soil formation.

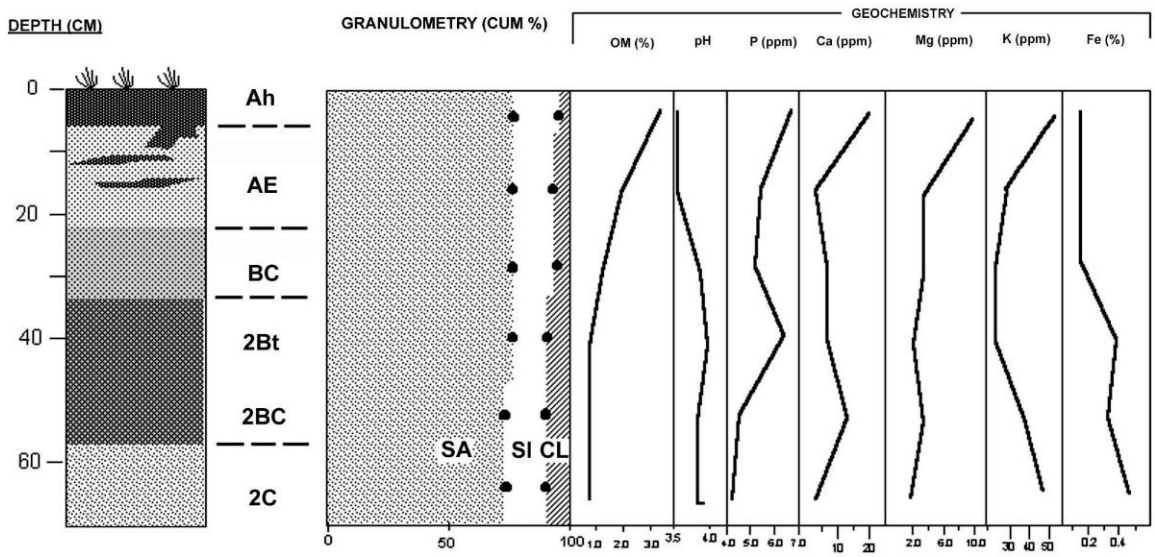

Figure H-4. Generic Stratigraphy of 7NC-J-227, Column at N68/E466.

The percent organic matter falls off rapidly below the surface (Ah horizon), reaching less than one percent by 40 cm down profile (Figure H-4). Rapid leaching of surface organic matter from sandy surficial deposits compromised the use of bulk samples to accurately date the buried soil. Bioturbation further complicates the analysis and was prevalent throughout the Sandom Branch Site Complex. At 7NC-J-227, there also appears to have been some anthropogenic disturbance associated with the prehistoric occupations. Consequently, even radiocarbon dates for wood charcoal and plant macrofossils from prehistoric features are problematic. The date of 180±40 BP (Beta-149037), for example, probably represents an intrusive disturbance of Feature 30 by tree root material, identified as white oak.

A sample of bulk sediment was collected for radiocarbon dating from the 2AB horizon at the top of the Columbia formation in the profile at N71/E463. The date of 1010±40 BP (Beta-149043) is considerably younger than anticipated for this stratigraphic contact. As discussed in the concluding section of this report, the Columbia formation sand and gravel beds are now considered to be middle Pleistocene in age (>400 ky old) and were deposited by a system of braided river channels. The three dates obtained on samples of bulk sediment from the top of the Columbia formation in the present study are late Holocene (Table H-2).

Table H-2. Samples of Organic Sediment collected from Stratigraphic Profiles at the Sandom Branch Sites (7NC-J-227 and 7NC-J-228)

Site	Transect	North	East	Horizon	Depth	Radiocarbon Age
7NC-J-227	NA	N71	E463	2AB	70 cmbs	1010±40 BP (Beta-149037)
7NC-J-227	1	N81	E470			Not submitted
7NC-J-228	3	N224	E451	BC	90 cmbs	3190±60 BP (Beta-149040)
7NC-J-228	3	N226	E453	2AB	70-90 cmbs	2270±50 BP (Beta-149042)
7NC-J-228	5	N222	E398	Cg1	23-25 cmbs	240±40 BP (Beta-149033)
7NC-J-228	5	N227	E398			Not submitted
7NC-J-228	5	N237	E403	Cg1	55 cmbs	680±50 BP (Beta-149041)
					Total	**5**

The artifact assemblage from 7NC-J-227 suggests two prehistoric components, Middle and Late Woodland. The Middle Woodland small, contracting-stemmed projectile points and Mockley ceramics occurred slightly lower in the stratigraphic column than the Late Woodland small triangular points and Townsend and Minguannan ceramics. As shown in Figure H-4, however, both components typically occurred in the upper 30 cm of the profile. The stratigraphic ordering and limited separation within the BC horizon suggests that the occupation surface during Woodland times was 10-20 cm lower than it is today and that incremental buildup of the surface and protracted soil formation are responsible for the present burial and preservation of the Woodland deposits.

It is noted that the thickness and stratigraphic integrity of the silty cover sands containing the archeology varied laterally across 7NC-J-227. This variability is expressed by the geoarcheological transects. Figure H-5 is a schematic cross-section of transect 2. At the southeast edge of the site, gravel splays were observed aligned southeast to northwest; these are illustrated in Figure H-6. Woodland features and cultural materials were found in siltier deposits overlying the alluvial splays. The most stable mid- to late-Holocene surfaces occurred between E470 and E478 on the 7NC-J-227 grid. Here there was relatively good preservation of the earlier Woodland occupation. Careful excavation permitted identification of these occupation levels in spite of some disturbance by Late Woodland features and modern roots and burrows.

The second stratigraphic column sampled at 7NC-J-227 was located at N77/E476. The same consistent decrease in organic matter downward through the profile was observed as at N68/E466 (Figure H-4). Here, however, there was no evidence for a preexisting soil at the top of the Columbia formation. Further, the Columbia formation was coarser-textured, (it contained over 85 percent sand) and may have been scoured or deflated prior to the initial accretion of the Holocene deposits.

Archeological evidence for prehistoric cultural activity trailed off at the eastern edge of 7NC-J-227 between E480 and E510 along transect 2 (Figure H-5). Presently, localized ponding occurs at the surface in this portion of the site complex. Surface runoff from the 10-25% grade of the slopes undoubtedly contributes much of the ponded water. Groundwater may also be perched, however, by variations in the sediment texture and induration of the Pleistocene sediments underlying the archeological contexts. Several small depressions were observed in this general area, between the local topographic high at the center of 7NC-J-227 and the slopes of the ridge to the east. The scrubby forest had presumably been cleared several times within the historical period. Refuse disposal and landfilling activities were also evident, particularly on the more densely forested slopes.

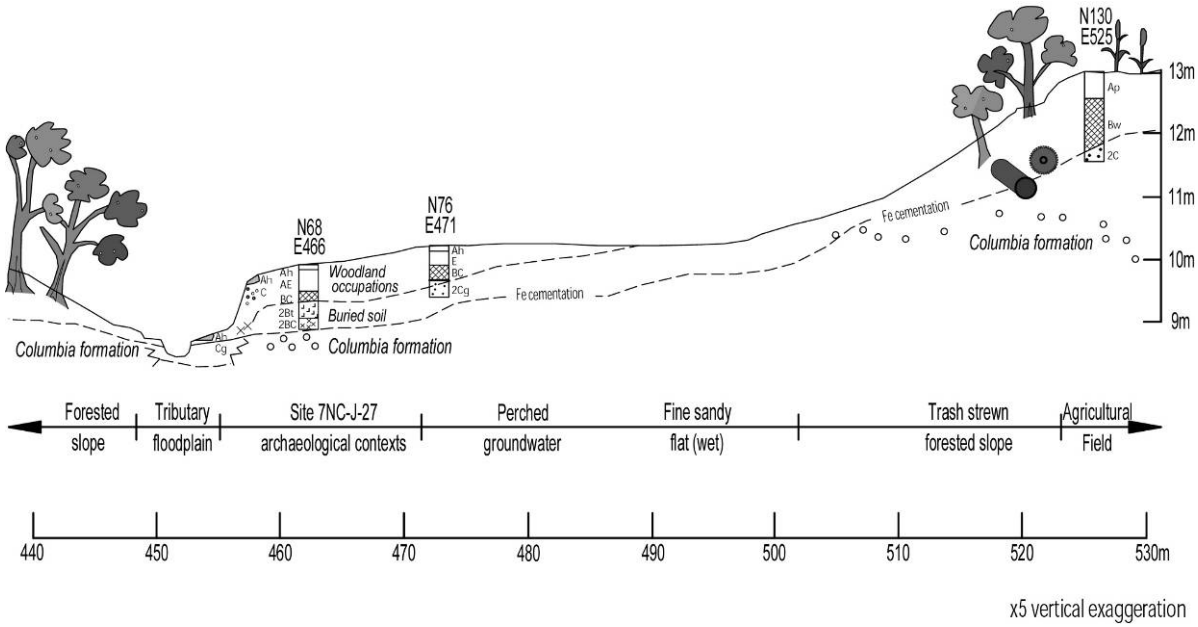

Figure H-5. Schematic Stratigraphy of 7NC-J-227 along geoarcheological transect 2 (NE-SW.

Figure H-6. Photo of Gravel Splay at N65-66 on the 7NC-J-227 Grid

7NC-J-228: Stratigraphy and Depositional Chronology

Site 7NC-J-228 was situated on a pronounced and elongated topographic high, at least two meters above surfaces exposed to Holocene flooding at Sandom Branch. The prehistoric pit features were excavated into the surface of this northwest-southeast trending positive feature. The Holocene surficial mantle was up to 50 cm thick with sandy loam to loamy sand textures, typically registered in O, A, E, and EB soil horizons. In most of the stratigraphic profiles, a strongly developed buried soil occurred at the top of the coarse-textured Columbia formation.

Radiocarbon dates of 3190±60 BP (Beta-149040) and 2270±50 BP (Beta-149042) were obtained for bulk sediment samples collected from the buried soil at 7NC-J-228 (Table H-2). These dates would imply a late Holocene age contemporaneous with the Late Archaic and Early Woodland occupation. The dates are somewhat young for the stratigraphic contact at the top of the Columbia formation. The determinations suggest limited contamination from overlying organic-rich horizons. Charcoal and other organics would certainly have been added to the Holocene sandy mantle by prehistoric cultural activities, which may have included limited deforestation. The stratigraphic position for both of these samples indicates that the sediments were deposited in the early Holocene at the latest, and probably earlier in the Pleistocene.

Figure H-7 presents the stratigraphy observed at N226.5/E451 combined with the results of sedimentological and geochemical analyses for a column of six samples. The 2ABt horizon of the buried soil shows an 8% clay increase over the underlying 2BC and a 14% increase over the coarse sand 2C sampled from well within the Columbia formation at 90-100 cm below surface. The 2ABt is slightly enriched in organic matter, available phosphorus, and exchangeable calcium, relative to both the underlying and overlying horizons. It is strongly enriched in exchangeable magnesium and potassium as well as citrate-dithionite extractable iron. The column corroborates strong soil formation at the site.

Lateral stratigraphic variation is also evident across 7NC-J-228, Geoarcheological Transect 3 (Figure H-8). This is an “interfluve” surface and was presumably forested throughout the Holocene (Newby et al. 1994; Watts 1979; Webb et al. 1993). Tree throw or tip over of dead or diseased trees is very common in Coastal Plain forests, particularly in high storm winds or during forest fires. Tree throw disturbs the sediments around the tree in ways which can mimic prehistoric cultural features (Mueller and Cavallo 1995). Figure H-9 illustrates one such feature, where surface organics from the A horizon have been displaced into the tree throw cavity and then buried by the lighter colored subsoil sediment which adhered to the tree’s roots. This “inversion” of the generic soil profile is readily identifiable and taken as possible evidence for a tree throw (Mueller and Cavallo 1995; Schaetzl et al. 1988a, 1988b).

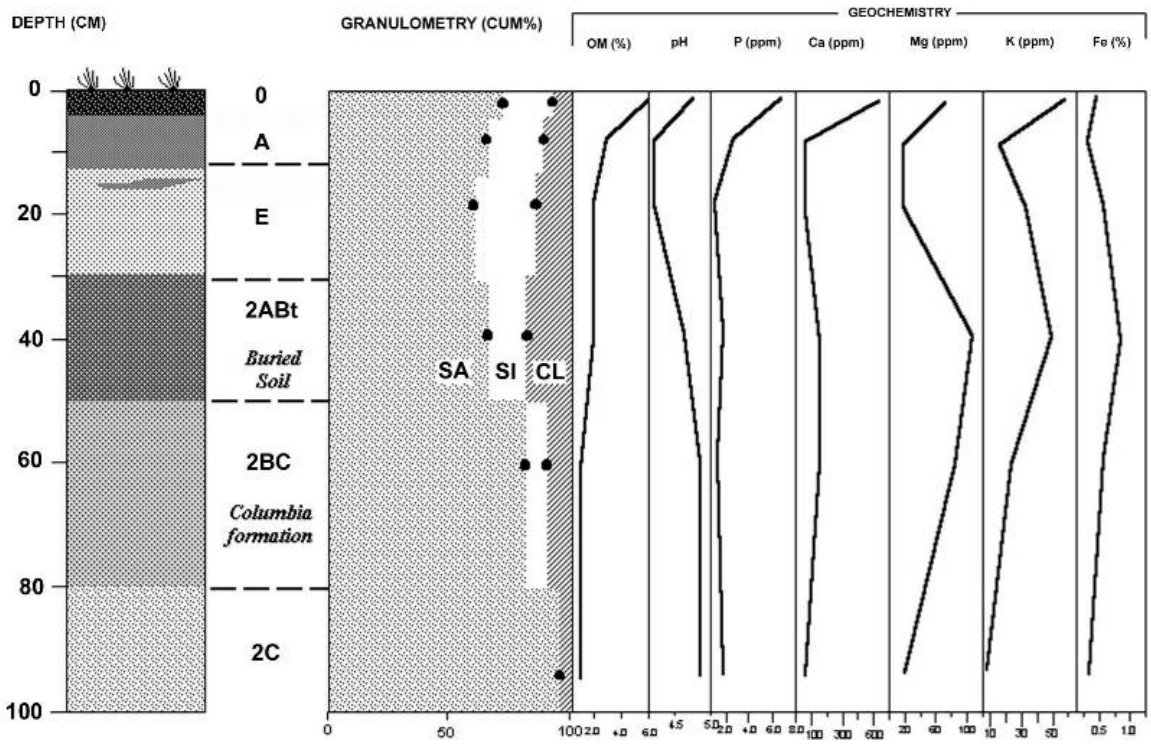

Figure H-7. Generic Stratigraphy of Site 7NC-J-228, Column at N226.5/E451

Disturbance by tree throw means that buried cultural material from several of the excavation blocks at 7NC-J-228 was subject to post-depositional displacement. On the other hand, it is possible that prehistoric people made use of some tree throw features to fashion dwellings or storage pits. It is therefore possible that several loci with these features may preserve evidence of in situ or near in situ occupation. In this landscape which was repeatedly occupied, both natural and cultural formation processes are likely to have been a factor in producing a broad range of artifact-bearing contexts.

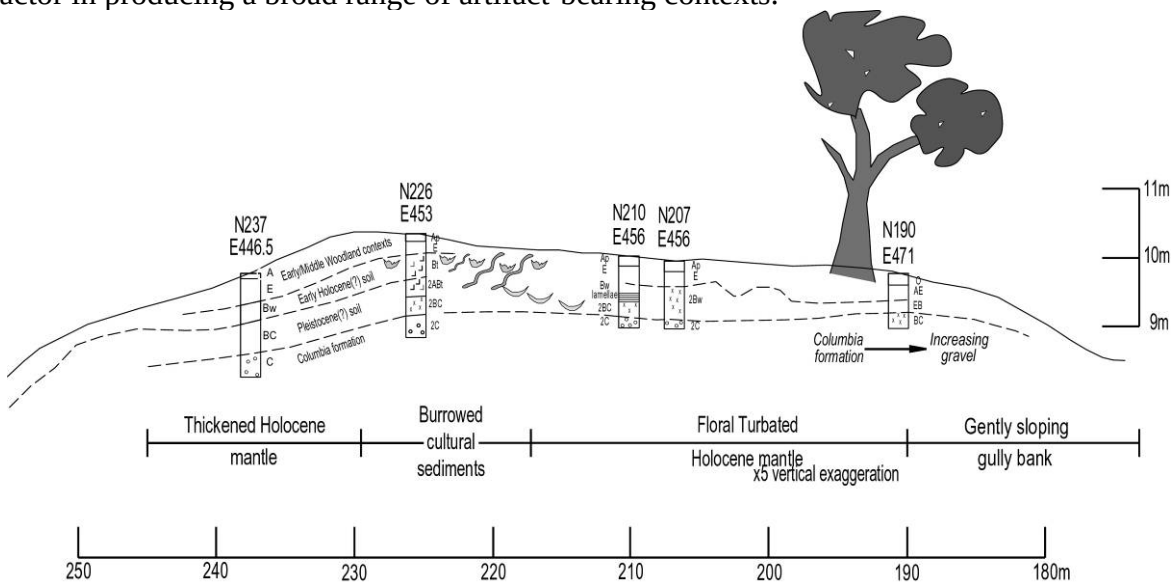

Figure H-8. Schematic Stratigraphy of 7NC-J-228 along geoarcheological transect 3 (N-S)

Figure H-9. Photo of basin-shaped stain probably caused by tree throw, 7NC-J-228

Faunal turbation is at least as common and certainly a more diverse disturbance mechanism as floral turbation in forested settings (Schiffer 1987:207-210; Wood and Johnson 1978). At 7NC-J-228, burrows ranged from less than a centimeter in diameter, typical of worms and insects, up to those of marmots and other medium-sized mammals. Larger burrows of the type illustrated in Figure H-10 extended for meters through the subsurface in some parts of 7NC-J-228.

Figure H-10. Photo of large burrow feature at N236/E449 on the 7NC-J-228 Grid

Areas of biogenic disturbance are not always as easy to distinguish from prehistoric cultural features as the examples illustrated above. Cultural features are often themselves targeted by both faunal and floral turbation since the sediments are looser and enriched in organic matter and other nutrients (Johnson 1990; Johnson and Watson-Stegner 1990; Stein 1983; Wood and Johnson 1978). Geochemical analysis distinguished the effects of biogenic disturbance from anthropogenic, and is presented below.

The range of geogenic, biogenic and anthropogenic site formation processes was evident at 7NC-J-228 along Transect 3. Floral turbation was most evident south of N225. Prehistoric artifacts were sparser in this portion of the site, and some of the deeper artifact distributions may be due to vertical mixing by floral turbation. The strongly developed buried soil formed at the top of the Columbia formation was rarely disturbed, however, either by floral or faunal turbation.

In the area between N225 and N235 (i.e. Block A), there had been extensive anthropogenic disturbance, primarily during the Early Woodland period. Combined with the faunal turbation which it fostered, prehistoric human dislodging of the former surface mantle supplied sediment that was transported further north along the transect. At N237, Holocene sediment was over 50 cm thick and featured a Bw horizon which must have been forming through at least a portion of the prehistoric occupation.

The profile sampled at N237/E446.5 (Figure H-11) was relatively undisturbed by faunal or floral turbation of the sort seen along the rest of the transect. Results of the sedimentological analyses clearly distinguish the upper 50 cm of the profile from the relatively coarse-textured Columbia formation deposit. The Columbia formation was a very well-sorted sand with a mean grain size of 0.3 mm (1.77ø). Forty percent of the C horizon was medium sand, and the low skewness value (0.02 ø) reflects relatively equal amounts of coarse sand and mud. Kurtosis values only slightly above 3.0 for the three lowest horizons indicate a nearly perfectly normal distribution.

The clay peaked at nine percent in the Bw2 horizon, representing a soil formed prior to deposition of the overlying sediment. The five upper horizons (O-A-E1-E2-Bw1) are all at least twenty percent silt, whereas the Columbia formation has less than ten percent. The fine tail in the grain-size distributions for these horizons makes them appear poorly sorted, right-skewed, and platykurtic when compared to the Columbia formation sands. As a result of the right skew, the mean grain size (3.74ø = 0.07 mm) is significantly smaller than the median (1.85ø = 0.3 mm) for the upper horizons. This sedimentological signature should characterize the Holocene mantle in general and will be useful as a reference for the interpretation of other stratigraphic columns from the DelDOT SR 1 Project.

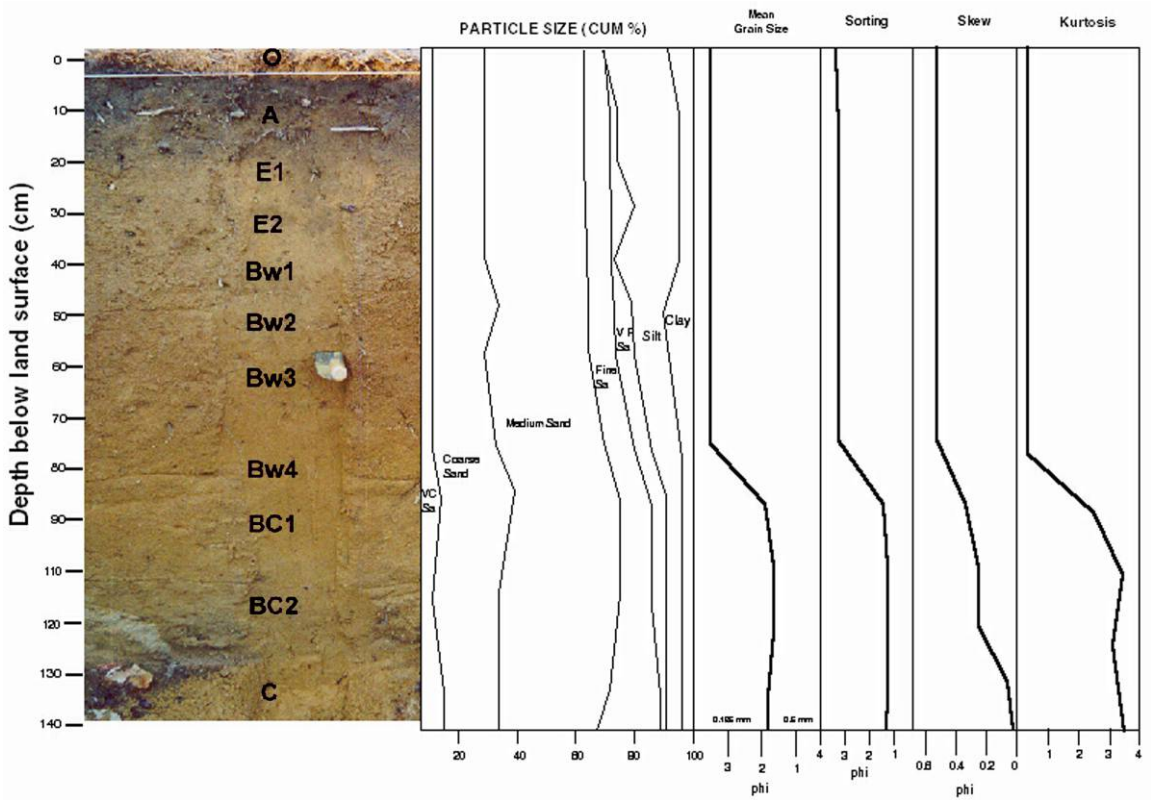

Figure H-11. Laboratory Results for Stratigraphic Column at N237/E446.5 Site 7NC-J-228

Figure H-12 summarizes the stratigraphy observed along transect 4. The transect ran east-west from the surface containing the archeological features downslope across the Holocene floodplain of Sandom Branch. Twelve hand auger borings were performed on the floodplain to characterize the sediments and to obtain samples for radiocarbon dating. Quartzose channel lag gravel was encountered at the base of all of the borings at depths ranging from 40-60 cm. A stratum of grayish brown (7.5YR5/1-5/2) fine sandy clay overlying the channel lag deposits registers the shift of the channel westward to its present location.

Woody detritus was common in the Holocene floodplain sediments. A radiocarbon age of 680±50 BP (Beta-149041) was obtained from detritus within the gravel in the boring at N237/E403. The date suggests that a channel traversed this location immediately prior to the Euroamerican settlement of the valley. The initial development of Sandom Branch cannot be determined precisely since this channel evidently scoured the upper valley reaches.

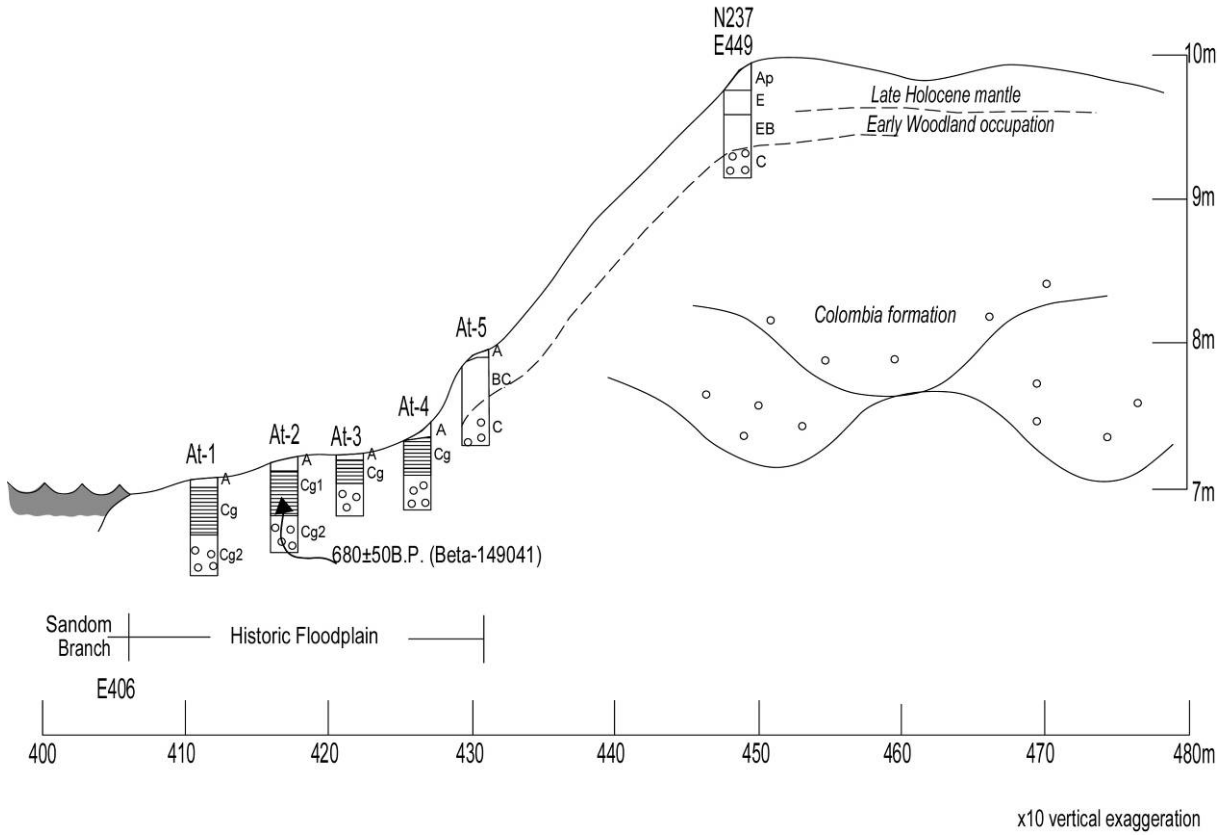

Figure H-12. Schematic Stratigraphy along Geoarcheological Transect 4 Across the Holocene Floodplain of Sandom Branch west of 7NC-J-228

Chemistry of Cultural and Noncultural Sediments

Several prehistoric activity areas on the higher interfluve loci were excavated at the Sandom Branch Site Complex. Observations made during hand excavation were the first source of information for feature morphology and probable function. Artifact, botanical, and faunal materials were also informative, when assemblages could be correlated with radiometric ages. In addition to these relatively traditional methods, however, the physical and chemical properties of the sediments have potential for providing evidence of refusal disposal and other prehistoric human activities (Butzer 1982; Schiffer 1987:291-292; Schuldenrein 1995). Such innovative earth science approaches to site formation have recently been applied to archeological settings in the Atlantic Coastal Plain (Blanton and Pullins 2000; Leigh 1998, 2001; Michie 1990; Mueller and Cavallo 1995; Petraglia et al. 1998).

A total of nineteen (19) samples of possible cultural sediment from the Sandom Branch Site Complex were selected for laboratory analysis (Table H-3). Tripartite grain-size distributions, soil pH, organic matter, available P, exchangeable Ca, Mg, and K, and citrate-dithionite extractable Fe were analyzed for all 19 samples. These same analyses were also performed for seven (7) control samples from site 7NC-J-227 and seven (7) control samples from site 7NC-J-228. Soil phosphate (PO3) was also fractionated for a total of 24 samples.

Seven (7) of these were from Site 7NC-J-227 features, twelve (12) were from 7NC-J-228 features, and the remaining five (5) were control samples from non-cultural contexts.

Statistical comparison of results for cultural and noncultural sediments has been successfully employed by Schuldenrein (1995) on hunter-gatherer activity areas throughout North America. This is also the method used in the previous study of the Lums Pond prehistoric site (7NC-F-18) in northern Delaware (Petraglia et al. 1998:251-265). Phosphate fractionation was employed in all of these studies as well as in the analysis of a sample from a historical Creek midden deposit from Fort Benning in Georgia (Thieme et al. 1997) and analyses of both prehistoric and historical contexts on Governors Island in New York Harbor (Thieme 1998).

Prior to analysis, five of the 7NC-J-228 specimens sampled were determined to be products of floral turbation, faunal turbation, and other disturbance processes contributing to the formation of the site. These samples were also run to provide a measure of verification of the geochemical methods applied to the entire sample population. The archeological interpretations were corroborated by the present independent analysis of cultural sediments.

Table H-3. Possible Cultural Sediments from the Sandom Branch Site Complex
(Selected for Sedimentological and Geochemical Analysis)

Site	Feature	North	East	Collected by:
7NC-J-227	5	N70	E465	Parsons
7NC-J-227	19	N74	E479	Parsons
7NC-J-227	30	N67	E467	Parsons
7NC-J-227	35	N69	E471	Parsons
7NC-J-227	36	N72	E471	Parsons
7NC-J-227	40	N72.5	E471.5	Parsons
7NC-J-227	41*	N71	E469	Parsons
7NC-J-228	1	N234.4	E450.4	Parsons
7NC-J-228	3*	N230	E446	GRA
7NC-J-228	3*	N230	E446	GRA
7NC-J-228	7	N229	E446	Parsons
7NC-J-228	8*	N230	E445	GRA
7NC-J-228	12	N218	E451	Parsons
7NC-J-228	13	N220	E455	GRA
7NC-J-228	34	N225	E446	GRA
7NC-J-228	38	N226	E443	Parsons
7NC-J-228	39	N226	E444	GRA
7NC-J-228	43	N228	E448	Parsons
7NC-J-228	45	N230	E443	Parsons
Total	**19**			

*Archaeological Analyses: Determined Non-Cultural

Using the approach previously employed by Schuldenrein (1995), no significant geochemical differences were found between the cultural sediments and noncultural control samples. The problem may be sample size or variability in the parent sediment population, since well sorted sands at the Sandom Branch Site Complex are the overwhelming matrix into which the features were excavated. As results below indicate, geochemical enrichment,

mineral mobilization and adsorption was unique and favored organic enhancement of the coarse grained sand population at 7NC-J-227. Additional analyses using the same approach are in progress pooling the results from the Sandom Branch Site Complex with those for the Frederick Lodge Site Complex (7NC-J-97/98/99) and the Black Diamond Site (7NC-J-225). With respect to the interpretation of the prehistoric features at 7NC-J-227 and 7NC-J-228, however, there are significant differences between the cultural sediments at these sites. The samples analyzed from 7NC-J-228 are also enriched in several elements relative to samples from contexts which have been determined to result from biogenic disturbance.

The seven (7) samples from 7NC-J-227 are coarser textured but enriched in organic matter compared to the more variable suite of samples from 7NC-J-228 (Figure H-13). The 7NC-J-227 features range from 76-82% sand and from 0.9-2.2% organic matter. The three C horizon samples in the profiles at N68/E466 and N77/E476 are from 73-86% sand but all have less than 0.9% organic matter. The horizons in the upper portion of these profiles have up to 3.6% organic matter but none is more than 75% sand. The sediments from the prehistoric cultural features somehow combine the sandier parent material with additions of organic matter.

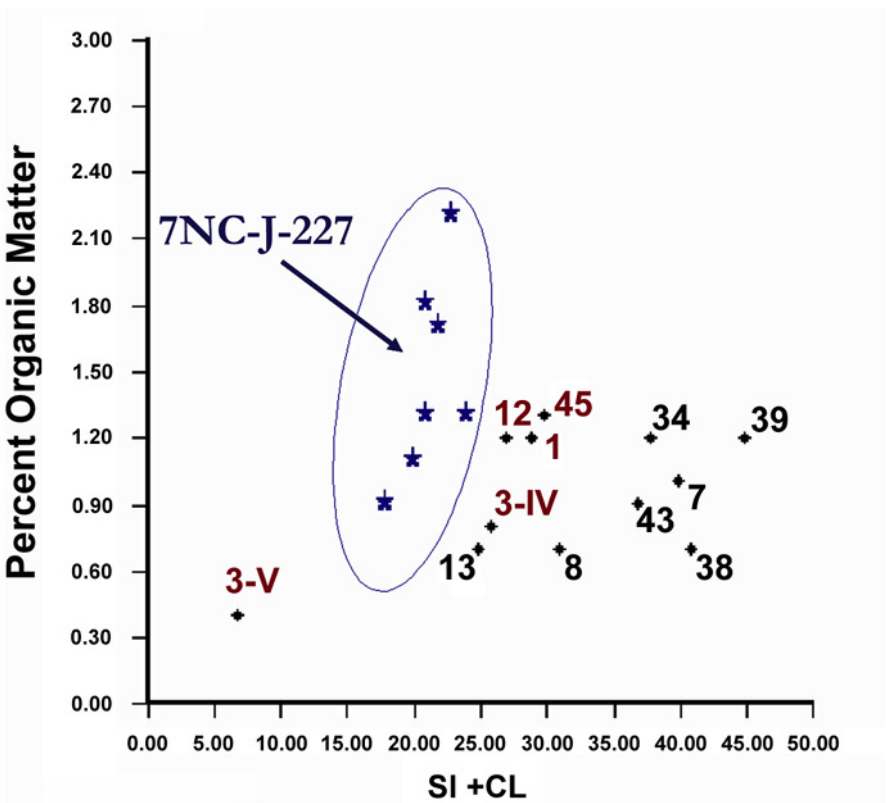

Figure H-13. Bivariate Plot of the Percent Silt + Clay vs. the Percent Organic Matter for 19 Samples of Possible Cultural Sediment from the Sandom Branch Site Complex

The contexts possibly resulting from biogenic disturbance at 7NC-J-228 are designated 1, 3-IV, 3-V, 8, 12, and 45 using their former feature numbers on Figures H-13 and H-14. The sediments from these contexts are coarser textured and depleted in total phosphate compared to the samples from prehistoric cultural features. The total phosphate is the sum of

the phosphate fractions shown in Figure H-15 on a ternary plot. The plot shows the same overlap of fields for cultural and noncultural sediments seen in the other geochemical analyses. Once again, however, the sediments do differ significantly between the two archeological sites. This is in part a geological phenomenon related to the thicker mantle of silty fines at the surface of 7NC-J-228. The relative abundance of Fraction I phosphate at 7NC-J-227 is quite consistent with what is known from the site's archeological record, however. Fraction I is the most loosely bound fraction, common in sheet middens and late prehistoric village contexts analyzed in previous studies (Anderson and Schuldenrein 1985; Schuldenrein 1990; Thieme et al. 1997).

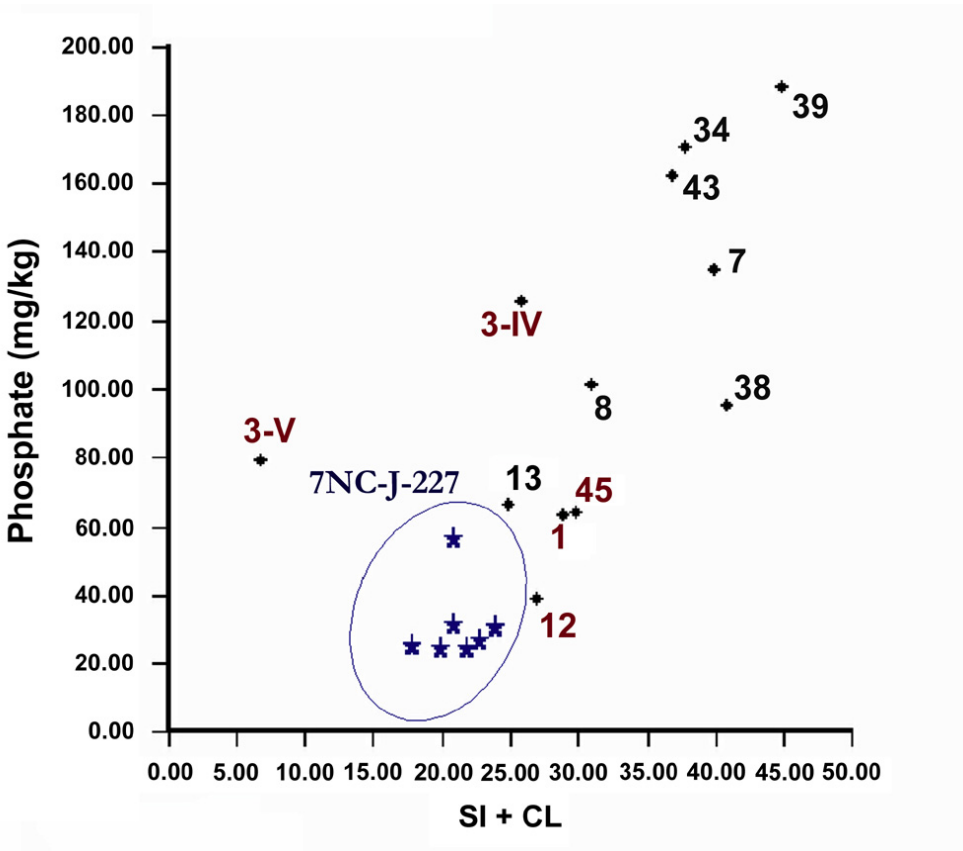

Figure H-14. Bivariate Plot of the Percent Silt + Clay vs. Available Phosphate for 19 Samples of Possible Cultural Sediment from the Sandom Branch Site Complex

Perhaps the most significant result of the geochemical analyses is the successful discrimination of contexts which were independently determined to result from biogenic disturbance at 7NC-J-228. As shown on Figure H-16, the samples from contexts designated as Features 1, 3-IV, 3-V, 8, 12, and 45 are depleted in exchangeable K, Ca, and Mg as well as in total phosphate compared to the samples of cultural sediment from Features 7, 13, 34, 38, 39, and 43. The samples from Features 38 and 39 are particularly enriched in all of the cations measured while Feature 13 is nearly as depleted as several of the samples from noncultural contexts. The abundance of potassium shows a nearly linear relationship to the abundance of silt and clay similar to that shown for phosphate in Figure H-14.

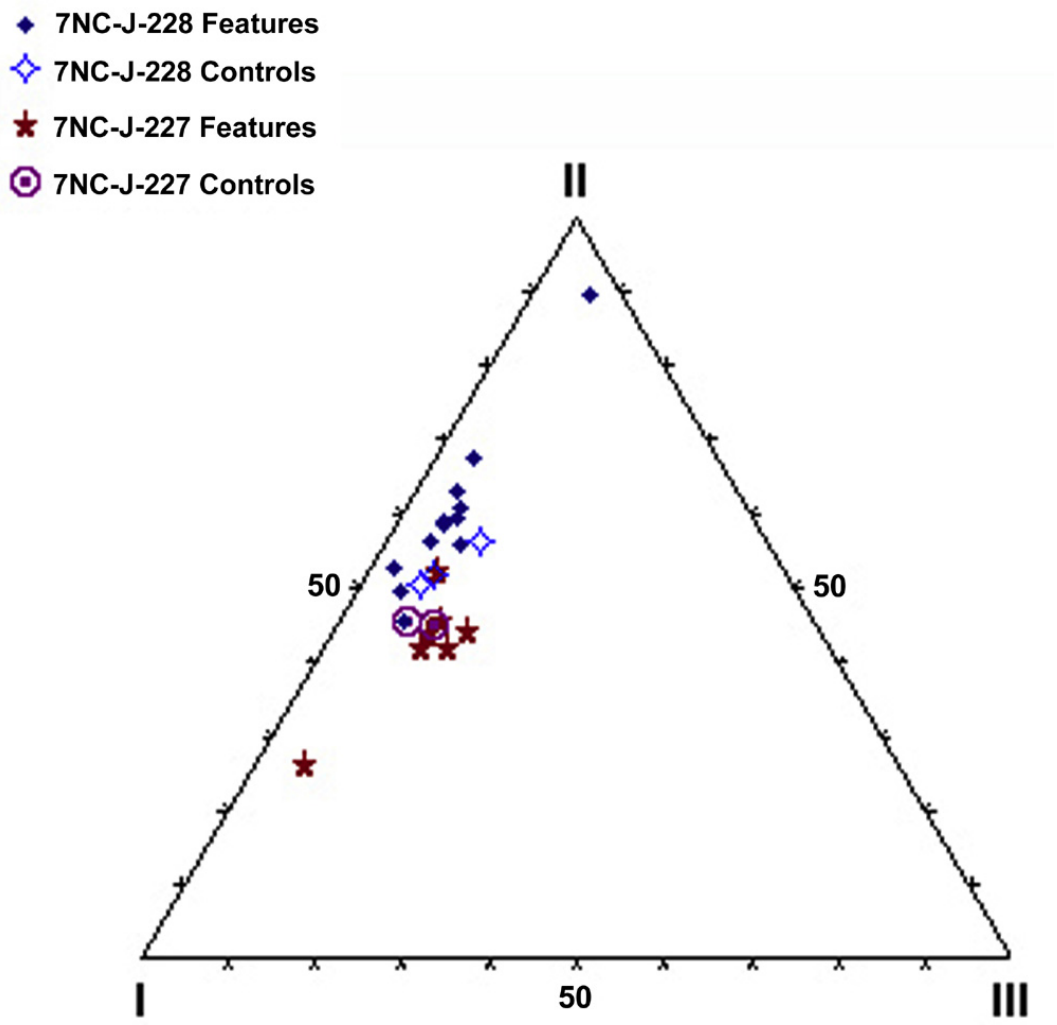

Figure H-15. Phosphate Fractionation results for 19 Samples of Possible Cultural Sediment and 5 Control Samples from the Sandom Branch Site Complex

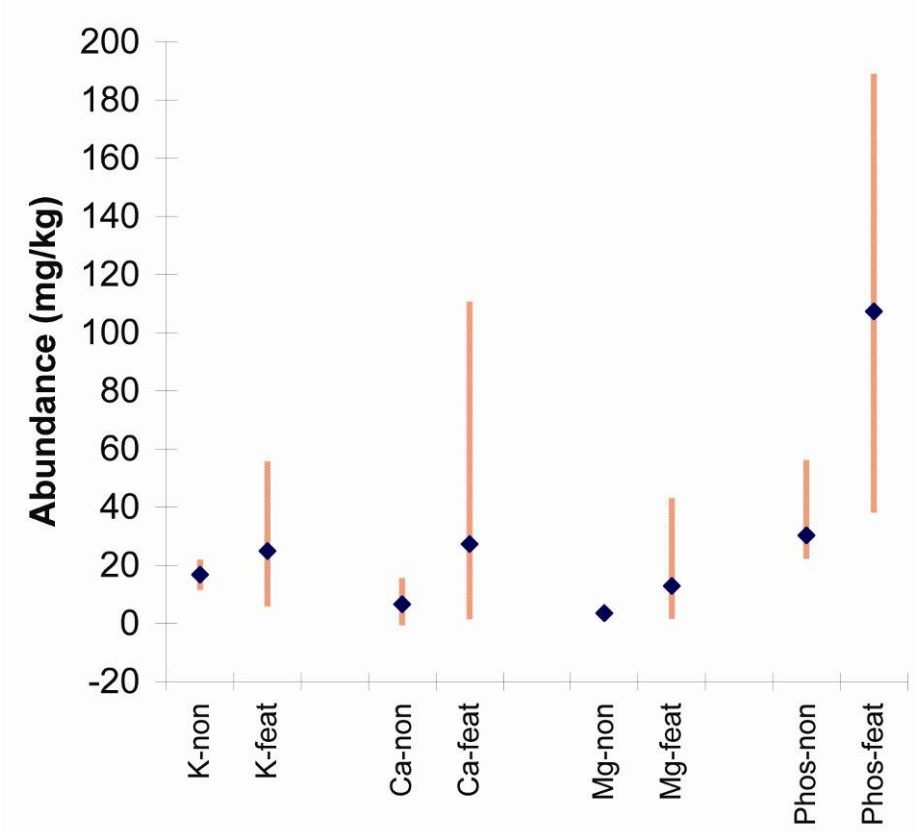

Figure H-16. Comparison of the chemistry of sediments analyzed for 5 non-cultural (disturbed) contexts and 7 prehistoric features from 7NC-J-228

The chemistry of the cultural sediments supports the hypothesis that very different activities took place at 7NC-J-227 and 7NC-J-228. The 7NC-J-227 cultural sediments show enrichment in Fraction I phosphate, typical of middens produced by late prehistoric villagers. The relatively low amounts of total phosphate and the relatively coarse texture of these sediments are less typical of middens. Some may be hearths, although the exchangeable potassium values are too low to suggest the presence of wood ash. The most likely hypothesis is that they result from secondary discard of material burned and processed elsewhere, implying a relatively long-term occupation of the site.

At 7NC-J-228, the high amounts of Fraction II phosphate may be partly due to the fact that these features are from an earlier cultural period. Fraction II is taken as an indicator of time (Eidt 1977; Schuldenrein 1995) and the amounts of Fraction II, the Fe- and Al-occluded phosphates, tend to increase as sediment weathers. Another plausible hypothesis is that the sediments with the highest Fraction II loadings came from pits excavated deep enough to include material from the buried soil underlying the archeological contexts. Fills from deep Early Woodland pits can thus be hypothesized to have high amounts of Fraction II phosphate as well as exchangeable Ca, Mg, and K. The relatively low amounts of organic matter in the 7NC-J-228 pit fills does not suggest stored food or refuse from dwellings. Rather, the pits may have filled gradually after the site was abandoned.

Stratigraphic Framework and Evidence for Environmental Change

Origins and Age of the Columbia Formation (Base of Sandom Sequence; pre-cultural)

The presence of intact, buried archeological contexts at 7NC-J-227 and 7NC-J-228 clearly demonstrates some net Holocene accretion in portions of both sites. A number of mechanisms have already been proposed for generating the sandy matrices in which prehistoric artifacts are found at Coastal Plain sites. The present study has shown how several of these mechanisms operated in conjunction with one another. Alluviation, colluviation, and aeolian deposition all occurred in portions of the Sandom Branch Site Complex. Biomantle processes also played a significant role in modifying configurations of the deposits, sometimes compromising the integrity of the archeological record.

To assess the relative roles of the individual depositional processes during the Holocene, it is important to review the extant stratigraphic framework the Quaternary of the Delaware Coastal Plain. Delaware is one of the few states on the eastern seaboard where Quaternary surfaces are not currently assigned terrace names based on relative elevation above mean sea level or local base level of modern trunk streams (Groot and Jordan 1999; Ramsey 1994). Terrace chronologies do appear in the earlier geological literature (e.g., Bascom and Miller 1920), and terrace names are projected onto geologic maps from adjoining states. For example, wave-built terraces representing interglacial sea level highstands were traced through the entire Atlantic Coastal Plain by Cooke (1930).

Scarps for the Sunderland, Wicomico, and Talbot surfaces were proposed for northern Delaware (Bascom and Miller 1920) in deposits which were later assigned to the Columbia formation. However, neither physiographic features, nor sedimentary strata were found by Jordan (1964:35) to correspond with the previously mapped marine terraces. Jordan described the Columbia formation as a braided stream facies lithostratigraphic unit which was deposited at a range of elevations in more than one channel belt. The channels were postulated to have been overloaded with meltwater from the waning stage of a major glaciation, such that the entire Columbia formation may be the product of a single deglaciation. One remote analogue for the Columbia deposits might be the “channeled scablands” which resulted from the late Pleistocene glacial Lake Missoula outbursts in the western United States (Bretz 1923, 1928; Baker 1973, 1987).

The logical place to search for correlates of the Columbia formation would appear to be glacial outwash terraces as opposed to marine terraces. Glacial outwash terraces traced the length of the Susquehanna River in Pennsylvania (Peltier 1949) were subsequently identified in the Delaware River valley as well (Peltier 1959). Slightly different terrace nomenclature was developed in New Jersey (Salisbury 1902; Salisbury and Knapp 1917; MacClintock and Richards 1936) but the valleys nonetheless appear to have aggraded during the same glacial intervals. Coarse sand and gravel extended down valley beyond the limits of the present shoreline, supplied by periglacial erosion as well as glacial outwash.

It has been proposed that the Columbia formation is the downstream equivalent of the Pensauken terraces of New Jersey (Bowman and Lodding 1969; Owens and Denny 1979; Owens and Minard 1979; Stanford 1997). The Pensauken deposits generally contain more

feldspar than the Columbia formation of Jordan (1964) and palynological results indicate a Miocene or perhaps Pliocene age (Owens and Minard 1979; Stanford 1997). To further complicate matters, the term "Columbia" was used by Salisbury and Knapp (1917) to designate a "group" including the Bridgeton, Pensauken, and Cape May formations, deposits which span the Tertiary through late Quaternary.

A Middle Pleistocene deposition during oxygen isotope stage 12 or possibly 16 is inferred by Groot and Jordan (1999:7-8) for the Columbia formation in Delaware based on pollen from the AMCOR 6021C cores. They note that the Columbia formation would therefore be younger as well as different in lithology than the Pensauken of New Jersey. A Middle Pleistocene age would also make the Columbia formation older than any of the terraces mapped in the Delaware River valley by Peltier (1959). It could be the same age as the "Pre-Illinoian" gravel which mantles bedrock surfaces over 60 m above river grade. A Middle Pleistocene age for the Columbia formation would be fully compatible with significantly different alignment of the master drainages relative to the bedrock valleys. At least six channels formerly outcropped, for example, in the cut for the Chesapeake and Delaware Canal between Chesapeake City, Maryland and Reedy Point, Delaware (Jordan 1964:30). This is a distance of over 20 km, and the base of several of the channels was below present mean sea level. The Columbia deposits consisted mostly of medium to coarse sand with some gravel, occupying the upper part of a sequence extending back into the Cretaceous (Pickett 1987).

A north-south trending Columbia formation paleochannel is shown in the vicinity of the Sandom Branch Site Complex but its thalweg is somewhat to the east. The modern drainage network, on the other hand, trends east toward Delaware Bay. Because the upper valley reaches were scoured by lateral planation, it was not possible to determine the date of the initial development of Sandom Branch in the present study. The late Quaternary drainage development exemplifies the process of "topographic inversion" (Daniels and Hammer 1992:144-158; Summerfield 1996:154-157) in that the present interfluves generally follow former stream thalwegs while the present valley floors have been incised through finer-textured tidal marsh or distal floodplain sediments. The local hydrogeography of the Delaware Coastal Plain has also been shaped by the lateral migration of the Delaware River during the late Quaternary and reduction in stream discharge as glacial meltwater declined at the onset of the present interglacial.

Locally, the Sandom Branch channel bed is ~5.5 m (18 ft.) amsl where it passes beneath State Route 13. This represents an incision of at least five meters below the height of the Columbia formation paleochannels. The topographic highs occupied by the sites stand at ~10 m (33 ft) AMSL while the Sandom Branch floodplain (T-0) is at 7-9 m (23-30 ft.) amsl. The T-0 extends for 50 m either side of Sandom Branch and also flanks the unnamed tributary immediately adjacent to the Sandom Branch Site Complex.

The sedimentology of the Columbia formation deposit at the base of 7NC-J-228 is consistent with previous results for 170 samples reported by Jordan (1964:10-16). The median grain size of 1.77ø falls within Jordan's modal class of 1ø -2ø, although it would be one of the finer-textured samples. The Sandom Branch deposit is also typical in terms of sorting, although slightly better sorted than Jordan's mean of 1.58ø for the sorting index.

Skewness ranged from 0.678 to -0.848 in Jordan's sample, bracketing the value of 0.02 for the C horizon at 7NC-J-228.

Jordan observed that the samples with greater clay and silt content tended to have unimodal grain size distributions with positive skew, as is the case for the Sandom Branch deposit. The clay and silt content tended to be higher in samples from further south. Perhaps the Chesapeake and Delaware Canal is the true dividing line, since the sample analyzed in the present study seemed typical of the Columbia formation as seen in exposures across the DelDOT SR 1 Project. Negatively skewed distributions, bimodal distributions, and smaller admixtures of silt and clay all tend to occur in the north (Jordan 1964:14-16).

Origins and Age of the Late Quaternary Deposits (Top of Sandom Sequence; artifact bearing)

The upper horizons at the Sandom Branch Site Complex are clearly of Holocene age, but they are not atypical of the Columbia formation as described by Jordan (1964). There is a large tail of fines in the samples sieved at 0.5ø from the profile at N237/E446.5. The presence of fines in the Columbia formation was ascribed by Jordan (1964, 1974) to overbank deposition in interfluve areas as well as estuarine influence at the south end of the Delmarva Peninsula. Aeolian reworking was not noted with the exception of dune fields along the coast or in areas which were coastal during sea level highstands.

Recently, however, Ramsey (1994) has described a silt cap characteristic of the upper portion of the Columbia formation which he attributes to late Pleistocene aeolian reworking. An age older than 10 ka is certainly indicated by evidence that large pebble and cobble clasts were displaced upward into the silt cap by frost heave. A mantle of silty "loess" up to 70 cm thick has also been described by Wagner (2000), overlying a truncated residual soil at the Cauffield Site in the Stoney Run Valley. The well-developed argillic (Bt) horizon may indicate an age of at least 10-12 ka. In eastern Maryland, Foss et al. (1978) described loess deposits similar in age and genesis. Aeolian deposition in the late Holocene has been inferred previously by Custer (1984, 1994, 1999) and others (Curry and Custer 1982; Custer and Watson 1987; Ward and Bachman 1987) based on Late Archaic to Early Woodland archeological contexts buried by a mantle of silty to fine sandy sediment.

Aeolian deposits are found downwind of closed depressions throughout the Atlantic Coastal Plain. These features are variously referred to as "Carolina bays," "Maryland basins," or "bay/basins" and most appear to be Pleistocene in age. Some of the downwind deposits have been given formation names and are sufficiently well characterized that they can be compared with sediments from archeological sites. The Parsonburg Sand as described by Rasmussen and Slaughter (1955) in southeastern Maryland, for example, is a poorly sorted, medium-grained sand with gravel and cobbles. Considerably finer-textured aeolian deposits interbedded with peat were also referred to as Parsonburg by Owen and Denny (1979), Sirkin and Owens (1976), and Sirkin et al. (1977). In Delaware, the Parsonburg was rejected as a formation name by Groot and Jordan (1999) because the peat and silt do not form a continuous, mappable deposit. Rather, they are deposited in shallow depressions on the surfaces of older deposits. The pollen results for bay/basin fills reported by Groot and

Jordan (1999:16-17) generally indicate cold climate but five samples with temperate affiliation may range from Holocene to the last interglacial.

Much of the literature converges around an aeolian origin and later Pleistocene age for the upper part of the Columbia formation particularly in southern Delaware. The silt layers found at the top of many profiles on archeological sites are extremely thin compared to the aeolian mantle deposits which have previously come to the attention of Quaternary geologists. The role of climate in generating the requisite wind strengths and vegetation gaps is much better demonstrated for the late Pleistocene. At the Pollack Farm site (Ramsey 1998), fines were mobilized during the deflation of "undrained depressions" which postdate the last interglacial. Sediments within these depressions are "a combination of sands locally reworked by seasonally ponded water and wind-blown material" (Ramsey 1998:30).

Webb et al. (1994) cored several ponds and closed depressions near the SR 1 Project to reconstruct local paleohydrology and vegetation change. They obtained twelve radiocarbon dates spanning 14.2-2.65 ka and inferred that a dry period occurred from 11-6 ka BP based on intervals of mud cracks bracketed by radiocarbon-dated mud. The limited paleoenvironmental proxy records therefore appear to accord best with a late Pleistocene or early Holocene age for deflation of closed depression features and sand deposition downwind. Throughout the Holocene epoch, the climate has certainly been warmer than it was at the last glacial maximum. There is some recent evidence, however, of cold, dry excursions caused by iceberg-rafting events in the North Atlantic Ocean (Bond et al. 1997). These excursions might conceivably be responsible for periodic erosion and aeolian transport of sand in Coastal Plain settings during the Holocene epoch (McWeeney and Kellogg 2001; Nicholas 1998).

Modeling Site Formation at Sandom Branch

The data from the Sandom Branch Site Complex presented above record very localized aeolian deposition which appears to occur during and after the Early Woodland cultural period (ca. 3,000 BP). Some of the more compelling data are the fining-upward trends in profiles at 7NC-J-227 (locus N77/E476) and 7NC-J-228 (locus N237/E446.5). The most immediate source of sediment for these profiles would be areas upwind which were stripped of vegetation by the Native Americans. This hypothesis appears to better explain the patterned depositional trends across both sites than a regional drought. The chronology of late Holocene droughts currently developed from baldcypress tree rings (Cook et al. 1992; Stahle and Cleaveland 1996; Stahle et al. 1998) may ultimately provide independent evidence to the contrary.

Many parts of the Sandom Branch Site Complex exhibit an upward-coarsening trend, as is typified by the profile at N228.5/E451 (7NC-J-228). The coarse sandy material in the upper 20 cm of this profile fits one general definition of a biomantle, "a differentiated zone in the upper part of soils produced largely by bioturbation" (Johnson 1990:84). The narrower definition in soil taxonomy (Soil Survey Staff 1975:21) specifies that the materials must be "sorted and brought to the surface by animals such as ants, termites, worms, and burrowing animals." The soil taxonomy definition also explains the profile coarsening by physical translocation of clay down profile. This is similar to the explanation of "desert pavements"

proposed by McFadden et al. (1987), in which a vesicular horizon conveys windblown fines down profile while the pavement clasts are "borne at the surface."

Aside from the coarsening-upward trend in the laboratory results for one profile, the evidence for faunal and floral turbation at the Sandom Branch Site Complex comes from the numerous areas of disturbance which were initially assumed to be prehistoric pit features. Geochemical results support the hypothesis that several of the larger pits are tree throws or the result of multiple burrows. As discussed above, however, burrowing organisms often target preexisting cultural pits, and the cavities initially created by tree throw may have been subsequently exploited for storage and dwellings by prehistoric hunter-gatherers.

Evidence for Holocene alluviation on the topographic highs at the Sandom Branch Site Complex is limited to linear channels filled with gravelly sands at the southern edge of 7NC-J-227. Stream deposition is unlikely elsewhere as the deepest cultural contexts are still more than a meter above the Holocene floodplain and more than twenty meters away from the active channel. The radiocarbon date of 680±50 BP (Beta-149041) for woody detritus in gravelly sand of the Sandom Branch floodplain suggests that these alluvial deposits are several thousand years younger than the Woodland occupation of 7NC-J-228. Valley incision probably began by 4,000 BP, indicating that there would have been a small stream fed by discharge from active springs at the time that both sites were most intensively occupied by Native Americans.

Internal processes account for many changes to Coastal Plain landscapes over both short and long time scales. Biomantle evolution (Johnson 1990) encompasses one group of processes which have been emphasized in explaining the sandy matrices at the Sandom Branch Site Complex. Gravity and chemical dissolution of the sedimentary lithologies are also responsible for modifying relief on the moderate to smaller scales represented in these sequences. These processes ultimately explain the topographic inversion mentioned above. Specific areas where mass wasting was most evident include the eastern edge of 7NC-J-227, the gullied areas between the two sites (N120-200), and the scarp to the west of 7NC-J-228 (E420-450). Colluvial mantles tend to be coarse-textured like the biomantles but are typically somewhat looser.

Some of the tree throws produced large enough cavities that mass wasting had subsequently occurred within them. The health and survival of trees in Coastal Plain forests is controlled by the supply of water in appropriate amounts to root systems. This in turn depends upon subsurface drainage through the partially lithified sediments. Chemical equilibria play as much of a role in this as the changing regional climate, since cements of silica, iron oxide, and occasionally carbonate fill the pore space and create preferential flow paths.

One consequence of the subsurface hydrology of the Delaware Coastal Plain is that groundwater reaches the surface in localized seeps or "springheads." These may have been what initially attracted prehistoric settlement, particularly at the northeast edge of 7NC-J-227. Presumably the activity of the seeps would have been higher during a warm, wet climatic interval such as the present. A detailed water balance analysis of both seeps and

closed depressions would contribute considerably to paleoenvironmental reconstruction of Coastal Plain settings.

Summary and Discussion of Research Significance

The Sandom Branch Site Complex can be considered fairly typical of the archeological record left by seasonally migratory hunter-gatherers in the Delaware Coastal Plain during the late Holocene. The archeological sequence was arranged laterally as well as vertically within the relatively shallow sandy deposits. The pits and areas of staining were as much the result of geogenic, and biogenic as well as anthropogenic site formation. Geochemical analyses help to sort out these processes. Charcoal was poorly preserved and did not always provide reliable radiocarbon dates for the artifact-bearing deposits. The geoarcheological approach of the present study emphasizes site formation processes as an investigative strategy. Discrete geoarcheological transects were structured to examine the range of stratigraphic variability across the sites and to sample the range of operational site formation processes.

While there is considerable evidence for both floral and faunal turbation at the sites, all of the "cover sands" in which the prehistoric artifacts and features were found do not fit the definition of a biomantle (Johnson 1990). There has been net accretion, primarily by aeolian deposition, in some portions of both sites. Because the aeolian packages defined by fining-upward textural trends occur downwind of the areas of prehistoric occupation, it is hypothesized that human disturbance played a leading role in their genesis. The occurrence of regional late Holocene droughts is another possible explanation, although the evidence for these is still incomplete.

Many of the problems of archeological site formation and prehistoric cultural ecology in the Delaware Coastal Plain are common to the Atlantic Coastal Plain in general (Blanton and Pullins 2000; Leigh 1998, 2001; Michie 1990). The relatively low relief of the landscape conceals considerable diversity in vegetation, controlled by surface and subsurface hydrology. The stratigraphic framework in Delaware is somewhat unique, however, because of the widespread Columbia formation fluvial deposits. These are currently considered to be middle Pleistocene in age (Groot and Jordan 1999) but they are capped by a late Pleistocene aeolian mantle of indeterminate thickness (Ramsey 1994). The modern drainage network has developed transverse to the Columbia formation paleochannels, but floodplain deposits are still relatively thin and apparently too young to contain deeply buried prehistoric archeology.

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