# IX. GEOMORPHOLOGY AND GEOARCHAEOLOGY

## Introduction and Objectives

Geomorphological and geoarchaeological investigations at Lums Pond (Figure 74) were undertaken for two phases of the cultural resources investigations in 1995. Testing was performed in January, while data recovery was completed in May and June. As archaeological research proceeded, it became apparent that prehistoric loci corresponded spatially and stratigraphically with discrete landforms-sediment complexes across the Lums Pond landscape.

Area 1 included limited artifact distributions largely confined to plow zone ("Ap") depths at the summit of the primary site interfluve, a residual outwash terrace of the Pleistocene Columbia Formation. Area 2 consisted of *in situ* features intrusive into weathered midslope soils of the same aeolian mantled interfluve. Area 3 preserved a series of stratified, compressed and spatially diffuse prehistoric deposits in alluvium underlying the T-0 surface of the contemporary Lums Pond impoundment.

Contemporary landscaping for Lums Pond State Park has extensively modified surfaces, topography, and, most significantly, the hydrography of the drainage basin. Changes to the groundwater regime have been so extensive that hydromorphic soils were identified at higher elevations (on the eastern slope of Area 2), thereby confounding initial stratigraphic interpretations. In sandy Coastal Plain settings groundwater movements may mask otherwise apparent weathering horizons and alluvial strata. Historically modified landscapes superpose an additional filter on the stratigraphic record. Consequently, it was necessary to apply a series of investigative and analytical methodologies to unravel the site formation chronology at each of the archaeological Areas.

Fortunately, prospects for comprehensive landscape reconstruction were enhanced by the site-wide pervasiveness of the erosional surface of the Columbia Formation. This litho-stratigraphic unit established a critical interface above which Holocene age sediments accumulated and/or soils weathered. Alluvial sedimentation was identified as the key process fashioning successive floodplain surfaces in Area 3 while episodic aeolian accumulations sealed in the features in Area 2. Stable surfaces in both landscapes were recognized by intact, albeit variably developed, soil profiles. Since the 19th century, soil stripping destabilized the slopes between the two areas and created a grade, offset by a veneer of reddish historic sands and silts covering the floodplain. It was therefore possible to isolate primary stratigraphic relationships at an early juncture of the field research in Areas 2 and 3.

Stratigraphic resolution was further enhanced with the assistance of diagnostic archaeological assemblages and a battery of radiocarbon dates. Groundwater oscillations, regulated by seasonal drainage and by more extensive landscape engineering, could have affected the reliability of the absolute dating because of vertical mobilization of decayed carbon through capillary action. This produced an especially deceptive stratigraphic problem in Area 3, where "groundwater podzols" provided initial indications of a dipping "buried A" soil. Because of this apparent source of carbon contamination, a select sample of identically provenienced radiometric specimens were processed from different source materials including cultural charcoal, decayed root mats, and isolated organic fragments (the latter were processed by AMS). By calibrating ages and cross-sampling different sources of the organic fraction it was possible to quantify degrees of contamination and test

consistency and accuracy of particular dating methods for the site. This is a methodology that has rarely been used at archaeological sites.

Archaeological assemblages spanning the period from the Delaware Early Archaic to historic periods (following the chronology in Custer 1984, 1989) are represented differentially across the project Areas. The archaeological record was sufficiently well preserved to facilitate inferences on site utilization and adaptive patterning. Preservation contexts enabled reconstructions of formation processes prior, during, and subsequent to occupation.

The present study has not been designed to model paleoenvironmental changes for the Holocene of northern Delaware. For such studies the reader is directed to several overviews on prehistoric environments and settlement that have been compiled over the past few years (see Kellogg and Custer 1994; Heite and Blume 1995; Custer et al. 1996; Riley et al. 1994). The perspective adopted for this study is uniquely geoarchaeological and attempts to read the stratigraphic and geomorphological records with an eye to the interaction of human populations with the landscape (in the sense of Leach 1992; Butzer 1982). Site formation, the significance and patterning of cultural residues, the logistics of site selection atop a landform, and the preservation of the archaeological record in certain sediments and soils, all become critical elements in a comprehensive geoarchaeological model whose objectives are integration with the artifact and settlement records. In contrast, traditional geomorphological or pedological site studies simply examine reconstruct landscape histories and weathering environments and leave the archaeologists to interpret process and man/land interactions.

Given this perspective, the research strategy formulated for Lums Pond addressed three objectives:

1) Vertical and lateral reconstructions of the Holocene floodplain and interfluves corresponding to >10,000 years of landscape evolution and human activity ;
2) Unraveling of natural and cultural processes that account for the archaeological records preserved in Areas 1, 2, and 3;
3) Comparisons of geoarchaeological results (*sensu stricto*) at Lums Pond with earth science oriented research undertaken in other portions of Delaware.

This study begins with an overview of the geology, geomorphic setting and the Late Quaternary landscape history of the project area. The methods used in the study are then outlined and applied in a systematic investigation of stratigraphy and sedimentation at Lums Pond. As noted, it was imperative to isolate the natural sedimentary and soil formation histories from the recently engineered environment. Observations are next synthesized into a reconstruction of local stream, aeolian, erosional, soil formation, and occupational

environments. Questions of cultural sedimentation and site preservation are then examined. Specific analyses stressing degradation, diagenesis, and mobilization of cultural residues (artifact, organic, and combinations thereof) attempt to separate various types of anthropogenic sediments from the general soil and sediment matrices. Finally a model of landscape archaeology is generated that traces the history of the site in stages. The diachronic model begins with the site's pre-cultural setting and traces the processes responsible for settlement and site preservation through the various periods of occupation and abandonment. The model culminates with an explanation of the configuration of the contemporary archaeological record.

## Geological Background and Site Landforms

*Regional Physiography*

The Lums Pond project area is situated in Delaware's High Coastal Plain, south of the Piedmont Uplands. This physiographic province is bounded by the Fall Line to the north and the Smyrna River to the south. Landforms are built up from the coarsest sediment facies representing the southernmost extension of the Pleistocene Columbia Formation (Jordan 1964). These deposits are typically weathered and erosion resistant, producing a rolling topography in which graded to moderately steep interfluves are characteristic; elevation differences are on the order of 10-15 m (33-50 feet). The most prominent topographic breaks are along the incised portions of lower order water courses. At Lums Pond, incision on the order of 5-10 m reflects active degradation of the landscape bordering the recontoured pond basin. The narrow floodplains (T-0 surfaces) are capped by thin veneers of redeposited sands that bury older Holocene sediments.

The Piedmont formed as a complex of crystalline igneous and sedimentary rocks, strongly metamorphosed during the later Pre-Cambrian. Locally, micaceous schists, gneisses, and migmatites of the Wissahickon Formation are the dominant rock types. These crystalline rocks slope south and southeast, creating a basement over which the wedge shaped sediments of the Columbia Formation accumulated (Spoljaric 1972). Field inspection of dominant sand grains along the floodplain of the headwater tributaries indicated mineralogical affinities with eroded Wissahickon Formation and Columbia Formation sediments.

Soils in the project area are typically of the Sassafras-Fallsington-Matapeake association and are characteristically well to moderately drained. They formed on the moderately coarse to medium textured sands of the Columbia Formation. Locally, thin veneers of finer grained sands and silts extend along the level surfaces of the T-0.

The site itself occupies an extensive interfluve variously incised by both southeast and southwest trending tributaries. Headward retreat is the dominant geomorphic process which has apparently been accelerated over the past decade by variable stripping of the vegetation cover, expansions of the Lums Pond basin, and seasonal fluctuations of runoff, whose large scale effects have been progressively enhanced by changing edaphic conditions. Relief across the occupied site surfaces is approximately 10 m (33 ft.) between Areas 1 and 3 and reflects propensities of aboriginal groups to settle on the stabilized surfaces of the interfluves (Areas 1 and 2) as well as on the lowerlying alluvial plain (Area 3). As discussed, despite the extensive landscape modifications the present floodplain apparently functioned as a larger drainage line in the prehistoric past.

*Hydrography and Drainage*

The regional catchment, or trunk drainage, is the Chesapeake and Delaware Canal which lies 3.2 km (2 miles) to the south of the site. In this portion of Delaware the drainage is classified hydrographically as the Drainage Divide, a reference to the location of the watershed along the spine of the Coastal Plain where runoff is discharged either westward to the Chesapeake or eastward into Delaware Bay.

The Chesapeake and Delaware Canal is, of course, a man-made feature that obscures the initial drainage lines. During the Pleistocene, drainage across the project area was south to southeast as meltwater streams discharged large volumes of sediment into the Delaware and Chesapeake Bays (Spoljaric 1972). There were apparently frequent overhauls in the flow regime and drainage net. Hydrogeological studies have concluded that major streams now flow in the areas which were topographically elevated during the Pleistocene. In the project area it has been noted that Dragon Creek, whose headwaters are 4 km east of Lums Pond, ".....clearly displays the adjustment of the flow direction around the thick part of the ancient channel" (Spoljaric 1967: 11 and figure 1). If the Holocene drainage adjusted its flow around the thickest accumulations of its Pleistocene precursor the considerable modifications to regional hydrography and the dynamism of the Early Holocene streams account for the absence of early archaeological components in the vicinity of Lums Pond. These observations are borne out by the virtual absence of Early Holocene sediments in northern Delaware generally and in the project area in particular.

While the canal was built in 1824, mid-nineteenth century maps indicate that the pre-industrial drainage basin featured a dendritic net of lower order feeders that converged to form the main channel of the former St. Georges Creek (see Hoseth et al. 1994: figure 2). At this confluence, ca. 1 km upstream of the juncture with the Chesapeake and Delaware Canal, the 1849 map already illustrated the mouth of Lums Pond extending into the canal. Preliminary interpretation of the historic hydrography is that the precursor to the present Lums Pond basin was a broad floodplain that sustained limited or seasonal channel avulsion in its lower reaches. Subsequently, the southwest draining tributaries were flooded after the

spillway to the canal was dammed (currently evidenced by spoil piles) and the inundated surfaces migrated northward as further landscaping progressed.

Figure 74 depicts the present drainage, landform relations, and geologic units in the vicinity of the site. As shown, water levels of the active Lums Pond basin are sustained by groundwater fluctuations. Vertical movements are governed by the high (near surface) aquifer as well as by discharge of the lower order feeders that drain into the impoundment from interfluves and Columbia Formation knolls overlooking the basin from the southwest, north and northeast (see Woodruff 1986).

*Surficial and Late Quaternary Geology*

The composite map of the landscapes and geology near Lums Pond (Figure 74) provides baseline information for previewing prehistoric landform relations during the mid to Late Holocene. This is because the depth of historic colluvium, prehistoric alluvium (Area 1) and upland dune sands (Areas 2 and 3) is typically <2 m, extending to the unconformity with the rubefied sands of the Columbia Formation. Figure 74 does not register any extensive accumulations of Quaternary deposits (see also Woodruff 1986). Typically, landscapes and surfaces across northern Delaware have been mapped as being capped by Columbia Formation sands of variable texture. The Columbia is therefore considered the oldest surface deposit. Further, the extent of the Formation is such that only accumulations in excess of 12 m (40 feet) are formally depicted in geologic maps (Figure 74; see Woodruff 1986).

The litho-stratigraphy of the Columbia Formation has been described in detail by Jordan (1964) and its identification was critical to indexing the depth of archaeological sensitivity across the project area. Accordingly, field profiles were examined to see to what degree sedimentary structures, composition, texture and stratification conformed to criteria widely recognized for the Columbia Formation, specifically in the northern portion of the state. Facies were recognized as being "..... essentially unconsolidated although locally there may be considerable differences in the degree of induration due to interstitial clay and/or iron oxides. Heavy bands of limonite-cemented conglomerate are common, especially towards the north. Colors range from white through yellow, tan and brown to reddish brown" (Jordan 1964: 2). While, only broad and generic descriptions have been invoked to isolate fluvial from shoreline estuarine facies, mapping and sedimentology verify that the primary site interfluve (Areas 1 and 2) represents a fluvial facies of the Columbia Formation (see Jordan 1964: Plate 9, pp. 30-31). The present work verified that the upper segment of the interfluve was modified by aeolian activity and weathering during the Holocene. As discussed, the weathered aeolian deposits along mid-slopes preserved archaeological features in Area 2. The criteria invoked to isolate these from the older Columbia Formation are presented in a subsequent section.

Detailed investigations of the subsurface stratigraphy have been reported by Woodruff (1986), based on a transect of boreholes whose depths extend in excess of 30 m (100 feet). One of the boreholes, Eb 12-3,b was emplaced 60 m (200 feet) northeast of Area 1 and disclosed a thickness of >6 m (20 feet) of Columbia formation sands; these conformably overlie the basal Coastal Plain formation, regionally the Potomac (see Figure 74). The Cretaceous Potomac sands are of fluvial origin and were laid down in shifting stream channels. Two additional boreholes, Eb 22-10,11, are 1.2 km (0.75 mile) south of the site along the margins of Lums Pond (Figure 74). A similar thickness of Columbia Formation sands was noted, but these overlie later Cretaceous sands of the Merchantville Formation.

The only landscape segments in northern Delaware formally mapped with post-Pleistocene sediments of significant thicknesses (>2 m) are channel floors in the Delaware River and major stream valley bottoms where erosion has removed most of the Columbia deposits (Woodruff 1986). Neither landscape segment is present in the Lums Pond project area; the lower order tributaries are too narrow to qualify as primary feeders. The oldest deposits at the site were dated at 10,710±80 BP (Beta-92103); these were derived from peats within a sandy gravel matrix 0.9 m below the surface of the wetlands margins. The determination and context attest to the scale of erosion at the Pleistocene-Holocene interface. The date also confirms the pervasiveness of thin post-Pleistocene sedimentary veneers regionally and eliminates the potential for deeply stratified archaeological contexts.

## Field and Research Methods

*Field Work*

The field work consisted of three stages: first, reconnaissance and mapping of the contemporary landform surfaces; second, subsurface investigations describing buried cultural horizons, soils, stratigraphic units and marker horizons; third, soil-sediment and radiocarbon sampling to resolve more detailed issues of sedimentation and soil formation.

After the first and second stages, a generalized landform chronology and site stratigraphy was established. The site stratigraphy focused on the alluvial sequence for Area 3 and the aeolian/colluvial succession for Areas 1 and 2. As discussed below, by viewing the site soils and sediments in terms of existing slope grades and toposequences--in pedogenic terms "catenas" (see Birkeland 1984; Yaalon 1975)--it was possible to develop a comprehensive model for landscape development that linked sedimentation and soil formation on the interfluve with synchronic sequences on the alluvial bottoms. Both

landform segments preserved reinforcing evidence for the range of Holocene landscape and climatic changes.

The second and third stages of field work involved investigation of the deeper excavation blocks (Area 3: Blocks A and B) and feature loci (Area 2). Additionally, a series of eleven (11) deep cores (>2-3 m deep) were emplaced at diagnostic locations including tracts outside the primary excavation locations. The purpose was to examine deeper (i.e., older) Holocene deposits or transitions in sediment matrix from cultural deposits to unmodified site soils and litho-strata.

Figure 75 identifies the locations of three (3) transects and all supplementary locations (i.e., boreholes) investigated for the geoarchaeological study. Figure 75 is

superimposed on a base map of the site grid. Initial examinations focused on the overall landscape during survey and testing of the project. The objective was to obtain a "bird's eye" perspective on landscape evolution and to structure fundamental landform relations; a landscape segmentation model was fashioned at this time. Subsequently, two (2) detailed stratigraphic transects incorporated observations along the key prehistoric loci in Areas 2 and 3. These serve as the basis for the detailed sedimentological analyses and site formation models.

Inspection of each of the available exposures was undertaken by the geoarchaeologist (Schuldenrein) and an assistant. Typically either the west or south faces were selected for primary descriptions and sampling. Other exposures were examined when they provided diagnostic micro-stratigraphy or unique bedding structures. Depths of excavation units were typically <2.0 m, since it became apparent that cultural materials did not extend beneath the lowermost alluvium atop the Columbia sands. In Area 2, the top of Argillic soil ("Bt horizon") contained artifacts and signaled the depths beneath which stratification was obviated in all cases but those of intrusive features. Detailed sections were assembled as a series of transects across key slope, landform and stratigraphic transitions to index systematic landscape and occupational changes.

In the field, stratigraphic nomenclature was standardized initially with reference to soil horizons (Buol et al., 1989; USDA 1975, 1990). This method was selected because of the relatively limited depth of excavation and preliminary field relations that sorted out sola by landform; soil horizons and related strata were eventually integrated with master litho-strata following resolution of chrono-stratigraphic questions (see discussion in subsequent section). In the field, stratum designations of the archaeologists were incorporated into the provisional, pedologically based sequences. Master statigraphies and soil horizon designations were finalized after the entire set of exposures was examined and laboratory analyses were completed. At the Lums Pond site overly detailed soil horizon descriptions were critical because of the subtle changes between the lower and upper floodplains (Blocks A and B in Area 3) and a similar transition from the alluvial basin to the toeslope of the interfluve (i.e., between Areas 3 and 2). Protracted historic slopewash rendered the passage morphologically indistinguishable.

Sampling and mapping involved identifications of "A", "E", "B", and "C" horizons to document facies variability and anaerobic conditions (in "Bg" or "Cg" horizons) and patterns of weathering (in "A" and "Bw" or "Bt" horizons); selection of grain size samples to isolate depositional variability; selection of "Bw" and "Bt" horizons for geochemical specimens; sampling of soil humates in "Ab" and "AB" horizons for radiometric dating; and removal of charcoal and/or soil humates from cultural features and stains for radiometric dating. Significantly, features and bulk organic sediments were taken from "Bw" horizons indicating broad preservation of organics and evolution of "cumulic soils"

(see Ferring 1992) in most subsurface contexts at the site. As noted, there were difficulties in sorting out contaminated radiocarbon specimens from within the "groundwater podsol" (see Hunt 1986).

Comprehensive soil-sediment descriptions and stratigraphic profiles were generated at each section examined. Geochemical and granulometric specimens were taken at 10 cm intervals and/or at natural stratigraphic breaks. Pedologic and sedimentologic characteristics were recorded on a detailed Soil-Sediment Form. Comprehensive identifications were made of sedimentological characteristics including color, structure, texture, ped development, mottling, stoniness, roots, cutans, and pedogenic, sedimentary, and especially hydromorphic inclusions. For soils, identifications of color, composition, and textural and structural features were made in accordance with standard guidelines (USDA 1975); this was especially critical for the recognition of aeolain soils. Specimens were then submitted for appropriate laboratory analysis.

*Laboratory Analysis*

Comprehensive granulometry and geochemical testing was performed on two complete stratigraphic columns from Area 3. These correspond to the best dated, stratified, and archaeologically representative sections in Block A (N228 E243) and Block B (N238 E257).

Composite granulometry (three fraction: sand, silt, and clay) was performed on these sequences to determine changes in channel activity and sedimentation (Folk 1974). Sand size fractionation was undertaken as well to determine frequency distributions that might isolate lateral accretion from overbanking. Dry and/or wet sieving segregated size grades within the sand fraction, while the hydrometer method separated the broader sand, silt, and clay fractions. To isolate variability within the size frequency distributions, a series of statistical parameters were also examined. In addition to standardized size grade fractionation, parameters of sorting (So), skewness (Sk), and kurtosis (Kg) were calculated using the method of moments (after Friedman and Sanders, 1978).

A battery of quantitative geochemical tests were applied to soil horizons to obtain signatures of limited weathering on the floodplain (T-0) and evidence for human occupation in the form of disaggregated cultural residues. Varying contributions of organic and chemical elements are often associated with formerly stable surfaces that may have sustained prehistoric occupations. At Lums Pond these tests were also critical for determining the degree to which colloids and clay-charged organics were mobilized vertically in the water table. Intact Archaic and Woodland components were also preserved in sealed "Ab", "AB" or even "Bw" horizons. It was possible to detect hidden cultural

signatures geochemically in the absence of well preserved features on the floodplain of Area 3.

The elements, or ions, tested to identify weathering and anthropogenic additions to the profile included calcium (Ca), magnesium (Mg) potassium (K) and phosphorous (P). The most common cultural residues isolated by these ion tests are bone, wood ash, excreta, and animal meat and tubers (Cook and Heizer 1965; Anderson and Schuldenrein 1985; Schuldenrein 1989; Kolb et al. 1990). To examine the degree of weathering and oxidation/reduction in the sola (i.e., "Bw", "Bwg", or "Bcg"), relative concentrations of mobile iron (Fe) and Manganese (Mn) were measured along with organic matter (OM) and pH. Covarying trends can help to determine if vertical or lateral changes in a profile are attributable to soil forming processes, human inputs into the sediments, or combinations of pedogenic and anthropogenic transformations to the matrix.

In Area 2, geochemical analyses of phosphates were undertaken in to infer human activity and behavioral patterns based on geochemical analysis of features. The extent and peformance of specific activities at the site was determined by measuring concentrations of inorganic phosphates and assessing fractionation patterns. The method facilitates reconstructions of the types of activities, duration, and even the relative antiquity of particular feature types. Techniques in this study followed the methodology initially outlined by Eidt (1984) for phosphate fractionation and subsequently refined by Schuldenrein (1995) for North American hunter-gatherer sites.

Composite granulometry and geochemistry (including phosphate fractionation) was performed at the Soils and Physical Geography Laboratory at the University of Wisconsin, Milwaukee.

## Stratigraphy, Sedimentation, and Landscape Chronology

*Stratigraphic Context; Terms, Definitions, and Organizing Principles*

In recent years the merging of archaeologically and geologically based stratigraphies has been facilitated by joint goals of site formation studies and landscape reconstructions (Harris 1989; Schiffer 1983; Stein 1990). At Lums Pond the need for a comprehensive stratigraphy is enhanced by complex horizonation of artifacts, soils and sediments across two discrete depositional environments--aeolian and alluvial--linked by a historical colluvium. The site is characterized by discrete occupational records at each landform, differing extents and depths of the archaeological horizons, differential development of discrete soils, and the contrasting dispositions of extensive late prehistoric assemblages (Woodland, Late Archaic).

Several terms and concepts must be clarified to offset the existing landscape from its substrate and to index buried archaeological remains to former occupation levels. Surfaces refer to the floors of human activity at the time of occupation. They evolve at the tops of lithological units and represent the uppermost accumulations of sediments or soils of a discrete depositional regime. Lums Pond spans two separate landforms and several attendant surfaces, associated individual occupations register corresponding periods of stability. Typically, alluvial surfaces (Area 3) close out more dynamic phases of flood discharge when net aggradation is minimal. Aeolian surfaces are much more difficult to isolate because of the "collapse effect" of protracted deflation that can homogenize artifact distributions of different time frames. Fortunately, since the occupations in Area 2 are represented by a series of features the significance of discrete surfaces (*sensu stricto*) is minimal and the demarcation between a former habitation level and the substrate is the time at which the feature is excavated into the substrate; in Area 2 a soil was forming at this time as well (see discussion below).

Lithologic units, underlie surfaces. They have been formally designated "....three-dimensional bodies characterized by the general presence of a.....(dominant).....lithologic type, or by the combination of two or more of these types" (Gasche and Tunica 1983: 328-329; see also Stein 1990, 1992). The principal lithologic units at Lums Pond are represented, in decreasing order of significance, by alluviation or floodplain building, fluvial sedimentation or channel filling, aeolian deposition, and hillslope erosion and redeposition. The latter constitute the most important contribution to the present landscape since the historic colluvium has mantled all surfaces and recontoured the prehistoric topography. A general estimate is that across the entire Lums Pond site terrain, about 70% of the surface sediment cover is represented by colluvium. The balance, is divided between the exhumed slope surfaces (15%; Area 2) and the narrow band of T-0 alluvium (15%; Area 3). Plow zone ("Ap"), reworked fills, and historic slope wash account for redistribution of the upper 0.25 to 0.75 m of sediment across most portions of the site complex. The lithologic units represent various contributions laid down by three separate agencies: water (alluvium), gravity (slopewash or colluvium), and wind (aeolian sediment).

Typically, differentiation between lithologic units is a function of change in the agencies, regimes or patterns of deposition. Locally, these discontinuities are offset either by unconformities when erosion occurs, by soils when weathering is active on a stable surface, or by hydromorphism when groundwater mobilization masks the stratigraphic signature. At Lums Pond, the most apparent break or unconformity--one which spans all surfaces and landform segments--is the top of the weathered Columbia gravels. A soil, for present purposes, refers to that part of the sediment that has been weathered or chemically transformed, at the top of a stable surface. Soils are divided into three master horizons: an A-horizon, the zone of humic matter accumulation that is usually darker than others in the

profile; the B-horizon, or zone of mineral enrichment and weathering, typically reddest in the profile; and the C-horizon or the unmodified parent lithology (i.e., alluvium, slopewash) of the profile on which the weathering process occurs. Two soils were recognized for the Lums Pond project area. The first, an Entisol, marked the contact between the buried floodplain and historic colluvium and was dated to ca. 400 BP. The second, an Argillic paleosol, offsets the Woodland features on the interfluve and is at least middle Holocene in age (ca. 7000 BP). Hydromorphism along the floodplain (in Area 3 and along the swamp margin of Area 2) obscures the Entisol but also attests to groundwater processes which inhibit soil formation.

An ideal A-B-C profile effectively preserves all evidence of subaerial weathering. However, at Lums Pond, slope stripping and lateral planation of floodplain surfaces has either physically or chemically removed all or portions of former "A" or "B" horizons from the stacked Holocene soil profiles. Some of the "A" horizons have survived near the top of the profile (Late Holocene) on the floodplain, been completely stripped from the interfluve, and been overprinted or masked in the basal alluvial sequence ("the groundwater podsol"). For the T-0, the parent material on which soil formation proceeds ("C" horizons) has accumulated immediately above the Columbia Formation gravels. These parent materials consist of various proportions of sands, silts, and clays that lie at the vertical limits of either former or seasonal water tables. Accordingly, evidence for anaerobic conditions is preserved in the soil horizons and is designated appropriately (i.e., "Cg" or even "Bg" and "Ag" when groundwater rises to the solum proper).

According to broad stratigraphic guidelines, if a soil sequence (exhumed or intact) is subsequently overridden by a new series of allogenic sediments a new lithologic unit may be designated (NASCN 1983). Thus, lithologic units may be separated from each other by soil horizons. Locally, however, since the generic mechanisms of sediment transport and subsequent weathering remained largely consistent throughout the Holocene, varying chiefly in relative intensity, only the most conspicuous breaks in weathering and/or lithologic composition warranted new unit assignments. For the lithologic units variability is recognized by changes in bedding configuration and particle size distributions; for soil horizons variability is expressed by color intensification and thickness and depth of mineral translocation.

Because several transporting agencies (i.e., water, gravity, and wind) accounted for penecontemporaneous sedimentation across discrete segments of the site landscape, lithologic units of equivalent chronological age were linked by Arabic numerals ("1", "2", etc.). To offset depositional agencies by landscape segment, sub-ordinate horizons were identified by letters ("a", "b", etc.). Thus, for example, historic alluvium was designated "2a" (Area 3) while historic slopewash was designated "2b" (Area 2). Verification of ages

was made on the strength of radiocarbon dates and diagnostic archaeological assemblages or artifact types.

The application of the principles of stratigraphic separation of the Lums Pond site resulted in the establishment of four (4) master Lithological Units (1-4) and subordinate strata in Units 2 and 3. The assignment of units was based largely on structural and textural changes in unit lithology that signaled first and foremost, threshold shifts in depositional environments that also affected landform evolution. Lithologic unit tops were either unconformities or surfaces on which soil formation evolved and/or prehistoric activity occurred. The composite stratigraphy spanning Lums Pond with Unit designations is as follows (youngest to oldest):

1) Contemporary soil (all surfaces) (Recent);
2a) Historic sandy alluvium (T-0, footslope surfaces) (Recent);
2b) Historic slopewash: fine sands and silts (midslope and footslope) (19th and 20th century);
3a) Prehistoric alluvium and fluvial sands (T-0 only) (Middle-Late Holocene);
3b) Prehistoric aeolian sands capped by paleosol (midslope and crest) (Early-Middle Holocene);
4) Columbia Formation gravels and sands (all landscape segments).

It is stressed that master lithologic units are not necessarily chronologically equivalent to master soil horizon counterparts. This is because a soil weathering profile must be evaluated independently of its broader geological contexts. This is especially true for Lithologic Units 2a and 3a where successive soils (or "sequaa") formed on intermittently laid down stream deposits (see Buol et al. 1987). In such situations the soil chronology is relative, recording changes specific to the pedon or locus specific soil body, while the lithologic unit is indexed directly to larger scale changes in sedimentary and hydrographic environments.

*Landscape Chronology*

Landscape chronology refers to the overall temporal zonation of landscape segments. During survey and testing it was recognized that three generic artifact-landscape associations were represented by the three investigation Areas. At this stage of the study, relative ages of the landforms were hypothesized on the strength of artifact assemblages, degree of soil development and maturity, and stratification and pedogenic features of alluvial soils. These relations are illustrated in Figure 76. Observations may be summarized as follows:

1) *Area 1.* Landscape segment is the crest of the interfluve. This is the oldest portion of the landscape. Archaeological assemblages are preserved in "Ap" horizon extending to "E" and uppermost "Bt" horizons. Landform is the highest and oldest Pleistocene remnant of the

interfluve underlain by Columbia Formation gravels at depths of 2m. >1m comprised of weathered aeolian sediments.

2) *Area 2.* Landscape segment is the midslope of the interfluve. Aeolian sands cap the sequence and are of probable middle Holocene age. Intact Woodland I activity areas were recognized as dispersed and superposed features within an exhumed "Bt" horizon. The epipedon has been stripped by accelerated hillslope retreat over the course of the later Holocene.

3) *Area 3.* Landscape segment is the active floodplain (T-0) which has been active since the middle Holocene. Clusters of prehistoric artifacts ranging from Archaic through all Woodland phases are contained in thin, laterally extensive, variably textured accumulations of alluvium (clay-silts to coarse sandy loams). Discrete features are not common but shallow stratification (±0.75 m) of dense assemblages isolates activity areas, only minimally disturbed by limited alluviation; in some cases it is possible that overlying and/or adjacent activity areas are superposed onto one another (palimpsests). Dominant assemblages are Woodland I.

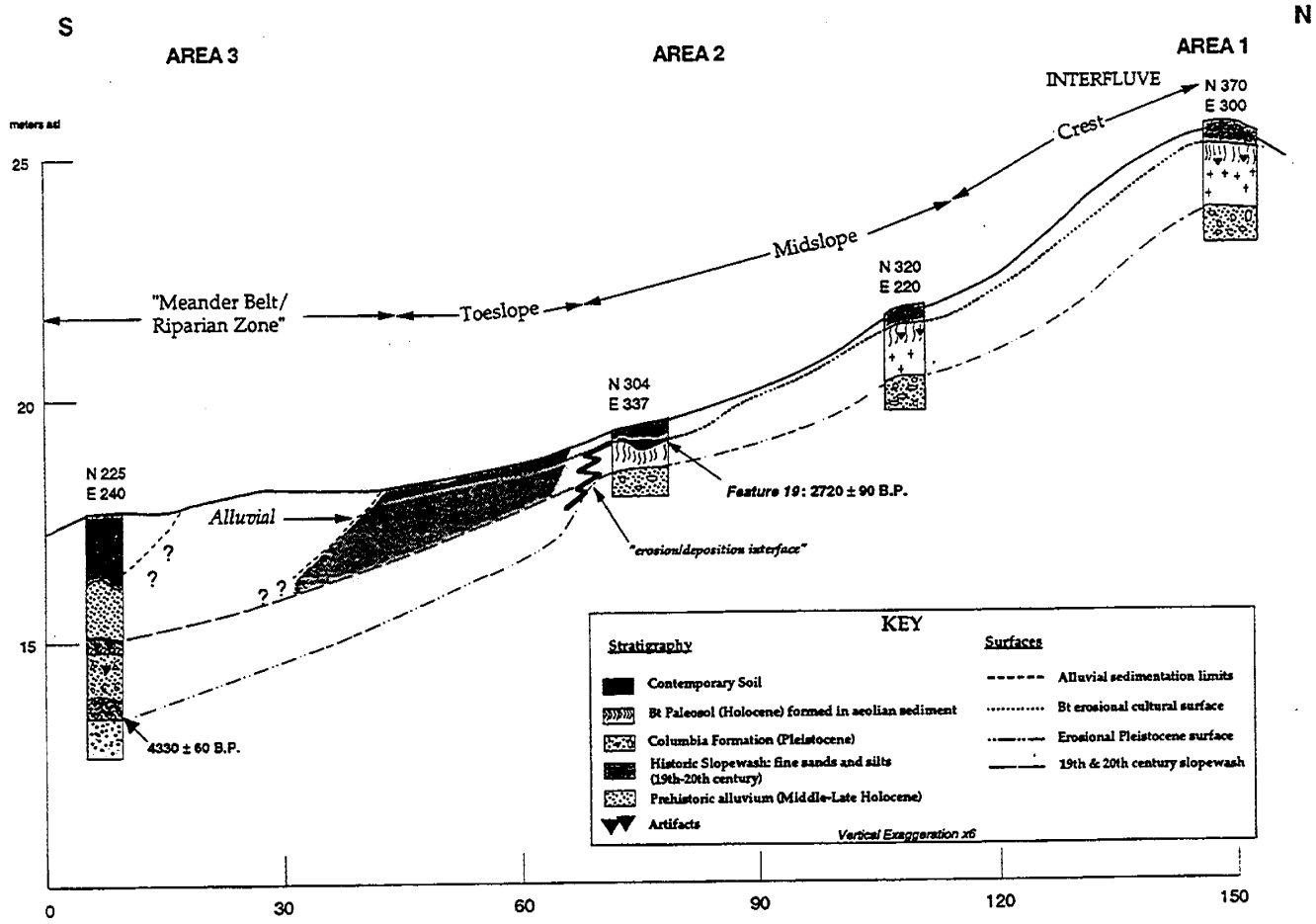


Figure 76. Landscape Segmentation and Chronology

In Area 1 preservation contexts have been somewhat compromised by plowing (in the "Ap"), although mobilization of artifact clusters is minimal. In Area 2 subsurface preservation is optimal and is a function of ongoing pedogenesis and the "upbuilding" of the Argillic ("Bt") soil horizon. The thickness of the solum increases directly with rising elevation and achieves maximum expression in the higher portions of the midslope. Features are sealed within the "Bt" because of ongoing soil formation that tends to impede erosion and seal in the in situ assemblage. In Area 3 artifacts are stored in the lower terrain of the meander belt of the active stream (T-0). Buried azonal profiles were recognized that featured two buried "A horizons", a lowermost that was gleyed ("3Ag") and an uppermost that offset the historic 19th century surface. The prehistoric floodplain is of mid-Holocene age, based on the earliest assemblages and dates represented (although see discussion on potential contamination of organics by groundwater).

The above discussion converges around complex relationships between landscape antiquity, topography, dynamism of sedimentary environments and preservation gradients. Older segments of the landscape are expectedly the least dynamic and likely to have sealed in the best preserved archaeological complexes (i.e., Area 2). More dynamic environments--the floodplain--are both lower and more unstable, thus less likely to maintain primary artifact configurations. Significantly, this trend contrasts with preservation potentials in higher order floodplains where deeper vertical sequences are more likely to seal in evidence of more protracted occupation. Lums Pond is one of the few examples of a low order stream environment that has stored a stratified prehistoric sequence in thin deposits; stream energy was perhaps sufficiently strong to mobilize artifacts locally, but not of such a magnitude to account for whole scale displacement. As shown, the processes and vectors affecting floodplain occupation and archaeological preservation are dictated exclusively by the dimensions of the meander belt. Accordingly, patterns of occupation, archaeological stratification and site formation reflect the geomorphic agencies particular to each of the three investigated areas. This is one of the few sites where sets of site formation processes can be isolated on a micro-environmental scale, delimited by the constraints of a clearly defined geomorphic context.

Figure 77 illustrates the landscape segmentation and chronology of Lums Pond. The figure emphasizes the discrete preservation and landscape settings of each Area. Most notably, the midslope of the interfluve contains the most intact prehistoric features which are excavated into the firm Early Holocene paleosol (Argillic "Bt" horizon). The toeslope marks the concavity of the slope where eroded and retransported slope sediments have accumulated (Figure 76: "erosion to deposition interface"); the onset of erosion has been dated to the latter 19th century. Finally, the meander belt of the T-0 in Area 3 has stored the

only stratified Archaic through Woodland period deposits, some of which may represent periodic occupations of the floodplain.

The aforementioned landscape, occupation, and preservation gradients established guidelines for more refined interpretation of site chronology and formation process. The reconstruction begins with a detailed resolution of the stratigraphic record.

*General Site Stratigraphy*

Figures 77 and 78 present the composite stratigraphy at Lums Pond keyed to the gross Lithologic Unit chronology and near surface sediment cover. Figure 77 is a transect across Block A of Area 3 and was selected because it contains each Lithologic Unit and illustrates facies changes and vertical and lateral breaks in sedimentation. Figure 77 highlights the complexities of the near channel environment and the need for examining the

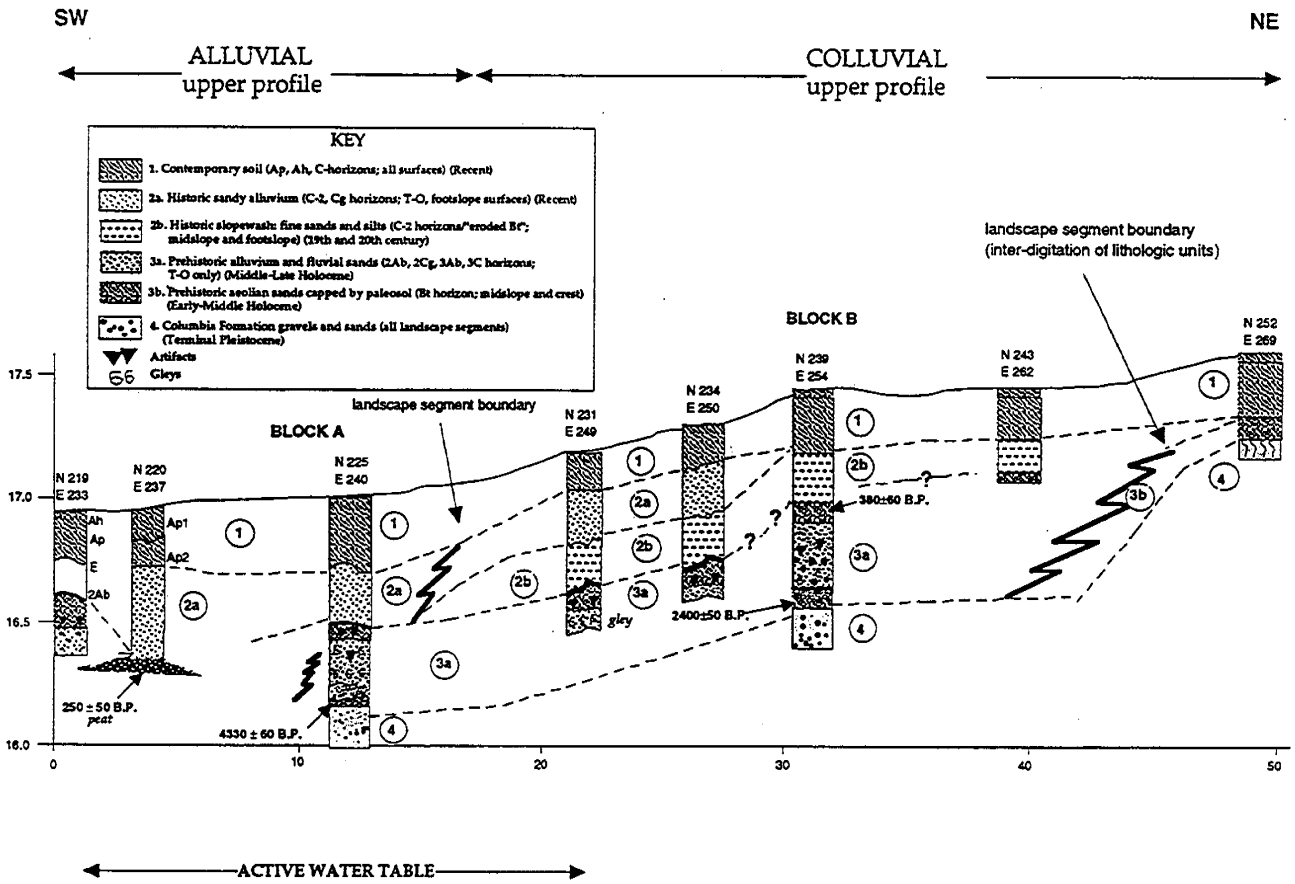


Figure 77. General Stratigraphy across Area 3

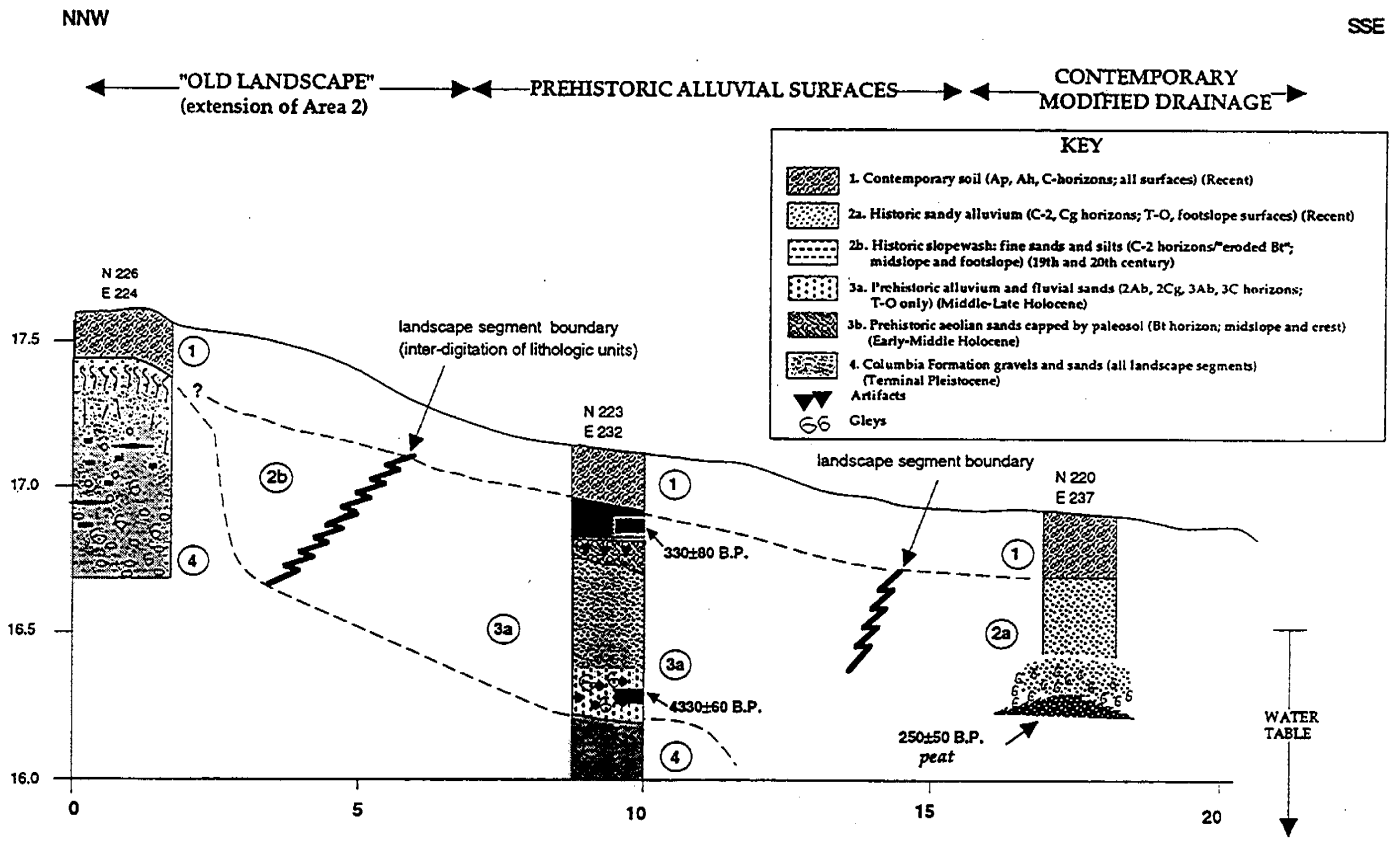


Figure 78. Detailed Stratigraphy across Block A, Area 3

archaeological contexts in terms of the contemporary hydrography. Figure 77 shows that there are three major landscape elements across the T-0 alone: the contemporary modified drainage; the prehistoric alluvial surfaces (antiquity verified by radiocarbon dates as well as artifact assemblages); and an older landscape segment, an eroded outcrop of the Columbia Formation.

Figure 76 supplements the stratigraphic section because it illustrates the broader range of geomorphic processes accounting for surface sedimentation in Areas 1 and 2 which

are not as stratigraphically complex as the floodplain (T-0) segments. Figure 76 isolates the critical erosional to depositional interface at the margin of the midslope which has resulted in the buried channel and floodplain environment and the exposure of the complex of features on the midslope of the interfluve. Perhaps even more significantly, Figure 76 illustrates how the colluvial mantle (i.e., slopewash) effectively melded the surface grade across the site as the landscape was recontoured in historic times. As noted, this process was accelerated over the past 200 years because of land clearance and agricultural overuse. Contemporary landform construction is exclusively a function of slopewash along the northern end of the site and alluviation along the narrow axis of flooding to the south. Beneath the Contemporary Soil (Unit 1), the variability in historic sedimentation is registered either by stream discharge (Unit 2a) or by colluviation (Unit 2b). Ten year and cyclical bankfull floods have resulted in overbanking to levels approaching 17.0 m as an upper limit (Figure 77). Prehistoric deposits are encountered beneath either Units 1 or 2.

Facies changes and soil horizonation are unique to the interfluve and alluvial landscapes (Figures 77 and 78) and reflect lateral variability in sedimentation, soil formation, erosion, and hydromorphism. Groundwater podsolization (in the sense of Hunt 1986) is most dominant in the southern area, in the vicinity of the floodbelt and disappears 40 m north of the stream bank. Prehistoric archaeological deposits are housed exclusively in Units 3a and 3b, the former along the stream bank and the latter on the interfluve. The following descriptions summarize key structural, textural, and soil properties or the Lithological Units stressing their unique dispositions and landform correlations (refer to Figures 77 and 78).

**Lithologic Unit 1** **Landscape Segments: All** **Age: Recent**

The uppermost sediments represent variable thicknesses of surface deposit that have been farmed and widely redistributed by mechanical equipment and soil stripping over the past 200 years. Historic records suggest that forest clearing accounts for much of the disturbance across the interfluve, while farming was dominant across lower surfaces from the T-0 to the toeslope. The matrix is coarser and structures are more massive on the interfluve while weak subangular blocky peds are characteristic of the epipedon on the low-lying terrain. Dominant colors are 10YR4/3 and 4/4. The most intact solum is preserved on the T-0 and toeslope where "Ap1/Ah-Ap2-C1-C2" profiles extend to depths of 0.5 m. "C-horizons" on the T-0 consist of moderately well sorted sandy loams of alluvial origin. Crest locations have aeolian parent materials that are extremely well sorted in the medium sand range in sandy loam to loam texture grades. On the crest "Ap-E" profiles are typical, while midslope locations consist of exhumed "EC" horizons and eroded tops of the "Bt" of underlying Unit 3b. The eluvial horizon ("E") is deepest along the crest and indicates localized podsolization and forest growth in historic times. The convexities of the toeslopes have accumulated poorly sorted fine sands, silts and clays interdigited with historic artifacts and debris. Base of the unit unconformably overlies the historic alluvium (Unit 2a) on the floodplain. Artifacts on the interfluve crest are diffusely distributed within

the matrix and range from historic to Woodland I. On the midslope assemblages of the Woodland period are formally associated with Lithological Unit 3b (see discussion below). There are no prehistoric artifacts south of the midslope in Unit 1. On the crest, patterned clusters of artifacts signify limited mobilization and redistribution within the loci of primary occupance. Distributions are increasingly diffuse along the midslope because of slope transport.

The base of the "Ap" generally follows present surface contours with the exception of a thickening to the base of the concavity of the toeslope. This suggests that even over the past 50 years erosion of the slopes has muted the interfluve-bottomlands relief. Typically "Ap" textures on the distal portion of the floodplain (i.e., Area B) are 5-10% finer than on the slopes because of combined contributions of suspended load discharge and settling of hillslope fines at the toeslope. On the T-0, "Ap" thicknesses are 1-2 times thicker than on the crest and midslope. On the crest and midslopes the "Ap" seals in artifact distributions and features.

No radiocarbon dates were obtained from Lithologic Unit 1 because of its plow zone context. Heterogeneous composition of the sediment is indicative of multiple primary orgins (alluvial and aeolian depending on elevation) coupled with reworking of hillslope matrix because of recent plowing and clearing.

**Lithologic Unit 2a** **Landscape Segment: T-0, footslope** **Age: Recent**

Sediments consist of between 1.0 and 0.1 meters of loamy to sandy alluvium whose thickness diminishes from the proximal (near channel) to distal segments of the T-0 (Figure 77). Sediment package disappears at the midslope, since it represents the maximum encroachment of discharge from the active stream. Soil horizons are "C" and "2Cg" with the latter more pervasive at depths of >1 m and restricted to the T-0. Unit 2a terminates at the interface between the prehistoric and historic strata and landscape segments (at soil horizon "2Ab" and lithologic unit "3a"). The deepest deposits are the channel fill and peats centered in excavation units N220 E237 where the historic stream has bisected the prehistoric surfaces.

Sediment composition within the parent materials ("C" horizons) is most variable of any Unit in the sequence with colors ranging from 7.5YR5/4 and 6/8 to 10YR4/4 and even N/7 in gley pockets. The rubefied matrices (i.e., 7.5 YR hues) represent redeposited Columbia Formation sediment while 10YR hues signifies older bedload and alluvium mobilized along the antecedent axis of the present stream. Textures are clay silts to well sorted silts to sands and gravels along the channel margins. The latter are bedload deposits. Included within the sediment complex are historic peats and sands that preview present anaerobic conditions and the groundwater podsolization that is registered in the prehistoric soil and sediment of Unit 3a. Gleys immediately underlie the peats and include ferric and manganiferous concretions. Gleys incorporate plinthite and and glaebules and parent sands are micaceous. Matrix structure is massive along the near channel. Ellipsoid shaped gravels, moderately pitted and well rounded to tabular, entrain the peats and occur as lenticular wedges in the near channel context. Parent sands are all strongly organic and can be considered histic (USDA 1994) at depths >1.5 m immediately above sediments of

prehistoric age. Along the slope, matrix consistence is slightly firmer and structures range to weak subangular blocky.

The base of Lithologic Unit 2a was difficult to isolate because it dips steeply in the channel bed and margins of the T-0. For present purposes stratigraphic separation was the top of the "2Ab" horizon of Unit 3a, since that soil demarcates the buried soil of the contact or terminal Woodland occupation. Isolated artifacts occur in the matrix, but these were mobilized from their primary contexts in underlying levels, probably by winnowing and receding floodwaters. Figure 78 shows that the contours of the landscape were considerably modified by the channel geometry and depositional regimen of the historic stream. An average of 0.5 m of sands and silty sands collectively contributed by stream discharge and alluvium (Unit 2a) and historic slope runoff (Unit 2b) account for the levelling of the surfaces between Areas 2 and 3, effectively doubling the relief between the former interfluve and the floodplain.

While it is difficult to pinpoint the initiation of contemporary stream activity, preliminary indications are provided by a single determination procured from the peats in the channel trough of excavation unit N220 E237. The determination of 250±60 BP is consistent with historic records that document intensive land use--presumably land reclamation accompanied by extensive slope stripping--by the beginning of the nineteenth century (Hoseth et al. 1994). Removal of the vegetation covers would account for the increased sediment load carried by the stream and more frequent episodes of bankfull discharge with time, as is evident by the widening belt of the floodplain.

**Lithologic Unit 2b Landscape Segment: Midslope, footslope Age: 19th and 20th century**

The deposition is maximally expressed along the footslope and consists primarily of silts and clays derived from slope runoff. The source sediment is the eroded cap of the Argillic horizon ("Bt" horizon; lithologic unit 3b ) of the midslope of the interfluve. The lateral extent of the sediment distribution is ca. 40 m. Accumulations thicken to 0.4 m with steepening slope in the direction of the stream and they interfinger with the alluvial sediments (Unit 2a) at the T-0/footslope transition.

Sediments are typically 10YR 4/4 silty medium sands with diffuse distributions of subangular gravels; structures are weak, subangular blocky to granular and matrices incorporate abundant organics and pedotubular infillings. Heterogeneous ped structures, variable consistence extensive root networks and irregular pore networks are evidence of retransport and disaggregation of primary peds (downslope). Sedimentological analysis demonstrates 5-10% enrichment of fines (silts and clays) from overlying and underlying horizons. This obviates *in situ* weathering as the agency of particle size transformation and is consistent with the argillic paleosol origins on the midslope of the interfluve. Only isolated prehistoric artifacts are entrained in the matrix and these are derived from mid-slope contexts and are secondarily transported. While matrix consistence is heterogeneous and vary considerably from location to location, the colors and textures are remarkably uniform, signifying penecontemporaneous erosion of the midslope, perhaps during a limited time frame and when massive clearance was performed across the landscape.

No radiocarbon dates were obtained from Lithologic Unit 2b since the colluvial origins of the sediment were apparent from initial mapping and identifications of this historic facies. Age of the sediment co-incides with the acceleration of slope erosion in the Lums Pond area between 200-300 years ago. Downslope thickening of the accumulation represents intensification of slope stripping of the past few decades.

**Lithologic Unit 3a** **Landscape Segment: T-0** **Age: Middle-Late Holocene**

Sediments consist of average 0.5 meter accumulations of silty sands to silty clay sands. The sand fraction ranges from 60-80% and clays rarely exceed 10% of total grain size population. Soil horizons include"2Ab-2AC-2Cg-2Cgox-3Ab(g)-3C" profiles. Two generations of soil were included in the lithologic unit because the change in parent materials--texturally and structurally--was minimal. Fining upward sequences indicative of a meandering stream regimen was preserved in both sola and the composite thickness of the alluvium was less than 0.8 m. This is the only prehistoric sediment package on the floodplain (T-0) and its lateral disposition varies between proximal and distal portions of the landform, sloping as much as 7° streamward between block B to Block A. Soil Horizon "2Ab" offsets Unit 3a from the overlying historic alluvium (2a) pedomorphically and radiometrically; the boundary between the two is sharp and abrupt and radiocarbon dates place the "2Ab" at between 300-500 BP. The horizon is uniform colorimetrically and texturally (10YR3/1 to 3/2; silty sand to silty clay sand). Both laterally and vertically stratified artifact assemblages ranging from Early Archaic to Woodland II are preserved within and below it.

Because the unit registers both fluvial and alluvial sedimentation modes--incorporating bedload and suspended load contributions from a formerly migrating channel flow--weak bedding structures can be detected in the substrate. These have been overprinted by bands of plinthites and segregated gleyed concretions. The "2Ab" registers the top of the groundwater podsol, a band of organics that has been mobile (initally above the "2Ab") and subsequently settled at the level of the uppermost artifact concentration; it is presumed that the artifact horizon and the dates are generally contemporaneous (see discussion below). The parent materials are typically well sorted below the "2Ab" and are progressively sandier and coarser with depth. Small gravels are dominant beneath depths of 1.2 m and the relative quartz compositon of the sand diminishes from 85% to 70%, with exotics increasing in frequency. Gravels are weakly to moderately imbricated. Colors of dominant matrix range from 10YR6/4 to N/7 (similar range to Lithologic Unit 2a) to 7.5YR 6/8 at the contact with the Columbia Formation (Unit 4). Isolated lamellae bands and plinthite distributions were noted near the outer margins of the T-0 in Block B. Artifact rich deposits wedge out eastward to the footslope which may have been a seasonally inundated swale.

Anthropogenic sediments occur in all horizons below the "2Ab". However, gleization has masked discrete occupation floors and surface breaks. It is probable that palimpsests of cultural residues and features span what may formerly have been more clearly differentiated surfaces. Prehistoric sediments are chiefly recognized by concentrations of artifacts since the extensive leaching of former organic and incipient weathering (i.e., "Bw") horizons has been completely obscured by oscillating groundwater

levels. Matrices of artifact dense deposits are typically granular to weakly subangular blocky silty sands of soft consistence; they are moderately cohesive (i.e., above water table) with abundant organic inclusions and films consolidating peds. Poorly oxygenated silts and clays ("Cg" horizons) are often linked to artifact horizons, attesting to post-occupational gleization.

The archaeological deposits were bracketed between two buried "A-horizons: the "2Ab" and the "3Ab". These were separated by between 0.3-0.4 m of generally sandy sediment and contained diagnostic artifacts spanning 5,000-6,000 years. In general artifacts tended to cluster at levels encroaching upward to the "2Ab" than below it. The inordinately low sedimentation rates (i.e., 0.7 cm/century), coarse mean grain sizes (>1Ø) argues strongly for dominantly lateral accretion and for mobilization of artifact assemblage within the margins of the meander belt. The fact that the densest artifact concentrations on the T-0 were in Block A, despite lower surface elevations and proximity to the present flooding axis confirm that prehistoric stream behavior did not conform to present channel geometry.

The floodplain may have been characterised by ridge and swale topography consistent with the postulated lateral accretion regimen. It is possible that occupations occurred on point bars within the flood belt. This is in line with observations of weak foreset beds below the "2Ab". Throughout Unit 3a stream sands probably accumulated as classic "top stratum" suspended load fines (Brakenridge 1988; Friedman and Sanders 1978), laid down by the meandering stream. It follows that horizons "2Ab" and "3Ab" represent the meta-stable soils (Entisols with "A-C" profiles) evolved on the margins of the stream when the channel flowed around the elevated prehistoric surfaces.

The aforementioned observations are bolstered by a battery of elevent (11) radiocarbon determinations obtained from T-0 contexts and attendant prehistoric loci. Four (4) of these were performed on humic fractions, two each from horizon "2Ab" and "3Ab". The "2Ab" dated to 330±80 BP (Beta-92101) and 380±60 BP (Beta-92102) while the "3Ab" determinations were 4330±60 BP (Beta-92099) and 2400±50 BP (Beta-92100). The "2Ab" dates are consistent stratigraphically, topographically and correlate with each other, marking the end of the stabilized prehistoric landscape prior to the inauguration of slope degradation by Euro-Americans. Further, these dates appear to converge with archaeological determinations in excavation Layer "C" (and perhaps "D1") that are bracketed between 400 and 700 BP. However, the "3Ab" dates range fall within a 2,000 year window of the upper Middle to Late Holocene. Significantly, archaeological dates in excavation Layer "D" range between 6400-3200 BP and with the exception of a single possible outlier (6350±60 BP; Beta-88108) they cluster in the 3000-3500 BP range. These dates are also consistent with a stablization interval between 4000 and 2000 BP. Additionally, topo-stratigraphic incongruities may be accommodated by the postulated ridge and swale landform reconstruction. The ramifications of the chrono-stratigraphy are discussed in greater detail below.

**Lithologic Unit 3b Landscape Segment: Midslope and Crest Age: Early-Middle Holocene**

This unit is associated exclusively with Area 2 and the developed Argillic soil on the interfluve crest and midslope. Aeolian origins were attributed to the parent material

overying the paleosol because of the absence of coarse clastics in the sediment matrix, slightly better sorting, and observation of southwest to northeast wind regimes. Sorting gradients are not highly variable in unmodified parent materials across the project terrain because of the dominance of medium sands (ca. 40% of grain size population in 2Ø size grade) in the upper Columbia Formation. Intact epipedons are preserved as "(Ap)-E-Bt1-Bt2-Bt3" profiles that may be up to 0.7 m in depth on the crest, but diminish to 0.4-0.5 m on the midslope with "E" horizons thinner and truncated. The "Bt3" grades into the Columbia Formation (Lithologic Unit 4) which is offset by coarser, gravel enriched parent matrix and 7.5YR5/8. Colors of the upper "Bt" are slightly less rubefied at 7.5 YR5/6. Ped structures range from coarse subangular blocky to medium prismatic and the horizon is up to 0.8 m thick. Argillic development is recognized by structural firmness, consistence, continuous cutans (i.e., clay skins), high plasticity, and enrichment (i.e., translocation) of clays which increase by ca. 10% from overlying "E" horizons. Micropore networks are extensive and micro-organics were identified at many exposures. Along the mid-slope surfaces have been exhumed but recent soil development (over the past 200 years) is creating incipient bi-sequal profiles (i.e., "Ap-E-Bw-E'-Bt").

Investigations reveal that this soil is effectively cumulative (see Birkeland 1984; Ferring 1992) in that the B-horizon evolved in conjunction with active, albetin intermittent, deposition. At various times during the Holocene the soil mantle was stripped, as evidenced by the thin veneer blanketing the "Bt" on the mid-slope and the incorporation of artifacts of a variety of ages within the solum to depths up to and including the "Bt2". These may have been displaced by vertical mobilization through structural cracks, but the lateral dispersal of artifacts to depth and in non-feature contexts suggests "overprinting" during the Holocene as successive populations re-occupied the landscape.

Generally, lithologic Unit 3b preserves the most intact prehistoric assemblage across the project area, maintaining a broad array of feature types whose morphologies are largely intact. Indications are that these activity areas were utilized at a time when a stable surface existed along the slope convexity; slope morphology was clearly different from that of the present. Significantly, however, the cumulative soil was forming as the surfaces along the mid-slope were occupied. As the landscape was constructed, incrementally through variable contributions of aeolian material, the "Bt" was "upbuilding". Highest concentrations of artifacts and features (n=10) are centered in the vicinity of N320 E290 and N300 E340. These proveniences correspond with occupations dated to the Woodland I period and stratigraphic contexts linked to the upper 20 cm of the "E-Bt1" soil horizons. Clay enrichment of the "Bt" in the vicinity of N319 E294 is lower than at other equivalent non-occupied pedogenic horizons sampled (i.e., 17% vs, average of 25% clays), suggesting that disruption of the matrix may have been a function of extensive human activity.

Areas 1 and 2 are the oldest segment of the landscape. This was initially indicated by the expression and maturity of the Argillic soil, which has been estimated to form between 2,000 and 12,000 years in the Middle Atlantic area (Bilzi and Ciolkosz 1977). The antiquity of the landscape was verified further by a borehole excavated along the eastern slope of Area 2 grading into the marsh basin. At a depth of 0.95 m humic clays immediately overlying gravelly sands of the Columbia Formation a determination of 10,710±80 BP (Beta-92103) may date the initiation of Holocene fluvial activity in the project area; however, more detailed investigations of the early Holocene stratigraphy were not undertaken. In all, a total of eight (8) radiocarbon determinations were obtained from

the midslope portion of Area 2. With the exception of the early Holocene humic specimen, all samples were taken from prehistoric features and dates ranged from ca. 800-2800 BP; the majority converged in the 2600-3000 BP time frame and point to extensive human activity, and optimal occupational environments, during Woodland I times.

**Lithologic Unit 4 Landscape Segment: All Age: Terminal Pleistocene**

This unit is the Columbia Formation, the most pervasive subsurface deposit across the landscape which marks the Pleistocene-Holocene interface. Depths to the upper contact from surrface range from between 0.4 and 1.5 m on the T-0 to 0.2 and 1.0 on the interefluves. As noted, the Columbia Formation in northern Delaware has been classed a fluvial facies and near surface outcrops are weathered (Spoljaric 1967, 1972; Woodruff 1986). Stratigraphic relations demonstrated a broad range of facies types ranging from well sorted coarse white sands near the base of the contemporary drainage (7.5 YR7/1) to clast supported silts and clays, to coarser gravels signifying high discharge environments. Typically, however, the dominant facies is a 7.5 YR5/6 to 7.5YR 5/8 weathered gravelly sand, strongly to weakly indurated. Along the floodplain this corresponds to an eroded Pleistocene paleosol, an outcrop of which is exposed within 20 cm of the surface in the vicinity of N226 E224, immediately north and west of Block A in Area 3.

Artifacts may be preserved in the upper levels of the Columbia Formation along the T-0. On the interfluves (Areas 1 and 2) the Argillic paleosol formed on deflated surfaces of the Columbia. However, the Holocene soil is sufficiently thick that even downward displacement of cultural materials from these contexts would not have reached levels of Lithologic Unit 4. On the T-0 it is possible that artifact clusters in Block A may be in near primary context on eroded surfaces of the Columbia Formation, because of the very thin veneer of alluvium that caps the formation (see Figure 78). No sediments of the unit were radiometrically dated.

*Sedimentology and Geochemistry*

One of the objectives in performing detailed sedimentological and geochemical analysis was to establish anthropogenic contributions to the parent sediment or soil matrix. Since cultural inputs were apparent in Area 2--they consisted of excavation of storage facilities and preparatation areas (i.e., features)--there was no need to sample columns on the interfluve. Cultural sedimentation was considerably more complex on the floodplain tracts of Area 3, where subtle artifact clusters interdigited with alluvium both laterally and vertically. Column sampling here would articulate changes in the matrix that might differentiate stable surfaces, modifications in the alluviation regime, and introduction of cultural residues to the matrix.

In Area 3, facies changes within Units 1, 2a, and 3a were often difficult to recognize because of subtle lateral boundary transitions (Figures 77 and 78). As noted, groundwater fluctuations also imparted sediment and chemical additions to the matrix, chiefly redox

staining and silt-clay contributions, that skewed primary depositional matrices. In the field observations of hydromorphic features were made to guide sampling and to facilitate *post hoc* interpretations of results. Cultural sediments on the T-0 were often obscured by the lensing and lateral facies changes within Units 2a and 3a. This was especially critical since water table movements and groundwater podsolization may have masked older aerobic humic surfaces that were subsequently reduced and "blackened" by settling of organic fines. These could have obscured features or archaeo-sedimentary boundaries. To assess the texture and chemical composition of cultural sediments, anthropogenic or organic horizons were sampled when cultural "signatures", chiefly in the form of dense artifact distributions, were apparent.

Results of the soil and sediment analysis for two site stratigraphic columns are illustrated in Figures 79 and 80 (refer to Figure 77 for general provenience). Proveniences were selected as representative of the patterns of sedimentation, weathering (albeit limited), and gleization (waterlogging). Column 1 (Figure 79) was taken in Block A of Area 3 at N228 E243. It is representative the lower T-0 elevations (below 17 m) and includes sediments of the stream bank flanking the most recently incised channel trench. Lithologic Units 1-2a-3a and artifact assemblages from historic through Woodland I/Archaic transition are contained within the column. Column 2 (Figure 80) records sedimentation along the upper, slightly better drained margins of the T-0 in Block B (N238 E257) above 17 m. It preserves evidence for lateral facies variation as well as the colluvial sediment contributions from the hillslope; Units 1-2a-2b-3a were sampled in this column. Artifact concentrations span a broader time frame and include artifacts of Archaic period affinity. These appear to be reworked specimens perhaps derived from an older, relict segment of the landscape. This location occupies the distal portion of the floodplain and thinner accumulations of historic discharge (Unit 2a). In all columns anthropogenic residues are confined to the upper horizons (below soil horizon "2Ab" Lithologic Unit 2a). Critically, all strata register the patterns of alluviation and accretion linked to the the last 5,000 years of flooding activity. They are critical to understanding changing patterns of flow and discharge for the Middle to Late Holocene.

The columns are organized to depict vertical changes in the stratigraphy for three discrete data sets. The first presents the depositional sequence and soil horizons grouped by Lithologic Unit. Radiometric dates are plotted to index the chronology; they may be taken from adjacent excavation units but equivalent strata. Immediately to the right the documented archaeological components are identified. The second set of data consists of the particle size distribution (granulometry) characterized by relative percentages (by weight) for three fractions: sands (<4Ø), silts (<8Ø), and clays (>8Ø). Values for grain size parameters of mean size (Mz), sorting (So), skewness (Sk), and kurtosis (Kg) are also presented. The third data set includes geochemical plots for pH, organic matter (OM), calcium carbonate ($CaCO_3$), phosphorous (P), iron (Fe), and manganese (Mn). For the trace

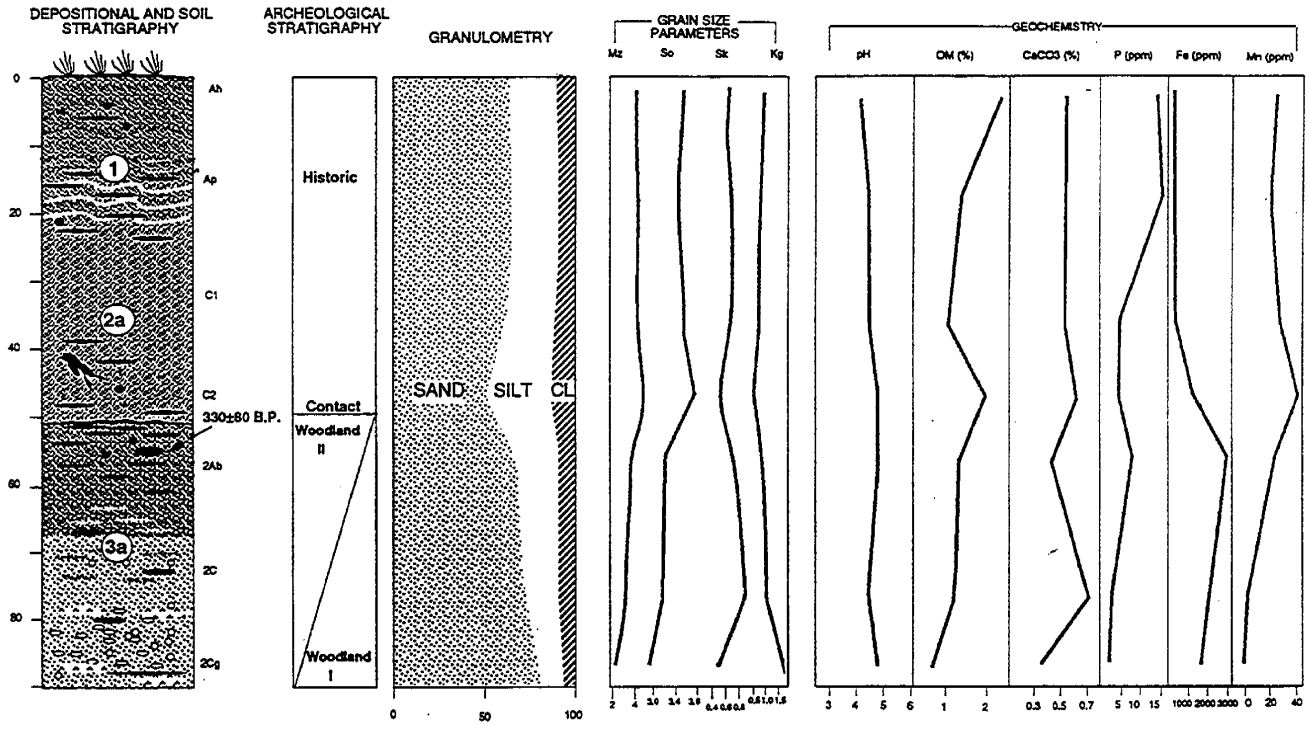


Figure 79. Stratigraphy, Sedimentology and Geochemistry of Block A, Area 3, N228 E243

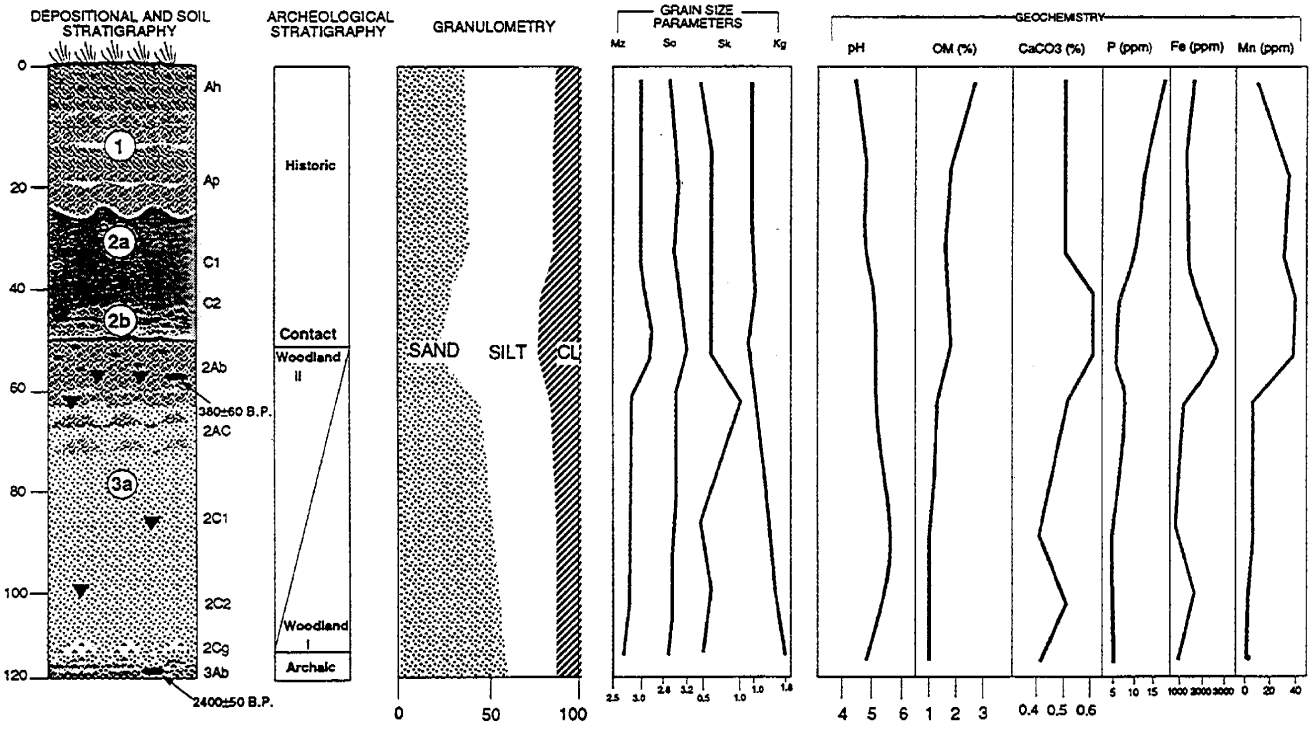


Figure 80. Stratigraphy, Sedimentology and Geochemistry, Block B, Area 3, N238 E257

elements (P, Fe, and Mn) concentrations are plotted in parts per million (ppm).

Beginning with Column 1, long term trends in alluviation history, soil formation, and site occupation are encapsulated in the 0.8 to 1.1 m sequence across the T-0. Comparisons of the alluvial textures from near channel and distal floodplain segments (Blocks A and B respectively), show that alluviation trends were largely consistent at this location over the past 5,000 years. There are significant changes in the particle size distribution with depth as discussed below, but the sand fraction accounts for 45-55% of the alluvial sediment population for the general depth of the column. The medium sand size grade is dominant (40-50% of total sand fraction at most depths). The critical exception is the contact between the prehistoric and historic alluvial fills. The stratigraphic break in both columns occurs at the level of soil horizon "2Ab" where clay and silt concentrations increase by 20%. Expectedly, the sand population is proportionately higher (by 15-20%) in the near channel location (Block A), reflecting the higher energy discharge environment adjacent to the stream trench.

Equally critical is the fining upward sequence represented in Lithologic Unit 3a for both Area A and B. The base of the unit at each location is 20% richer in sands than the top of the unit; this is reflected in the Mz values which are larger on the order of 1.2Ø. Degree of sorting diminishes up the sequence as well, again consistent with the fining upward trend and confirming a more competent discharge regime early in the succession. Skewness values are more irregular and oscillate between 0.4 and 0.7 in Lithologic Unit 3a, perhaps reflecting either settling of fines in the matrix or entrainment of pockets of silt either due to waterlogging and eddying; these could be syn-depositional or post-depositional phenomena. The granulomteric signatures and grain size parameters conform to the postulated point bar microenvironment in which higher, episodic aggradations of bedload account for buildup of the channel margin landform throughout the prehistoric period. More uniform grain size distributions characterise the upper portions of each column. Accordingly, Block A features a 65-25-10 ratio of sands-silts-clays and Block B ratios are 40-45-15 near the top (above soil horizon C2; Figure 79, 80). All grain size parameters are uniform and unwaverying with depth for the upper portions of the columns. In both Areas A and B, these trends are coeval. They demarcate a dramatic transition to suspended loads in the upper depositional regime which reflects the dominance of overbanking of the historic alluvium (Units 1 and 2a) and the silt rich contributions of the historic slopewash (Unit 2b) immediately underneath. The granulometric parameters signify a clear break in alluviation patterns between the aboriginal and historic settings of the Lums Pond floodplain.

The granulometric data underscored the different fluvial mechanisms responsible for floodplain construction between the historic and prehistoric periods. These shifts are also mirrored in vertical changes in the geochemical parameters measuring chemical

modification and human input to the alluvial matrix. It is instructive to use the data from column N228 E243 as a baseline for gauging anthropogenic inputs into the alluvial matrix because it is in the vicinity of the densest artifact concentrations on the T-0. In the upper portions of the column, the contemporary soil and historic alluvium (Units 1 and 2a) are expectedly acidic as measured by pH. Organic concentrations diminish gradually with depth confirming the Entisol profile and the transition to the parent material. P values are low but also decline with depth and Fe concentrations are stable, signifying minimal "B horizon" development and confirming the azonal soil environment of the contemporary floodplain. Manganese content is also fairly uniform.

Near the base of Unit 1 Fe, Mn, and OM concentrations increase dramatically, a function of water table activity and mobilization of dissolved Fe and Mn ions. OM increases undoubtedly represent adsorption of humic clays and colloids in gley matrices; these occur at the levels of silt and clay spikes in the column; this is the level at which the depositional environment changes from a lateral accretion regime to one dominated by overbanking and slopewash. These trends are paralleled in Block B and are further highlighted by the discrete geochemical and granulometric signature of Unit 2b (Figure 80), the historic colluvium. On the higher surfaces, fines from the slope were laid down beneath the historic alluvium (Unit 2a). This is registered granulometrically by the 20% surge in silt and clay and underscored by the addition of $CaCO_3$ presumably derived from the slope transported limed and tilled soils that were formerly farmed on the crest. Increases in Fe and Mn may reflect continuous oxidation and reduction of both the slope soils and the historic alluvium at seasonal groundwater levels in soil horizons C1 and C2.

Evidence for cultural residues and modification to the alluvium must be sought in Lithologic Unit 3a. Figure 80 shows peaks in OM, $CaCO_3$, P, Fe, and Mn within a 0.1 band of the trans to the upper prehistoric soil "2Ab". Groundwater movement may explain most of these trends, chiefly the vertical translocation of free ions specifically within the zone of clay and silt enrichment. However, gradually reduction in Fe and Mn do not mirror more dramatic changes in the textural sequence. Sand concentrations increase by nearly 30% to the base of Unit 3a appears to exceed the dilution of the free ions. On the higher surface of Block B (Figure 80: N238 E257), Fe concentrations actually diminish and increase midway down the sequence, while Mn and OM remain consistent low. These data may indicate that while water table activity was a major mechanism in redistribution of minerals, it may also mask incipient soil formation--or emergent "B horizons" in the form of Inceptisols that may have evolved during the later Holocene when water tables were significantly lower than present. The Fe trends in the "2Ab" are consistent with oxidation during pedogenesis (Sidhu et al., 1977). P data do not furnish any compelling evidence for high level cultural activity because of the limited range of total P represented anywhere on the T-0 (<10 ppm) (see Eidt 1977; Anderson and Schuldenrein 1985; Butzer 1982). It is certainly possible that

the groundwater removed P into the permeable sands and gravels of the underlying Columbia Formation (Unit 4).

Geochemical indicators converge around the major transition between Units 2 ("a" and "b") and 3a. To some degree these would appear to measure cultural activity coupled with some masked evidence for limited soil formation. The anthropogenic indicators are largely derived from artifact concentrations, however, and not from geochemical modification. Accordingly, artifact densities begin to rise in excavation levels C1 and C2 in Blocks A and B, conforming to stable soil "2Ab" and radiocarbon dates fix the mean residence time of dated organics to ca. 400 BP. Thus artifact, pedogenic, and radiometric evidence converge around stabilization of surfaces at this time. Underlying horizons are also rich in artifacts, especially in levels D in Block B, but there is minimal evidence for soil formation and the coarsening of the sediment matrix suggests that the earlier occupations may have been more diffuse and linked to a near channel environment (see discussion below).

*Depositional Environments*

Table 32 integrates the depositional, soil, and archaeological sequences for Lums Pond. Reconstructed Middle to Late Holocene histories for three principal landform segments--T-0, and the midslope and crest of the interfluve--are advanced based on converging lines of evidence. These landforms conform to the main excavation areas and the locations where primary archaeological contexts were confirmed. Comprehensive landscape reconstructions cover approximately 5,000 years since the two earlier dates (10,710±80 BP, Beta-92103; 6350±60 BP, Beta-88108) were not obtained from representatively sampled locations and extended beneath depths of archaeological deposits. In Table 32, the primary Lithologic Units are initially identified (Column 1) and tracked across the landscape segments in which they occur (Column 2) by average depth (Column 3). Depths are schematic means only, based on thicknesses of individual Lithologic Units at proveniences most representative of site wide stratification. Column 4 is an inventory of radiocarbon dates, assigning stratigraphic designations to each of twenty (20) determinations; the majority of the dates are from prehistoric Units 3a (n=11; 55%) and 3b (n=8; 40%). Column 5 assigns the cultural component for each Unit, determined from diagnostic artifact assemblages and feature contexts. Column 6 is the composite reconstruction of depositional and soil forming environments synthesized from field mapping, observation, sedimentological and geochemical analysis, and the archaeological and radiocarbon records.

Spatio-temporal relationships between the landforms and Lithologic Units are, perhaps, the most productive means for viewing the evolution of the Holocene occupational

and natural landscapes. Site-wide geomorphic processes accounting for stratification have been presented earlier (Figure 76) and the composite alluvial and slope sequences have been variously depicted (Figures 77 and 78). A three-dimensional rendering emphasizes the variable thicknesses and articulations of the "landscape-artifact" packages in Figure 81. Complex earth surface processes and differential burial of alluvial and aeolian prehistoric loci implicate multiple periods and patterns of site transformation. As shown, unique archaeological contexts at Lums Pond represent interactions of depositional, pedogenic and occupational, and post-occupational variables. For example, point bar landscapes are postulated for much of the earlier prehistoric succesion (Archaic and Woodland I) on the younger alluvial landscapes of the Middle Holocene on the T-0. On the interfluve, 9 m (30 ft.) above the floodline, an Argillic paleosol contains the most intact activity areas at the site. Next, post-occupational signatures vary between the two locations. Along the floodplain a complex regime of waterlogging accounts for transformations of the primary sediments and soils by seasonal gleization; on the interfluve erosion of the paleosol is the process that exposed the site loci while firmness of the argillic clays account for preservation. In reconstructing site history, it is instructive to follow a time-stratigraphic vector that traces the initial depositional contexts from the Pleistocene-Holocene transition to the progressively more complex settings that evolved along the various landscape segments during the Holocene.

The oldest segment of the Late Quaternary landscape at Lums Pond was registered in BH-9 (elevation: ±8 m) on the eastern flanks of Area 2. As noted, a date of 10,170±80 BP was obtained on humified sands within a well sorted sand-gravel complex. While the landform has not been dated, its coarse textures and composition are consistent with basal channel flow over the exhumed surface of the Columbia Formation. Supplementary cores suggested a broad distribution of bedload matrix laid down by a braided stream, perhaps antecedent to the meandering channel identified on the T-0. The Early Holocene date is not incompatible with early evidence for the initial post-glacial hydrographic adjustments along the High Coastal Plain, although more systematic data must be collected to confirm the hypothesis. No formal Lithologic Unit was assigned to this segment, although it may be significant that the oldest archaeological date from the site is derived along the eastern marsh slope only 30 m to the northeast (6350±60 BP; Beta-88108).

The earliest formal stratum overlying the Columbia Formation and the braided sands are the prehistorically dated units on the interfluve (3b) and the T-0 (3a). The catenary transect from floodplain to slope is dramatic, with the passage from a weak floodplain Entisol to an Argillic soil formed either over thin aeolian parent material or, more typically, a coarse fluvial facies of the Columbia sands. If it is assumed that the Argillic horizon of Unit 3b developed between 12,000 and 2,000 years as has been regionally postulated (Bilzi and Ciolkosz 1977), and features dated within a range of 2,500-3,000 years are lodged in the "Bt1" to "Bt2" horizons (see Table 32), it is possible

| Lithologic Units | Soil Stratigraphy by Landform | | | Mean Depth (cm) | Radiocarbon Dates (B.P.) | Cultural Chronology | Depositional and Soil Environments |
|---|---|---|---|---|---|---|---|
| | T-0 | Midslope | Crest | | | | |
| 1 | Ah-Ap-C1-C2 | E-C | Ap-E | 0-30 (T-0)<br>0-20 (Midslope)<br>0-50 (Crest) | NA | Recent | Contemporary soil with contributions from overbank fine sands on T-0; accumulation of silty sands on footslope because of recent landscaping and clearing; agricultural soil (Ap) caps entire landscape, more prominent on near level surfaces below Area 2. |
| 2a | C2-Cg | NA | NA | 30-50 (T-0) | 250±60 | Recent, Historic | Well sorted alluvium of channel and near channel includes silts, sands and gravels; formation of convavo-convex floodplain in past 200 years; episodic high energy floods and formation of historic peats and gleys with seasonally high water table. |
| 2b | NA | C | NA | 20-40 (Midslope) | NA | Historic | Pinkish veneer to slope transported fine sands and silts along footslope; disaggregated, heterogeneous rubefied peds from crest soils ("Bt"); historic artifacts suggestive of accelerated slope erosion over 250 years. |
| 3a | 2Ab-2AC-2Cg-2Cgox-3Ab-3Abg-3C | NA | NA | 50-100 (T-0) | 330±80, 380±60, 400±50, 700±80,("2Ab"); 640±50, 2400±50, 3240±90, 3320±70, 3440±90, 4330±60, 6350±60 ("3Ab") | Historic, Contact, Woodland I and II, Archaic | Fining upward sequence capped by "2Ab"; meandering channelwith lateral accretion deposits; "2Ab" (Entisol?) marks terminal prehistoric occupation, with vertically, laterally discontinuous archeological sequence on point bars; groundwater podsol. |
| 3b | NA | Bt2-Bt3 | E-Bt1-Bt2-Bt3 | 40-90 (Midslope)<br>50-100 (Crest) | 810±60, 1150±90, 2660±100, 2670±90, 2720±90, 2780±60, 2960±60 | Woodland I and II | Argillic paleosol intact on Crest, eroded and exposed on mid-slopes; Woodland features associated with lower "Bt1", upper "Bt2"; eastern segment of landscape registers early Holocene sandy bog. |
| 4 | 4C | C | C | >100 (all segments) | 10,710±80 | NA | Well sorted sands and gravels of Columbia Formation underlies entire landscape; several outcrops feature deeply indurated, weathered profiles; locally a fluvial facies. |

Table 32. Landform Stratigraphy

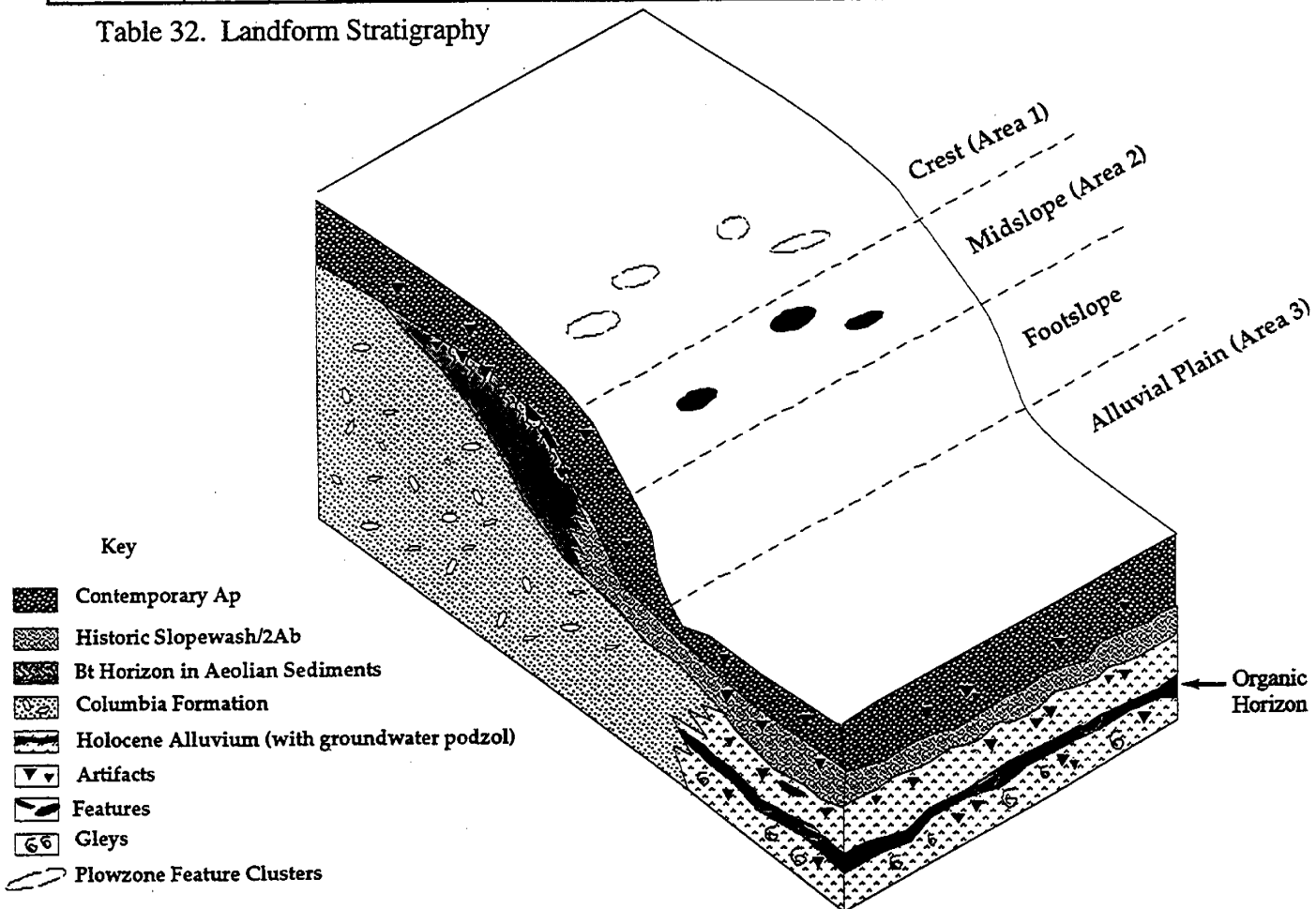


Figure 81. Three Dimensional Rendering of the Lums Pond Landscape

that the age of the mature Argillic soil is on the order of 7,500 years. This would accommodate 4,000-5,000 years for Argillic horizon development. Further, the source of the soil's parent material (deflated sands) may have been concavities along the Middle Holocene floodplain in which finer suspended load silts and sands dropped out along the margins as floodwaters receded, perhaps when the stream regimen passed from a braided to meandering mode.

Confirmation of the initial age of the buried floodplain (Lithologic Unit 3a and soil horizon "3Ab") is potentially problematic. As noted, groundwater podsolization is a major source of mobilization of clays and organic colloids that may be secondarily adsorbed onto surfaces by capillary action, thus either depressing or advancing ages of radiometric samples. Cautionary qualifiers have been advanced by several authors in analogous situations (see Hunt 1986; Nelson 1992). However, in most instances age displacements are on the order of several hundred years (Nelson 1992) and contemporary pre-treatments are able to isolate secondary contaminants (Hood, personal communication).

More significantly, the presence of diagnostic assemblages served as a control for the radiometric determinations at Lums Pond. Earlier Woodland I artifacts were found in the alluvium below the "2Ab" while later Woodland deposits were housed in the "2Ab" itself. Table 32 shows that the radiocarbon age determinations from the general Lithologic Unit (3a) sorted out bimodally, separating deposits contained within the lower soil ("3Ab") and immediately above it from those within the capping and masked Entisol ("2Ab"). This separation also corresponds to a hiatus in the depositional regimen where lateral accretion deposits give way to an overbanking regime characterized by silts and clay accumulation (see Figures 77 and 80). Accordingly, the mean age of archaeological dates associated with the "3Ab", migrating stream, and the Archaic assemblages is 3388 BP. The mean age of the "2Ab", overbanking stream, and Woodland assemblages is 452 BP. Limited numbers of samples, possible contamination, and diverse sources of radiocarbon notwithstanding, the discrepancy in ages between upper and lower portions of Unit 3a is sufficiently pronounced, ca. 3,000 years, to distinguish discrete time-stratigraphic breaks. The dates argue for unique sedimentary environments for the Archaic and Woodland within Unit 3a. Archaic assemblages are stored in the basal portion of the floodplain and are laterally and vertically dispersed across it. Archaic occupation emerged during construction of a floodplain built initially by point bars and then stabilized by lateral accretion. In this regard, it is stressed that Archaic assemblages may vary in elevation across the floodplain because of the irregular contours of point bar topography. This phase of construction probably began around 5,000-6,000 years ago, given the mean age of the radiocarbon dates taken from the lower middle portion of the Lithologic Unit. Woodland occupations appear to be more directly linked with a broader horizontal surface and continuous floodplain at a threshold in the depositional history of the stream when the channel trench was fixed and overbanking

became the dominant depostional mode. At the same time surfaces were more durable and occupation was more extensive.

Lithologic Units 2a and 2b represent the historic alluvial and colluvial sediment packages that overlie Unit 3a unconformably. 2a chronicles bankfull discharge of the contemporary Lums Pond stream and its flood axis extends to the distal portions of the floodplain (Block B; see Figure 77). Unit 2b is a slopewash facies comprised chiefly of transported and disaggregated peds of the 3a Argillic paleosol; it wedges out southward within several meters of the stream bank line. The earliest deposits date to approximately 250 years ago, based on historic records of land clearance on the colonial Lums Pond property (Hoseth et al. 1994; Petraglia and Knepper 1994). Since the mean age from soil horizon "2Ab" is ca. 450 BP (uppermost Unit 3a), there is an interval of approximately 200 years between terminal prehistoric and earliest historic occupation. The transition from limited, perhaps seasonal occupation in the Woodland to intensive colonial and industrial age agriculture left an indelible imprint on the landscape. The exponential overhaul of the tract may be quantified by an estimate of changing sedimentation rates, calibrated by the radiocarbon record for the prehistoric vertical sequence and by written and map records for the historic succession. Excavation units N239 E254 and N225 E240 were used to index sediment thicknesses because they contained all historic and prehistoric units. The following rates are calculated:

| Sequence | Range (yrs BP) | Mean Deposit (m) | Sedimentation |
|---|---|---|---|
| Prehistoric | 5000-450 | 0.45 | ca. 1.0 cm/century |
| Historic | 450-present | 0.45 | ca. 10 cm/century |

The data verify that Euro-American clearance and reclamation strategies account for a sedimentation rate fully ten times that during the aboriginal period.

Summarily, there are three discrete archaeological loci differentially buried across three discrete landscape segments at Lums Pond. The oldest landscape segment is of Early Holocene age and pre-dates evidence of prehistoric occupation. It signals the initial adjustment of the High Coastal Plain to the overhauled hydrographic regimes of the post-glacial period. A braided stream flowed through the alluvial bottoms of Lums Pond at this time. The middle Holocene is the period during which a linked record of landscape change and prehistoric occupation is first evident. At that time on the interfluves an Argillic paleosol formed on eroded Columbia Formation sands capped by an aeolian veneer. On the lower floodplain surfaces, around 5000 BP, the braided stream regimen gave way to a meandering stream. The early Holocene point bars were irregularly occupied by Archaic populations on meta-stable surfaces as represented by the "3Ab" horizon. Assemblages are discrete, confined, and laterally and vertically separated. By Woodland I times, the interfluve was extensively utilized and an extensive alluvial surface formed on the T-0 along with an Entisol. Both the interfluve and T-0 witnessed maximum settlement during

this period, with two well dated peak occupation windows: between 3500 and 2500 BP (all segments) and around 400 BP (primarily on the T-0). On the T-0 seasonal and longer term groundwater movement has mobilized minerals and soil nutrients in the prehistoric horizons overprinting them with gley features and obscuring lower stratigraphy. Finally accelerated slope erosion over the past 200 years has spread a thick (0.5-1.0m) mantle of colluvium at footslope locations, effectively recontouring the terrain across the project area.

## Archaeo-stratigraphy, Taphonomy, and Site Formation Processes

Archaeo-stratigraphy refers to the temporal context for ordering archaeological sediments. While a variety of schemes have been developed for structuring such relationships with geological units (see Gasche and Tunca 1983; Stein 1990), the litho-stratigraphic sequence and soil chronology developed for Lums Pond is a baseline for integrating archaeological levels into the overall site stratigraphy. A corollary concern for establishing an archaeo-stratigraphy is the reconstruction of the time-line associated with the life history of cultural residues and artifact assemblages from the time of prehistoric occupation, to abandonment, and finally recovery by archaeological techniques. This reconstruction informs on the overall history of the site as a cultural landscape. It is instructive to initiate the reconstruction by grouping the geologically based stratigraphic associations (lithologic units and soil horizons) and then incorporating additional data sets (i.e., lithics, pottery, bone, seeds, radiocarbon dates, archaeological sediments) under the archaeo-stratigraphic rubric.

The primary geologic associations of archaeological concern are Lithologic Units 3a and 3b. Effectively two distinct sediment packages contained archaeological assemblages in 3a: first, lateral accretion deposits in the basal sediment housing diffuse lithic materials or discrete lenses of older prehistoric age (i.e., possible Archaic and the basal Woodland I); second, a weak paleosol ("2Ab") sustaining a more extensive and continuous surface for the more pervasive Woodland I manifestation on the floodplain. Neither of the floodplain (T-0) contexts contained formally defined features. Lithologic Unit 3b included a complex of features registered by distinctive fills and stains. These were intrusive into the Holocene soil.

In order to segregate cultural deposits it was necessary to differentiate between earth matrices that were largely anthropogenic--or mechanically or chemically transformed through human activities--from those that were naturally deposited or weathered (i.e., geological sediments and soils). In some cases this differentiation was readily discernible. Prehistoric storage or activity pits, for example, are apparent as organic stains; these were especially prominent in Area 2. More problematic, however, are artifact clusters in matrices that have not been visibly modified by mineral enrichment or depletion; these were

prominent in Area 3. Finally, there are the effects of agricultural cultivation, such as liming, that enhance the native nutrients of the soil and increase or reduce chemical ingredients, thus masking the geochemistry of human activity.

To account for these effects and to test the potential of the greater Lums Pond landscape for preserving a "prehistoric geochemical signature", samples of the earth surface and substrate from Areas 2 and 3 were taken for geochemical tests. The suite of analyses undertaken has been described earlier (see section II). For the initial analyses three groups were recognized (number of samples in each group is presented in parentheses):

1) *Anthropogenic*- these include sediments clearly modified by cultural activity and included apparent features (typically from Area 2); deposits containing artifact clusters even if not visibly modified (Area 3); and buried organic horizons associated with occupations (i.e., "2Ab" and "3Ab" horizons in Area 3) (n=19).
2) *Pedogenic/sedimentary*- these include deposits laid down by mechanical processes and soils that have weathered in them (n=16).
3) *Agricultural*- these refer to deposits and soils that have been worked for cultivation and which may or may not have been enriched by chemical treatments; expectedly, only surface or near surface proveniences were sampled (n=8).

To determine whether or not these groups could be isolated statistically, a Kruskal-Wallis test was performed on each of the ions (variables) by group. This analysis tests the hypothesis that two or more groups are derived from the same distribution against the alternative that at least one of the groups comes from a different distribution. A nonparametric test was selected because these data cannot be assumed to feature normal distributions. It has the additional advantage of being resistant to outliers, critical because of the relatively small size of the sample populations. Tests were performed using the program STATVIEW on a Macintosh 650 platform (Abacus 1992).

Table 33 summarizes results of the analysis. P-values display an inordinately high discriminatory index for most of the variables among the three categories. If a significance level of .05 is considered the lower limit, the most discriminatory variables are (in descending order): pH, P, OM, Ca, and K. Closer examination of the Mean Rankings (Table 33) shows that pH is the most diagnostic measure of anthropogenic activity, although the reasons for its dominance in features and cultural sediments are not apparent. Additions of bases to cultural residues could derive from human waste products as well as bones and shells that would be perishable residues in processing and related activity loci (i.e., Area 2). OM, P, and K register chemical additions of liming agents to cultivated soils and are agricultural indicators; these same components are prevalent in anthropogenic matrices, albeit in reduced quantities. High values of Ca appear to underscore the dominance of the

calcareous parent materials in the Columbia Formation and on the weathering products (soils) formed in them.

The overall value of the analysis is that it segregates and quantifies elements that constitute the various strata and horizons at archaeological sites. While in many cases, these strata and horizons are visible, the chemical analyses sort out the processes by which natural sedimentation, weathering and, most significantly, human inputs alter the composition of the surfaces on which past cultural activity has taken place. As discussed below, these methods facilitate more pointed the intensity and pattern of human activity across discrete segments of the landscape.

*Area 1: Record of Activities in the Plow Zone (Ap)*

Spatial and techno-typological analyses conducted by excavators identified activity clusters largely in plow zone contexts. Subsurface features were not encountered, but the largely intact horizontal configurations of assemblages demonstrated only minimal disturbance by decades of cultivation. Geoarchaeological contexts were not examined extensively, but observations confirm those of the archaeologists and other researchers across the Eastern Woodlands that plow-zone sites often retain significant spatial integrity. This, in turn, informs on past behavior and land use.

*Area 2: Integrity, Evolution, and Preservation of Activity Areas*

Excavations in Area 2 demonstrated that a locus of high activity was concentrated in a series of ten (10) features in block C of Area 2. Artifact densities were typically low with the exception of Feature 19 and Feature 14, both of which had high counts of fire-cracked rock (FCR) and elevated frequencies of lithic debris. Macrofloral remains in most features were dominated by nutshells (*Carya*) and wood charcoal (*Quercus*). As noted earlier, features were typically excavated into the early Holocene paleosol and dates converged around a peak occupation between 2500-3000 BP. While these data provide unequivocal evidence of intensive utilization of the landscape over a limited time frame they do not supply information on site function or structure. In Delaware, in particular, researchers are concerned with the question of "pithouse formation" and evolution, one prospective example of which, Feature 10, was identified in Area 2.

Table 33. Summary of Results of Statistical Analysis, Lums Pond Geochemistry

**Kruskal-Wallis Test for P mg/kg**
**Grouping Variable: Soil Sediment**

| | |
|---|---|
| DF | 2 |
| # Groups | 3 |
| # Ties | 9 |
| H | 13.430 |
| P-Value | .0012 |
| H corrected for ties | 13.442 |
| Tied P-Value | .0012 |

**Kruskal-Wallis Rank Info for P mg/kg**
**Grouping Variable: Soil Sediment**

| | Count | Sum Ranks | Mean Rank |
|---|---|---|---|
| Anthropogenic | 19 | 436.000 | 22.947 |
| Agricultural | 8 | 275.500 | 34.438 |
| Pedogenic/sedimentary | 16 | 234.500 | 14.656 |

**Kruskal-Wallis Test for K mg/kg**
**Grouping Variable: Soil Sediment**

| | |
|---|---|
| DF | 2 |
| # Groups | 3 |
| # Ties | 3 |
| H | 6.338 |
| P-Value | .0421 |
| H corrected for ties | 6.341 |
| Tied P-Value | .0420 |

**Kruskal-Wallis Rank Info for K mg/kg**
**Grouping Variable: Soil Sediment**

| | Count | Sum Ranks | Mean Rank |
|---|---|---|---|
| Anthropogenic | 19 | 386.500 | 20.342 |
| Agricultural | 8 | 256.000 | 32.000 |
| Pedogenic/sedimentary | 16 | 303.500 | 18.969 |

**Kruskal-Wallis Test for Ca mg/kg**
**Grouping Variable: Soil Sediment**

| | |
|---|---|
| DF | 2 |
| # Groups | 3 |
| # Ties | 0 |
| H | 7.075 |
| P-Value | .0291 |
| H corrected for ties | 7.075 |
| Tied P-Value | .0291 |

22 cases were omitted due to missing values.

**Kruskal-Wallis Rank Info for Ca mg/kg**
**Grouping Variable: Soil Sediment**

| | Count | Sum Ranks | Mean Rank |
|---|---|---|---|
| Anthropogenic | 16 | 157.000 | 9.812 |
| Agricultural | 2 | 15.000 | 7.500 |
| Pedogenic/sedimentary | 3 | 59.000 | 19.667 |

22 cases were omitted due to missing values.

Table 33. Summary of Results of Statistical Analysis, Lums Pond Geochemistry

**Kruskal-Wallis Test for Mg mg/kg**
**Grouping Variable: Soil Sediment**

| | |
|---|---|
| DF | 2 |
| # Groups | 3 |
| # Ties | 0 |
| H | 4.348 |
| P-Value | .1137 |
| H corrected for ties | 4.348 |
| Tied P-Value | .1137 |

17 cases were omitted due to missing values.

**Kruskal-Wallis Rank Info for Mg mg/kg**
**Grouping Variable: Soil Sediment**

| | Count | Sum Ranks | Mean Rank |
|---|---|---|---|
| Anthropogenic | 3 | 15.000 | 5.000 |
| Agricultural | 7 | 109.000 | 15.571 |
| Pedogenic/sedimentary | 16 | 227.000 | 14.187 |

17 cases were omitted due to missing values.

Table 33. Summary of Results of Statistical Analysis, Lums Pond Geochemistry

**Kruskal-Wallis Test for pH**
**Grouping Variable: Soil Sediment**

| | |
|---|---|
| DF | 2 |
| # Groups | 3 |
| # Ties | 13 |
| H | 19.289 |
| P-Value | <.0001 |
| H corrected for ties | 19.393 |
| Tied P-Value | <.0001 |

**Kruskal-Wallis Rank Info for pH**
**Grouping Variable: Soil Sediment**

| | Count | Sum Ranks | Mean Rank |
|---|---|---|---|
| Anthropogenic | 19 | 586.000 | 30.842 |
| Agricultural | 8 | 75.000 | 9.375 |
| Pedogenic/sedimentary | 16 | 285.000 | 17.812 |

**Kruskal-Wallis Test for OM%**
**Grouping Variable: Soil Sediment**

| | |
|---|---|
| DF | 2 |
| # Groups | 3 |
| # Ties | 11 |
| H | 8.593 |
| P-Value | .0136 |
| H corrected for ties | 8.652 |
| Tied P-Value | .0132 |

**Kruskal-Wallis Rank Info for OM%**
**Grouping Variable: Soil Sediment**

| | Count | Sum Ranks | Mean Rank |
|---|---|---|---|
| Anthropogenic | 19 | 323.000 | 17.000 |
| Agricultural | 8 | 259.500 | 32.438 |
| Pedogenic/sedimentary | 16 | 363.500 | 22.719 |

**Kruskal-Wallis Test for CO3%**
**Grouping Variable: Soil Sediment**

| | |
|---|---|
| DF | 2 |
| # Groups | 3 |
| # Ties | 4 |
| H | 2.500 |
| P-Value | .2865 |
| H corrected for ties | 2.673 |
| Tied P-Value | .2628 |

17 cases were omitted due to missing values.

**Kruskal-Wallis Rank Info for CO3%**
**Grouping Variable: Soil Sediment**

| | Count | Sum Ranks | Mean Rank |
|---|---|---|---|
| Anthropogenic | 3 | 31.500 | 10.500 |
| Agricultural | 7 | 73.500 | 10.500 |
| Pedogenic/sedimentary | 16 | 246.000 | 15.375 |

17 cases were omitted due to missing values.

Table 33. Summary of Results of Statistical Analysis, Lums Pond Geochemistry

**Mann-Whitney U for pH**
**Grouping Variable: Soil Sediment**

| | |
|---|---|
| U | 12.500 |
| U Prime | 41.500 |
| Z-Value | -1.709 |
| P-Value | .0875 |
| Tied Z-Value | -1.724 |
| Tied P-Value | .0847 |
| # Ties | 4 |

**Mann-Whitney Rank Info for pH**
**Grouping Variable: Soil Sediment**

| | Count | Sum Ranks | Mean Rank |
|---|---|---|---|
| F10 | 6 | 62.500 | 10.417 |
| Other features | 9 | 57.500 | 6.389 |

**Mann-Whitney U for OM%**
**Grouping Variable: Soil Sediment**

| | |
|---|---|
| U | 18.000 |
| U Prime | 36.000 |
| Z-Value | -1.061 |
| P-Value | .2888 |
| Tied Z-Value | -1.076 |
| Tied P-Value | .2819 |
| # Ties | 4 |

**Mann-Whitney Rank Info for OM%**
**Grouping Variable: Soil Sediment**

| | Count | Sum Ranks | Mean Rank |
|---|---|---|---|
| F10 | 6 | 57.000 | 9.500 |
| Other features | 9 | 63.000 | 7.000 |

**Mann-Whitney U for P mg/kg**
**Grouping Variable: Soil Sediment**

| | |
|---|---|
| U | 6.000 |
| U Prime | 48.000 |
| Z-Value | -2.475 |
| P-Value | .0133 |
| Tied Z-Value | -2.479 |
| Tied P-Value | .0132 |
| # Ties | 2 |

**Mann-Whitney Rank Info for P mg/kg**
**Grouping Variable: Soil Sediment**

| | Count | Sum Ranks | Mean Rank |
|---|---|---|---|
| F10 | 6 | 69.000 | 11.500 |
| Other features | 9 | 51.000 | 5.667 |

**Mann-Whitney U for K mg/kg**
**Grouping Variable: Soil Sediment**

| | |
|---|---|
| U | 16.500 |
| U Prime | 37.500 |
| Z-Value | -1.237 |
| P-Value | .2159 |
| Tied Z-Value | -1.243 |
| Tied P-Value | .2139 |
| # Ties | 2 |

**Mann-Whitney Rank Info for K mg/kg**
**Grouping Variable: Soil Sediment**

| | Count | Sum Ranks | Mean Rank |
|---|---|---|---|
| F10 | 6 | 37.500 | 6.250 |
| Other features | 9 | 82.500 | 9.167 |

Table 33. Summary of Results of Statistical Analysis, Lums Pond Geochemistry

**Mann-Whitney U for Ca mg/kg**
**Grouping Variable: Soil Sediment**

| | |
|---|---|
| U | 15.000 |
| U Prime | 39.000 |
| Z-Value | -1.414 |
| P-Value | .1573 |
| Tied Z-Value | -1.414 |
| Tied P-Value | .1573 |
| # Ties | 0 |

**Mann-Whitney Rank Info for Ca mg/kg**
**Grouping Variable: Soil Sediment**

| | Cou... | Sum Ranks | Mean Rank |
|---|---|---|---|
| F10 | 6 | 36.000 | 6.000 |
| Other features | 9 | 84.000 | 9.333 |

Geochemical and phosphate fractionation methods were applied to differentiate between features and to address more specific questions of feature formation at this location. These issues are addressed following an initial discussion on the geochemical methods applied for the analysis. The analysis concludes with a detailed examination of feature function, focused on the most distinct specimens of the sample population: Features 14 and 19 containing dense artifact and refuse concentrations; and Feature 10, chronologically and morphologically separate from all other feature types.

While the unique properties of P and related compounds have been variously applied to archaeological situations, recent advances have been successful in inferring activity trends by combining results of total phosphorous concentrations (Total P) and fractionation of the phosphate compound. The methods and interpretations were initially developed by Eidt (1984) and have been modified and applied to hunter-gatherer sites (Schuldenrein 1995). The reader is directed to these studies for a summary of principles and geo-chemical foundations.

The initial measure of cultural residues in a given feature or cultural locus is the abundance of total P. Eidt (1977) has calculated the following concentration ranges (in mg/kg) to classify and rank cultural activity levels: 10-300 for hack farming and ranching; 300-2,000 for dwelling, gardening, manufacturing, and garbage dumping; and >2,000 for burials, refuse pits, slaughter areas, and urban living areas. Most hunter-gatherer sites have concentrations in the basal range (10-300 mg/kg). Samples collected for Lums Pond include a variety of control columns including the baseline (i.e., sterile) soil profile and incremental depths for deeper features (Feature 10 and Feature 17). Finally, fractionation data from a broad sampling of prehistoric sites with known utilization patterns were drawn upon for inter-site comparisons.

The range in the sum of the phophate fractions (79-161 mg/kg) establishes Area 2 of Lums Pond as a moderately active prehistoric locus. This is apparent because P concentrations increase with depth down the soil control column, peaking at the "Bt2" (P=163). Results appear to confirm the pedogenic interpretations that this horizon was the former surface of the landform during occupation. Interpretations are partially borne out by the earlier Kruskal-Wallis Rank Analysis for available P (see Table 33) that demonstrates that the element is diagnostic in segregating pedogenic, agricultural, and anthropogenic sediments (note, however, that *available* P and not *total* P is an indicator of agricultural use). Somewhat lower values were registered for deeper features, since these would not be expected to house anthropogenic debris *sensu stricto*, but rather vegetative materials degraded by natural decomposition and not infilled with residues of human origin. The total P values provide indications for minimal feature infillings. Anthropogenic residues were retained on the occupation surface (i.e., animal wastes, bone debris, evidence for extensive burning). In sum, it appears that the top of the Bt2 was the active surface at the

time of the Woodland I occupation. Surface reworking spread these residues and resulted in feature infillings.

Once the quantitative P analysis evaluated the magnitude of human impact in Area 2, the fractionation method attempted to differentiate specific activity sets. The technique involves chemical separation of inorganic settlement phosphate into three components by means of non-overlapping extractions (see Eidt 1984: 40-44 for discussion of procedures). Fraction I corresponds to loosely bound aluminum and iron phosphates; Fraction II to occluded forms of these same phosphates; and Fraction III to calcium phosphates. A corollary application of fractionation is as a relative dating technique since it is possible to measure the degree to which the phosphates have occluded, from weak (Fraction I) to chemically bound forms (Fraction II); calculation of the Fraction II/Fraction I ratio indexes the time elapsed between initial phosphate deposition and occlusion to its fixed form. Lillios (1992) has combined Eidt's interpretive parameters, to model diminished and shifting land use (i.e. ,total P) through time (i.e., changing Fraction II/I ratios) at the site of Agroal, Portugal in one of the only tests of this paramter.

Calculations of the relative loadings of phosphate levels on each fraction provide a refined index, or "print", of land use type. Graphic, tri-axial mapping of the "print" isolates variability through time and space of a constellation of land use types or activity areas (following clustering of "prints" as outlined in Schuldenrein 1995). If a site supported a range of activities, each of which left discrete phosphate concentrations, these could be sorted out by measuring variability in the relative loadings on each of the phosphate fractions. Figure 82 is a ternary plot of the phosphate fraction and control sample readings for the Lums Pond specimens. Each axis represents the percentage loading on one of the three phosphate fractions. For comparitive purposes two additional data sets are included. One is from trash discard pits from the Mississippian Rucker's Bottom (Georgia) and Goldkrest (New York) prehistoric sites; a second presents nine (9) reference land use "prints". The trash discard pits registered the highest concentrations of total P and thus the strongest evidence of intensive anthropogenic input and highest level of cultural modification to a natural sediment. The reference "prints" are mean determinations of discrete feature types (i.e., platforms, floors and paths; see key in Figure 82) assembled for different activity sets across the world (Eidt, personal communication).

Examination of the phosphate fractionation plots calls immediate attention to the cluster of Lums Pond features in the vicinity of reference types 3, 4, and 6. These index an evergreen forest (type 3), planting ridges (type 4), and floors and paths (type 6). The evergreen forest "print" is consistent with both the present arboreal setting and Holocene paleovegetation reconstructions locally which argue for systematic displacements of mixed forest covers (see Kellogg and Custer 1994). The match between the Lums Pond features and the reference print validates, to some degree, the applicability of the method to the data

base. Types 4 and 6 have been interpreted elsewhere as generic indicators of land clearance (Schuldenrein 1995); in a strict sense they index activity for villages where total P values are higher (>300 mg/kg). Since land clearance is an activity performed at both short term and long term sites, the same fractionation pattern with low total P values can attest to clearance activities of more limited scope and extent.

More detailed examination of the phosphate fractionation plots distinguishes a single activity cluster (upper left portion of Figure 82) keyed to a heavy loading on Fraction II (50-70%), with proportionately lesser weights on Fractions I and III. The cluster encompasses what may be considered a generic matrix for Woodland I land use on the hillslope. The reference prints implicate the initial evergreen forest cover. Subsequent clearance was accompanied by preparation of surfaces (print type 4). The general fractionation distributions do not conform to prints diagnostic of extensive activity surfaces

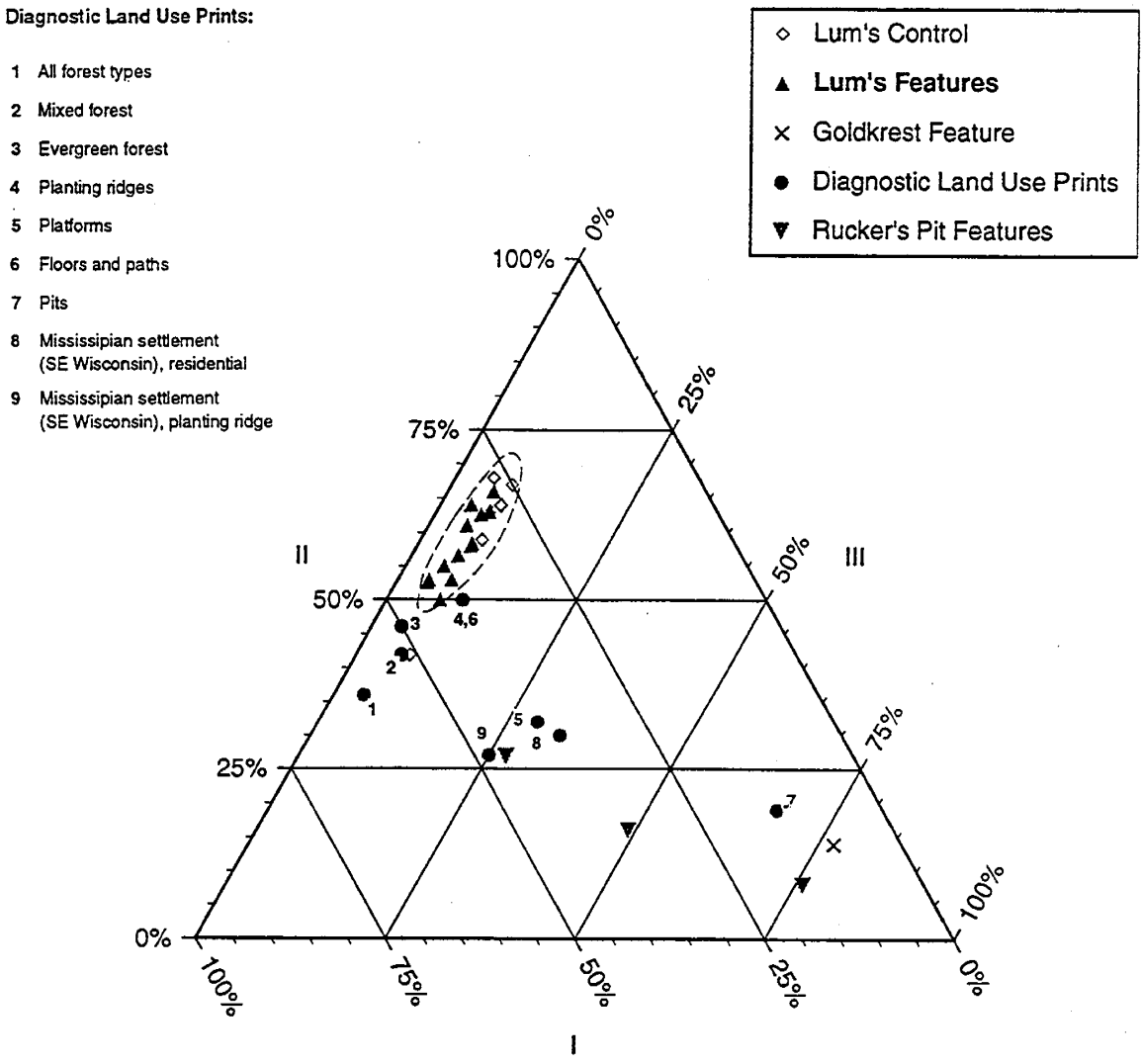


Figure 82. Phosphate and Land Use Prints, Area 2

(i.e., middens) that would be repeatedly occupied for long durations. Such prints would cluster in the central portion of the ternary diagram (Figure 82). Similarly, the activities across Area 2 are inconsistent with pockets of extensive discard of subsistence debris (i.e., animal food remains, trash pits, meat processing stations); these prints are typically registered by type 7, on the lower right and central portions of the diagram. In general, the cluster represents performance of specific tasks keyed to levelling of the terrain and functions accommodated by low level activity, perhaps of limited duration. The need for levelling is also suggested by measurments of the feature depths which argued for a northerly slope to the field in prehistoric times (see discussion in *Feature Analysis*).

In this connection, the minimal variability between features prints shows that the feature signatures are more similar to each other than they are to any diagnostic land use print. This would argue for homogeneous use of the landscape and, by extension, an expected uniformity of feature function. Variability within the Lums Pond phosphate population is only evident for the control samples--the pedogenic profile--which appear to load even more heavily on Fraction II than the features themselves. This again underscores the potential of the fractionation method for isolating anthropogenic from pedogenic process, as borne out in the statistical analysis.

*Features 14 and 19*

Archaeological analysis disclosed that these features contained high concentrations of macrobotanical material, refuse, fire-cracked rock, and relatively large concentrations of chipping debris, including diagnostic projectile points. Single dates were obtained from each (2660±100 BP, Beta-88102, Feature 14; 2720±90 BP, Beta-88104, Feature 19) and they are both from the same locus (Area 2/Block C).

Sorting of the geochemical analysis results disclosed that the highest concentrations of calcium (Ca) are associated with these features. Concentrations typically exceed 400 mg/kg, thresholds not attained by any other feature in the sample population. Generally, elevated levels of Ca are taken as evidence for food processing because of the presence of the element in animal by-products, especially bone (see Schuldenrein 1995 and references). Co-variant concentrations of Ca, lithic debris and macrobotanical remains suggest that these features may have been processing or discard facilities for foodstuffs.

*Feature 10*

The morphology of Feature 10 was distinct from that of other features; it was larger, deeper and more irregularly shaped. It was also located apart from the general feature cluster in Area 2 and conformed most closely to the "D-shaped or kidney-shaped" form that

has been interpreted as a regional variant of the "pit house" or alternatively dismissed as a "tree throw" (see Cavallo 1996; Custer and Silber 1995). These features were dominant during Woodland II times and the single date obtained for Feature 10 was 1150±90 BP (Beta-88101). Feature 10 is also the only sampled feature in Area 2 dated outside the third millennium BP.

Geochemical analyses were applied to separate, excavated levels of Feature 10 to determine if and how the unique properties of the feature were preserved in particular elements. If so, it was hypothesized that these might inform on feature function or evolution. An initial step was to prove that samples from Feature 10 (Group 1) differed chemically from samples of the general feature population in Area 2 (Group 2). A Mann-Whitney U test was performed to test the null hypothesis that the distributions underlying the two groups are the same. A nonparametric test was selected because these data cannot be assumed to feature normal distributions. Since the Mann-Whitney test does not examine the observations but instead considers their ranks, it is resistant to outliers of either group. Tests were performed using the program STATVIEW on a Macintosh 650 platform (Abacus 1992).

Table 33 summarizes results of the analysis. P-values show a generally low discriminatory index for the variables tested between groups. If a significance level of .05 is considered, the only discriminatory variable is, not surprisingly, P. If the significance level is lowered to .10, pH is also diagnostic.

These data reinforce the sensitivity of P as an anthropogenic barometer of site formation. In light of this observation, and the depth of Feature 10 (to 90 cm; sampled to 80 cm) the pattern of vertical transformations of P provides critical clues on processes of site evolution. Archaeological excavation and analysis suggested that rodent disturbance and bioturbation had severely disrupted the integrity of the feature. This interpretation is at least partly confirmed by the P data. Accordingly, Figure 83 illustrates fractionation trends with depth and shows that the highest levels of P (161 mg/kg) were registered for what was recognized as the cultural levels in the field (40-60 cm). Given that Fraction II records time transgressive developments, Feature 10 records the degree to which phosphates have occluded from weak to chemically bound forms *below* the cultural level. *Above* the cultural level there is no distinctive chrono-stratigraphic trend, consistent with stasis or lack of phosphate mobilization and occlusion. The deepest fills would have beeen introduced at the time of feature excavation and utilization. Lower concentrations of phosphate, presumably derived from younger or disturbed sediment contributions upslope are lower in Fraction II, thus reflecting less time for occlusion.

The pattern of phosphate occlusion may have ramifications for interpretation of the presumed "pit-houses". As noted, arguments for the identity of the basin features range

from claims of prepared and functional structures (Custer and Silber 1995 and references) to classifications as probable tree throws (Cavallo 1996). Intermediary positions have also been taken, including claims that "tree throw" accounts for displacement and disturbance of de facto archaeological features. Following the catastrophic action (often initiated by fire), hollows created by uprooting are infilled by the same cultural sediments whose integrity was initially compromised (Strauss 1978; Wood and Johnson 1978). Along similar lines, it has been postulated that once excavated, larger tree hollows may serve as optimal storage facilities.

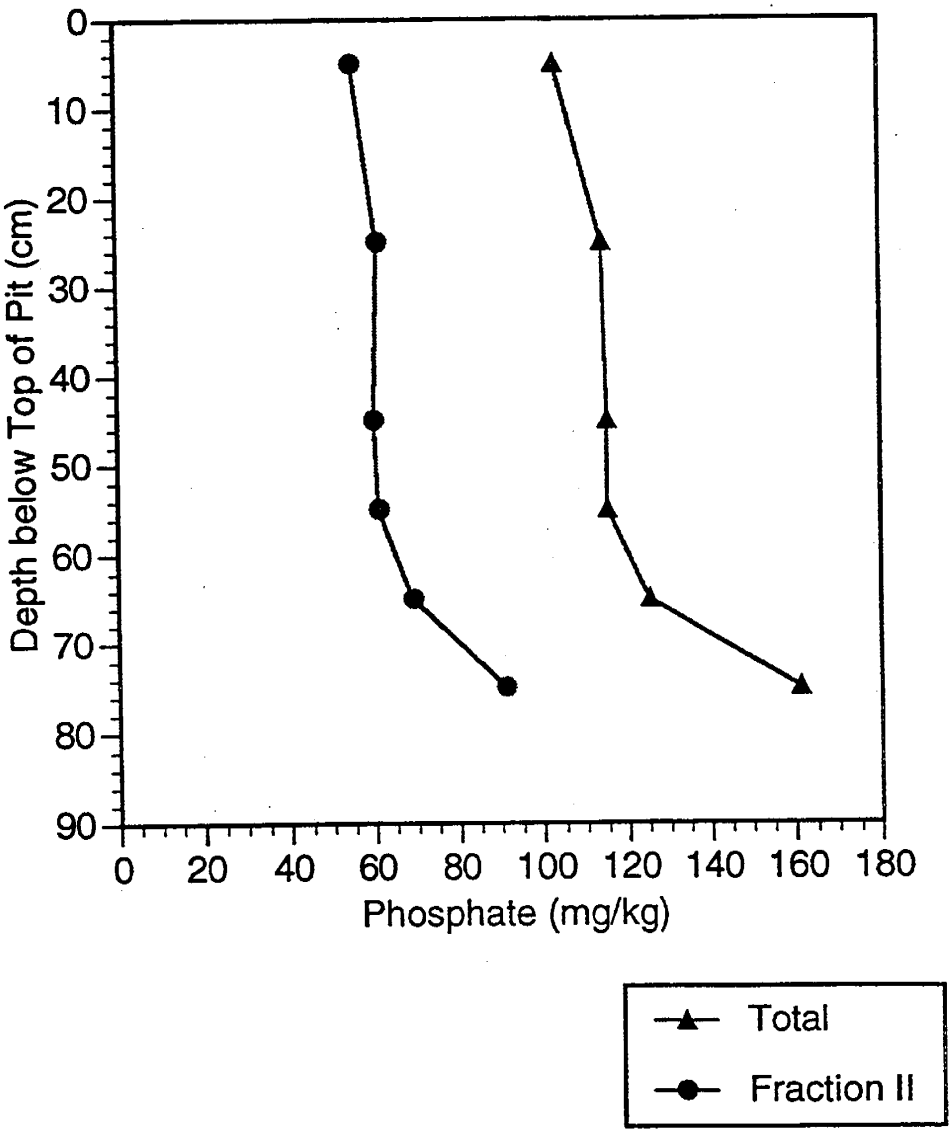


Figure 83. Increase in Occluded Phosphate (Fraction II) with Depth, Feature 10

To date the application of geoarchaeological techniques to interpret these phenomena have been limited (although see Macphail and Goldberg 1990 on recognition of

disturbance by micromorphological techniques). At Lums Pond, it has been possible to trace at least systematic accumulation of cultural debris in Feature 10, if only for a single level (40-60 cm). This hypothesis is tentatively advanced *because of the progressive occlusion registered on phosphate Fraction II, a time transgressive phenomenon.* Several alternative scenarios can be hypothesized in light of this observation.

1) *The basin formed initially as a tree throw,was briefly utilized as a discard area, and then abandoned.* This would be sustained by the thin accumulation of cultural debris, the occlusion pattern below and the random infilling of the upper portion of the basin.

2) *The tree throw occurred following abandonment of Area 2 and was the locus of natural infilling that included cultural debris.* This would also account for the occlusion pattern since all of the cultural debris swept in is contemporaneous and a single event may have produced an episodic infilling. The chronology is accommodated since the age of the feature post-dates the major locus habitation by ca. 1,500 years, sufficient time for enrichment of Fraction II.

3) *The basin was deliberately excavated, and used periodically.* The earliest use of the feature would have introduced a single level, or several levels, of debris. Subsequent occupation, depending on feature use, would have resulted in widening of the feature and considerable mixing of sediment that would have perpetuated ongoing bioturbation.

Since there was only a single example of the "D-shaped" feature at Lums Pond, it is not possible to reconstruct the formation history with any degree of confidence. It is clear however, that geochemical techniques, and phosphate analysis in particular, can be significant in addressing the question of basin identity. This can be done by tracking the mobilization and concentrations of the compound through the substrate and isolating cultural residues systematically.

*Area 3: Dynamism of the Floodplain and Assemblage Variability*

The preceding section on Depositional Environments proposed a geomorphic context for the antecedent Lums Pond stream that accommodated variable assemblage contexts for the >5,000 years of documented occupation. Initially, the earliest lithic assemblages (latest Archaic or Woodland I) were interspersed in lateral accretion deposits (lower Unit 3a) of the middle Holocene floodplain. Deposits were both vertically and laterally stratified, a context accommodated initially by the undulating contours of point bars, and eventually by an emergent concavo-convex floodplain over the course of the middle Holocene. The latter emerged as the stream regimen shifted from a braided to meandering channel. Basal archaeo-stratum 3a was dated to 4500-2500 BP.

As the landscape stabilized into a continuous linear feature parallel to the stream, a formal surface containing later Woodland I assemblages was idenitified in the form of an Entisol (horizon "2Ab", upper Unit 3a); artifacts were also present in the immediate substrate of overbank fines. Over the course of Woodland I there was a dramatic shift in the floodplain geography. The depositional regimen shifted from lateral accretion to overbanking, in a dramatic sedimentation shift that terminated at ca. 400 BP. The alluvial surface formed on the T-0 was extensive. Subsequently, seasonal and longer term groundwater movement mobilized minerals and soil nutrients in the prehistoric horizons overprinting them with gley features and obscuring lower stratigraphy. Thus the assemblages on the T-0 were either not associated with features or evidence for intact perishable residues (i.e., staining or recognizable discoloration) was lacking.

The absence of a well-defined archaeological stratigraphy on the T-0 required an examination of other lines of evidence for resolution of assemblage contexts. These required more detailed investigation of the following parameters in Area 3:

1) The radiocarbon record;
2) Vertical stratigraphy and the integration of excavation levels C and D;
3) The floodplain morphology and lateral continuity of Blocks A and B.

*Radiocarbon record*

A general discussion of the radiocarbon chronology based on the entire battery of dates has been presented elsewhere in this report. For present purposes it is instructive to focus on anomalies in that record that emerge from the dating of the various materials that structured the absolute chronology for Area 3: charcoal, soil-sediments, and charcoal dispersed within soil-sediments.

Soil-sediments are typically considered the "least reliable" sources of dating for a variety of reasons. This is because soil organic matter is derived from a variety of sources and any one of three organic fractions--total, humic acid, and residue--may be dated (see Martin and Johnson 1995). Even if a single procedure is followed and one laboratory is used to guarantee uniform processing the age of the bulk soil organic carbon presents what is known as a "mean residence time" (MRT) of the steady state organic matter. It has been argued that there is no clear definition of what MRT implies and invariably the dates obtained from such samples contain influxes of organic matter that are mobilized upward or downward (more common) because of pedogenic, hydromorphic, or depositional processes (Wang et al. 1996).

Nevertheless, the MRT serves as a critical barometer of a *terminus ante quem* in the absence of other dateable materials at an archaeological site. Of critical relevance to Lums

Pond is the concern that the deepest, laterally undulating organic horizon (soil "3Ab" at the base of lithologic unit 3a) demarcates sediments beneath which archaeological materials did not occur. Archaeological materials were housed between "3Ab" and "2Ab" and charcoal was preserved and dated for the intervening excavation levels (C and D). It has also been variously postulated that archaeological materials are not likely to occur earlier than 6000 BP in floodplain contexts in central Delaware (see discussion in Synthesis section). Finally, the geomorphological reconstruction postulated an earlier point bar alluvial environment that stabilized to an undulating floodplain. Under this scenario a variety of vertically disjunct dates, confined to the mid-Holocene, could be expected. Thus the procurement of several humic acid dates from these contexts would cross-check the archaeological dates, confirm the regional antiquity of floodplain environments in central Delaware (<6000 BP) and establish the validity of the dynamic and emergent migrating floodplain.

The battery of radiocarbon dates included two pairs of determinations bracketing soil horizons "3Ab" and "2Ab" in Blocks A and B respectively. For Block A the "2Ab" was dated to 330±80 BP (Beta-92101) and the "3Ab" to 4310±60 BP (Beta-92099). Equivalent determinations for Block B are 380±60 BP (Beta-92102) for "2Ab" and 2400±60 BP (Beta-92099) for "3Ab". The determinations for "2Ab" are internally consistent and confirm the continuity of the alluvial landform in the late Holocene, an interpretation that was independently reached by the sedimentological analysis. These dates, even though slightly young, corroborate the latest Woodland occupations along the floodplain; the measured date may have been artificially elevated by settling overlying organics. The "3Ab" determinations are both relatively young in terms of the archaeological stratigraphy and are internally separated by 2,000 years. The relative youth of the determinations may reflect the introduction of younger organics through percolation; as noted, this date represents the MRT. The discrepancy of 2,000 years between horizon "3Ab" in Blocks A and B may be a partial function of MRT variability, but it is more possibly an artifact of the migration of the stream and the eastward shift of the depositional locus between 4000 and 2000 BP when, as noted, the stream was still not permanently stabilized in its channel. In either case, it is significant that the 4000-2000 BP interval brackets the ages of three of the charcoal specimens taken from excavation Layer D all of which converge around 3300 BP. Lithic assemblages indicate that these dates are fully consistent with the cultural chronology. The ramifications of the radiocarbon chronology for segregation of excavation levels C and D are discussed below.

*Vertical stratigraphy: integration of excavation levels C and D*

A critical concern in the examination of the archaeological levels in Area 3 is the alluvial or even fluvial orgins of the sediments themselves. Alluvial contexts refer to the floodplain while a fluvial designation confers significance to active channel sedimentation.

As Lums Creek passed from a meandering stream to a stabilized trench with a flanking floodplain, less evidence for fluvial action was preserved in the sediment record. Since the general sedimentology argues for a graded transition--particle sizes do not record dramatic energy level changes--this is a subtle point. However, lateral accretion regimes still underscore sufficient tractive force to mobilize artifacts. Therefore, it can be argued that the deeper the excavation extended into the coarser matrix, the greater the potential for encountering archaeological deposits that have been mobilized from their original locus of discard. Since the evidence suggested that the antecedent Lums Creek also migrated laterally, there is also an expectation that artifacts were mobilized horizontally.

Given these concerns, it may be argued that the chronology of events on the floodplain are best indexed by a combination of converging lines of evidence from the assemblage and radiocarbon data bases. As discussed above, the radiocarbon dates generally establish "3Ab" as the *terminus ante quem* for Area 3 even if the actual determinations represent an MRT and dates obtained for the sediment are too young. An age range of 4000-2000 BP accommodates three of the five cultural dates obtained from Area 3, excavation level D. The single date of 6350±60 BP (Beta-88108) would appear to be too old and is certainly inconsistent with the artifact typologies generally represented on site. The single younger date of 640±50 BP (Beta-88107) was housed in the upper level and may be anomalous.

The vertical distributions of the artifacts demonstrate that the richest concentrations of artifacts are bimodally distributed. The lowermost archaeological deposits are linked to sediments immediately overlying soil "3Ab" (central portion of Lithologic Unit 3a) and in direct association with horizons 2C and 2Cg. Uppermost archaeological deposits articulate directly with buried soil "2Ab". More specifically, in Block A highest artifact frequencies occur in levels D4 and there is a minor peak in E1. In Block B, bimodal distributions are noted for levels C1 and D2. The bimodality of the artifact concentrations obtains across the excavated blocks and have suggested to excavators that the deepest archaeological sediments are discrete.

The vertical disposition of artifacts is troubling in the sense that the two contexts articulate with ostensibly incompatible alluvial contexts. The uppermost deposits are tied to a discrete soil ("2Ab") as well as to an interval when stream energy levels reduced markedly as the stream became entrenched in its present channel. All of these indicators point to florescence of the occupation on a stabilized landform underlain by an evolving soil. The lowermost deposits, however, would be expected to correlate with soil "3Ab" and they do not. In this regard, however, it is stressed that the stream was considerably more dynamic at the time of the earlier Woodland I period (ca. 3000 BP). Given that undulating surfaces have been postulated, it is possible that artifacts have been somewhat displaced from their original loci of discard. Second, it is probable that groundwater podsolization may have

leached minerals from sediments immediately overlying the "3Ab" and that evidence for an original occupation floor is obscured. The occurrence of artifacts in a "Cg" horizon illustrates that the seasonal post-occupation groundwater level is co-incident with former archaeological level D.

*Floodplain morphology: lateral continuity of Blocks A and B*

Artifact distribution data have largely confirmed analogous occupations between Blocks A and B. Moreover, the parallel bimodal distributions for artifact density corroborate continuity in pattern of occupation across the floodplain.

Sedimentological data corroborate these observations, insofar as the most critical break in the sedimentation regime--passage from lateral accretion to overbanking--occurred at the time of the later Woodland occupation (I/II) when soil "2Ab" was forming (see Figures 79 and 80). At this time it clear that the landform of occupation was continuous. Between 4000 and 2000 BP it is has not been unequivocally demonstrated that the morphology of the floodplain had been stabilized. As discussed above, the radiocarbon date for soil "3Ab" (2400±60 BP; Beta-92099) offers at least a possibility that the locus of sedimentation shifted eastward. Subsurface excavations into the lower sediments of Area 3 were not sufficiently extensive to reconstruct the earlier Holocene alluvial sequence in sufficient detail to determine vectors of channel flow and sedimentation for these earlier time frames.

Topographic variability within and between Blocks A and B argue for limited lateral and vertical mobilization of artifact assemblages in the coarser fills of basal unit 3a. While artifact concentrations may have centered immediately above soil "3Ab" the sandy alluvium bespeaks a moderately competent stream flow, sufficient to have displaced artifacts within limited horizontal and lateral parameters.

In overview, the geoarchaeological investigations of site formation suggest:

1) Habitation of higher portions of the landscape, specifically raised surfaces of point bars and alluvial islands during Woodland I.
2) Short term and episodic occupations during Woodland I associated with Unit 3a. Assemblages are neither thick nor laterally extensive.
3) Absence of an extensive surface in Unit 3a. Soil horizon "3Ab", may mark the top of a meta-stable surface, but it is masked by hydromorphic features and and retains no anthropogenic signature.
4) Migration of the channel resulting in erosion of former topographic highs and burial and creation of others. This generally occurred between 4000 and 2000 BP.

5) Repeated occupation of elevated floodplain segments (i.e., above the floodline) and settlement above newly constructed topographic highs. Repeated occupation is expressed as palimpsests. The latter produce superposed, albeit thin, cultural sediments and assemblage packages.
6) Winnowing out of fines in topographic highs by recessionary floodwaters that causes collapse of "artifact horizons", if they existed initially.
7) Stabilization of floodplain surfaces after 2000 BP and the construction of a continuous landform near the end of the Woodland period.
8) Dramatic hydromorphism in historic times.

*Overview*

Table 34 correlates changes in the landform history at Lums Pond with cultural sedimentation patterns for the individual archaeological components. The composition of the archaeological sediments for each component reflect the unique preservation matrix associated with the parent materials or soils that articulate with the component. Finally, an estimate of preservation potential is offered across the general landscape based on the reconstructed landform events and cultural formation processes and the preservation matrix. Preservation potential is also estimated for those earliest prehistoric components (Paleoindian, Archaic) either not represented or intermittently preserved at the site. Low probability determinations for the Early Holocene occupations is grounded on the reconstruction of high energy stream environments that dominated the floodbasin prior to 5000 BP thus precluding settlement across the extant terrain (see discussion below). Generally, Table 34 shows that a preservation "gradient" articulates with the Archaic and Woodland components that is a function of three factors as follows:

1) Low energy depositional environments or exhumed surfaces and Lithologic Units (3a and 3b respectively).
2) Articulation with the Argillic paleosol (3b only).
3) Locus topography along the crest of the occupational landform (3a only).

## Synthesis: A Model of Landscape Archaeology

*Landscape Evolution, Occupation and Site Preservation*

A comprehensive record of post glacial landscape evolution is contained within two separate landscape segments at Lums Pond. Unique depositional environments characterise the intefluve and lower lying alluvial plain. For the early Holocene the record is sporadic, but for the last 5,000 years much of the archaeology is in primary or near primary context. Site function and location varied by time and by geography. Floodplain dynamics, soil formation, and hillslope erosion also account for the differential storage and maintenance of the archaeological record.

| Archeological Component | Lithologic Unit | Occupational Landscape | Cultural Sedimentation Pattern | Preservation Matrix | Preservation Potential |
|---|---|---|---|---|---|
| Historic | 1, 2a, 2b | Massive mobilization of historic sands, silts, and clays; recontoured terrain (concavo-convex slopes) obscures steeper prehistoric gradients; accelerated clearing still active promoting deflation (uplands) and alluviation (T-0) | Diffuse and occasionally dense clusters of 19th and 20th century debris; "inverted stratigraphy" resulting from episodic flooding (2a) and massive hillslope erosion (2b) | Organic and inorganic fills in secondary context | Moderate |
| Woodland I, II | 3b | Intact Interfluve crest and eroded Interfluve midslope; well structured Argillic paleosol spans entire landform; access to lower lying meandering middle Holocene stream | Complex of thin to deeper cultural features; discrete and superposed laterally and intrusive into Argillic paleosol ("Bt" horizon); diffuse artifacts displaced by bioturbation and pedoturbic processess | Firm and well structured matrix of "Bt1-Bt2" pedon on interfluves; features excavated into eroded surface; intact "Ap-E-Bt" epipedon on crest; aeolian sediments overlying and underlying occupation contexts | High |
| Woodland I, II | 3a (upper) | Upward fining sequence succeeded by vertical accretion fines (T-0 only); stabilized channel flow; accelerated construction of concavo-convex floodplain; Entisol overprinted by gleys | Organic cultural sediments, laterally and vertically variable, overprinted by groundwater activity; probable continuous paleosurface obscured by overthickening of historic sediments and hydromorphic features | Organic sediments overridden by overlying slopewash and alluvium (units 2a and 2b); some bioturbation; lateral stratification and truncation of subjacent fills | Moderate |
| Archaic | 3a (lower) | Lateral accretion deposits, fining upward sequence; exhumed surfaces, discontinuous, largely truncated; migrating stream; emergence of differentiated basin environment; island surfaces; grounwater podsol | Leached and thin sediment lenses; limited concentrations of lithics and related debris; diffuse concentrations of perishables; no discrete features | Inorganic (upper 3a) to slightly organic (lower 3a; soil "3Ab") archeological matrices within crests of point bars or swale margins of distal former floodplain; laterally and vertically separated to interdigited palimpsests | Moderate |
| Paleoindian | 4 | Upper surfaces of Columbia Formation, currently eroded; swampy margins of first and second order drainages characterised by braided streams along downstream reaches and overlooking estuaries | NA | NA | Low |

Table 34. Landscape Context and Archaeological Preservation at Lums Pond

| Archeological Component | Lithologic Unit | Excavation Level | Occupational Landscape | Cultural Sedimentation Pattern | Preservation Matrix | Preservation Potential |
|---|---|---|---|---|---|---|
| Historic | 1, 2a, 2b | A,B | Massive mobilization of historic sands, silts, and clays; recontoured terrain (concavo-convex slopes) obscures steeper prehistoric gradients; accelerated clearing still active promoting deflation (uplands) and alluviation (T-0) | Diffuse and occasionally dense clusters of 19th and 20th century debris; "inverted stratigraphy" resulting from episodic flooding (2a) and massive hillslope erosion (2b) | Organic and inorganic fills in secondary context | Moderate |
| Woodland I | 3b | All | Intact Interfluve crest and eroded Interfluve midslope; well structured Argillic paleosol spans entire landform; access to lower lying meandering middle Holocene stream | Complex of thin to deeper cultural features; discrete and superposed laterally and intrusive into Argillic paleosol ("Bt" horizon); diffuse artifacts displaced by bioturbation and pedoturbic processess | Firm and well structured matrix of "Bt1-Bt2" pedon on interfluves; features excavated into eroded surface; intact "Ap-E-Bt" epipedon on crest; aeolian sediments overlying and underlying occupation contexts | High |
| Woodland I | 3a (upper) | C | Upward fining sequence succeeded by vertical accretion fines (T-0 only); stabilized channel flow; accelerated construction of concavo-convex floodplain; Entisol overprinted by gleys | Organic cultural sediments, laterally and vertically variable, overprinted by groundwater activity; probable continuous paleosurface obscured by overthickening of historic sediments and hydromorphic features | Organic sediments overridden by overlying slopewash and alluvium (units 2a and 2b); some bioturbation; lateral stratification and truncation of subjacent fills | Moderate |
| Woodland I; Archaic | 3a (lower) | D,E | Lateral accretion deposits, fining upward sequence; exhumed surfaces, discontinuous, largely truncated; migrating stream; emergence of differentiated basin environment; island surfaces; groundwater podsol | Leached and thin sediment lenses; limited concentrations of lithics and related debris; diffuse concentrations of perishables; no discrete features | Inorganic (upper 3a) to slightly organic (lower 3a; soil "3Ab") archeological matrices within crests of point bars or swale margins of distal former floodplain; laterally and vertically separated to interdigited palimpsests | Moderate |
| Archaic; Paleoindian | 4 | NA | Upper surfaces of Columbia Formation, currently eroded; swampy margins of first and second order drainages characterised by braided streams along downstream reaches and overlooking estuaries | NA | NA | Low |

Table 34. Landscape Context and Archaeological Preservation at Lums Pond

A diachronic site formation model demonstrating the interaction of landscape evolution, settlement, and site preservation is presented in Figures 84-85. It begins during the terminal Pleistocene (ca. 12,000 BP) with the emergence of a fluvial terrace marking a former channel of the late glacial period. It then tracks five (5) depositional, erosional, and soil forming cycles, keyed to the principal intervals in the emergence, occupation, abandonment, and recovery of prehistoric activity loci. The structure of the model follows classic paradigms of landform development bolstered by absolute and cultural chronologies.

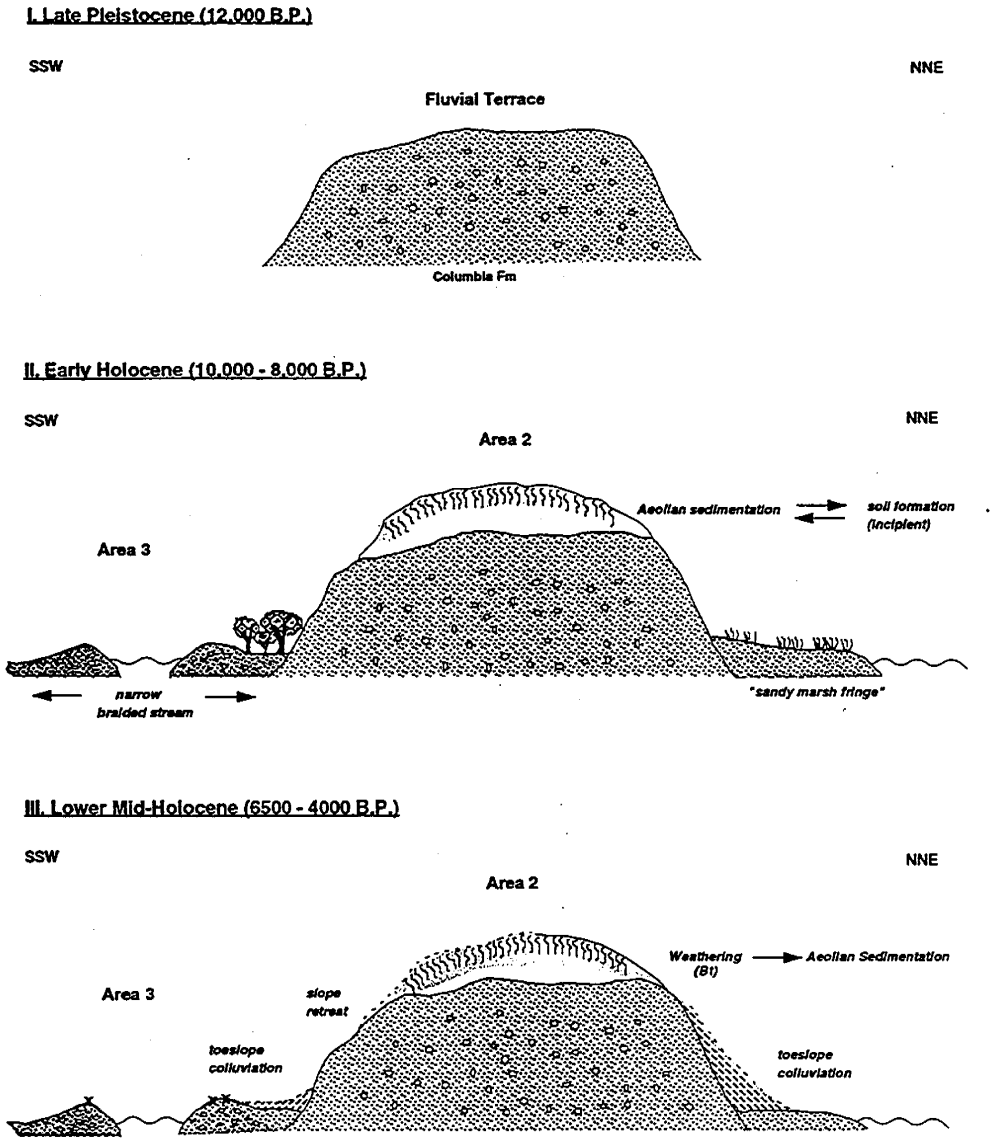


Figure 84. Site Formation Model, Lums Pond, Early Stages

As shown in Figures 84-85, the five cycles conform to critical periods in Delaware's prehistoric chronology. The archaeological record is integrated into the model schematically by denoting the major prehistoric manifestations associated with the primary

depositional sediment bodies and soil horizons. These include features, occupation surfaces (or buried soils), and activity areas. The model covers the principal prehistoric segments, Areas 2 and 3.

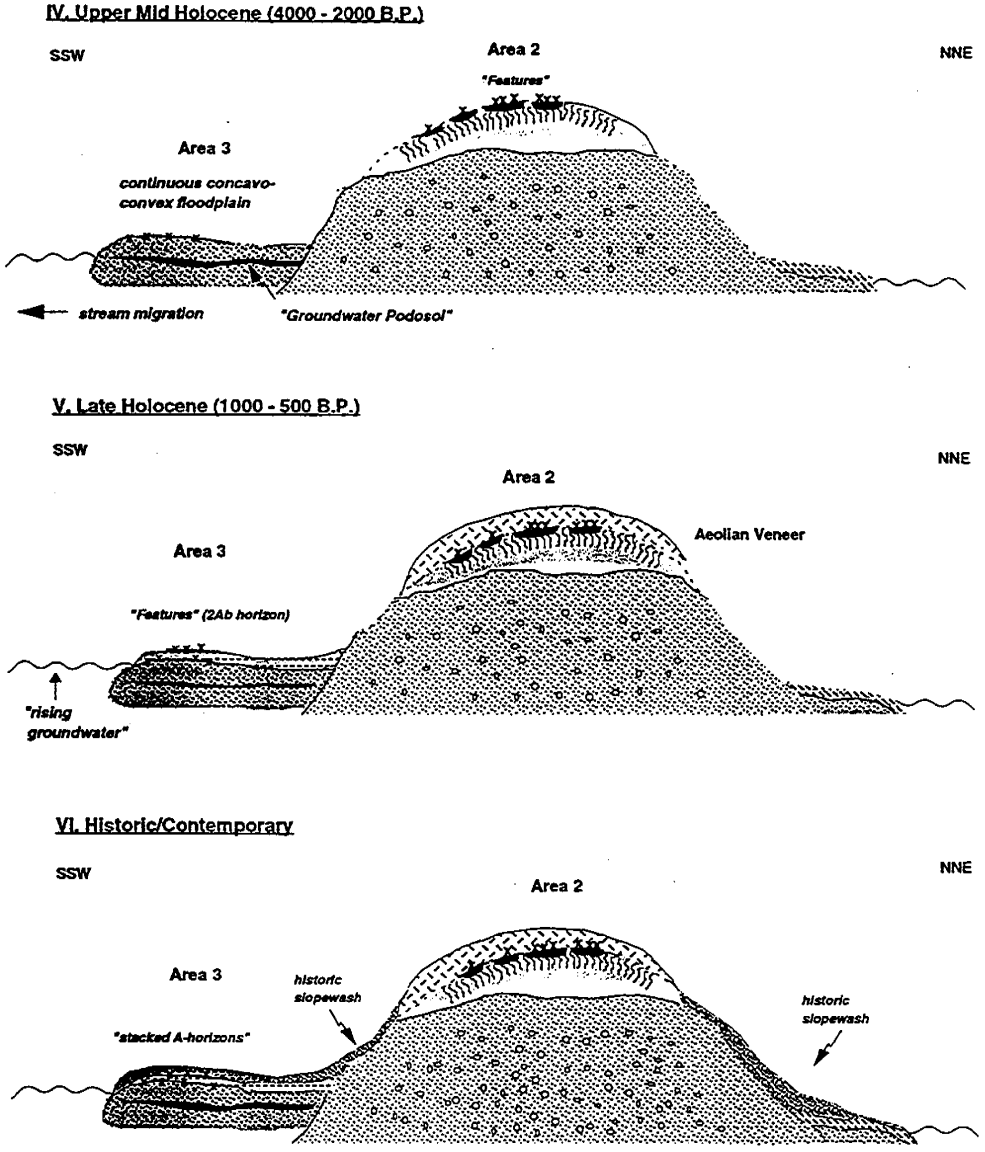


Figure 85. Site Formation Model, Lums Pond, Later Stages

Following the terminal Pleistocene (Cycle I), early Holocene hydrographic adjustments are represented by new channel and drainage nets. The channel floors were covered with reworked gravels and sands and supported a complex of braided stream flows. Supporting sedimentary and stratigraphic evidence was accumulated and dated in Area 2; it was subsequently traced to the basal Holocene sediments in Area 3 At this time the interfluve, which had been eroding, began to accumulate an aeolian mantle. Pedo-sedimentary equilibrium on the interfluve was disrupted in the Early Holocene as the

Argillic soil ("Bt") began to form. Its age has been estimated between 10,000 and 8,000 years. The Early Holocene channel laid down a broad series of sand and gravel bars along a coarsely floored stream bed. At this time the antecedent Lums Pond stream freely traversed the floodplain (Cycle II).

Cycle III (6500-4000 BP) activity was marked by mid-slope erosion and soil formation on the interfluve and initial occupation of the point bars on the floodplain. Archaeological floodplain deposits date to as early as ca. 6300 BP but reliable evidence for widespread habitation does not pre-date 4500 BP. Activity loci was confined to topographic highs and islands formed on former point bars of the meandering stream. By ca. 5000 BP the stream belt narrowed somewhat and a lateral accretion depositional regimen was activated. The Middle Holocene stream traversed a somewhat finer grained channel bed. Stream levels stabilized, as an axis of channel migration emerged concomitant with construction of a laterally discontinuous floodplain, the T-0. Sediment accumulations were laterally zoned and the substrate was permeable because of the dominance of the sandy channel and near channel deposits. The T-0 supported habitable surfaces separated by channels. They may have formed seasonally discontinuous surfaces (i.e., meander scrolls) or longer term islands. While channel movement was generally to the west and south, co-incident with lateral point bar aggradation, during high discharge periods overflow lines traversed more poorly drained bars. Thus erosion of occupation loci kept pace with influx of settlement and habitation of newly created topographic highs on the T-0. Along the interfluve, slopewearing was accelerated, as fines were washed into the toeslopes on both sides of the interfluve.

Following another interval of erosion, Cycle IV (4000-2000 BP) marks deceleration of the fluvial regime and progressive channel adjustment. This resulted in transformations of fluvial landforms (channel and point bars) that eventually coalesced to form a more extensive but segmented concavo-convex floodplain. Sedimentation was initially more rapid and built up the surface. Ongoing aggradation conformed to the latter phases of a fining upward regime. Water tables began to oscillate, in response to changing evapo-transpiration balances. Thicker accumulations of sediment progressively elevated the continuous landform that was in excess of 2 m high. Seasonal inundations are registered by the complex of redox features in the "3Ab" soil horizon. While this probably dictated pursuit of seasonal settlement and subsistence rounds, the cycle witnessed peak prehistoric activity across the highly differentiated Lums Pond landscape On the interfluve, seasonal activities were pursued, as registered by the proliferation of nut and seed processing features dated to 3000-2500 BP.

Between 2400 and 800 BP there is only one (1) dated feature at Lums Pond (1150±90 BP on the interfluve). While a second phase of extensive floodplain exploitation occurred in later Woodland times (Cycle V), evidence suggests that rising water tables

began to create critical drainage problems, and, more significantly, forced realignment of subsistence environments around this time. No formal features are recognized for the terminal Woodland, but an Entisol developed that may have camouflaged discrete cultural signatures (i.e., middens). Channel flow began to stablize as the stream trench was permanently contained in its channel. This is registered by the transition to an overbanking sedimentation regime which reinforced the rising water table by retaining water in impermeable (i.e., clay enriched) substrate. Gleying extended to distal portions of the floodplain and impeded drainage along the toeslope as well. It is probable that as protracted basin impoundment proceeded, the floodplain was abandoned, although evidence would not be expressed stratigraphically, since the following phase of hillslope erosion resulted in accumulations of massive silts along all lower lying segments of the site terrain.

Finally, by historic times (Cycle VI) the upper surfaces across the lower terrain were mantled by a veneer of silts. These are interdigited with contributions from bankfull discharge sands from the contemporary stream, and episodic slopewash. These sedimentation regimes are most directly related to contemporary landscaping. Archaeological materials are all in secondary context, although along the floodplain, some of the earliest historic discharges (Unit 2a) have reworked prehistoric materials on former point bars and island contexts.

*Regional Correlations: Holocene Environments of the Delaware Coastal Plain*

Reconstructions of paleoenvironmental sequences have been attempted across the Coastal Plain of Delaware in conjunction with several prehistoric excavations (Figure 86). The focus of most of the sequences has been on general sedimentology and palynology. Because of the complexity of the Coastal Plain, in which estuarine and continental processes are interactive and dependent on the transgressive Holocene sea level curve (Kraft 1976), these studies have demonstrated a large degree of asynchroneity between paleoenvironmental data sets. As discussed below, neither recurrent nor comprehensive sequences have been confirmed across the physiographic region. There is no widely recognized barometer for regional paleo-climatic patterns, geomorphic responses and site preservation contexts.

The extent of local paleoenvironmental variability is underscored most prominently in Kellogg and Custer (1994), who assembled a series of independent palynological, paleohydrologic, and paleoethnobotanic studies spanning a 40 km Coastal Plain segment along the eastern flank of Delaware's mid-drainage divide (Figure 85). Research centered on upstream and central segments of the Appoquinimink, Smyrna, Leipsic, and St. Jones drainages, all of which empty into Delaware Bay (see Kellogg and Custer 1994: figure 2). Relevant geomorphological and pollen studies have also been undertaken upstream on the

St. Jones in conjunction with excavations at site 7KC 107 (Blueberry Hill) (Heite and Blume 1995). While all locations are within 50 km south of Lums Pond, dates of tidal

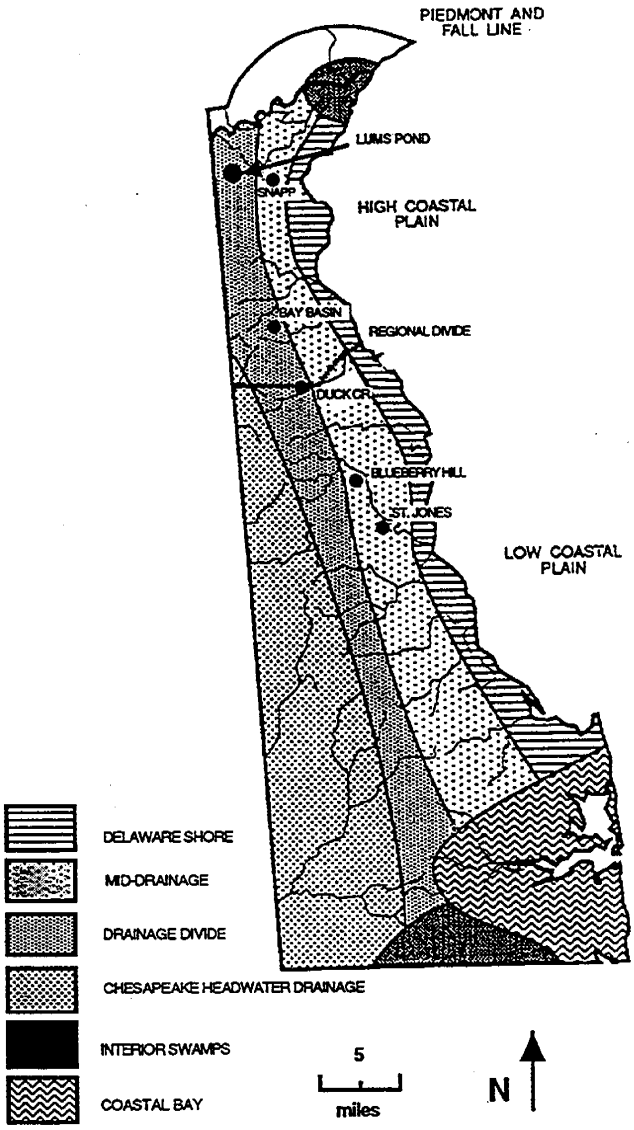


Figure 86. Paleoenvironmental Study Sites in Delaware

incursions fluctuate dramatically from 2000 BP at St. Jones to 500 BP at Leipsic. Comparability of these locations with Lums is further compromised by the latter's location at the northern edge of the Coastal Plain, effectively on the margin of the Piedmont, where unique topographic, hydrographic and geological variables control stratigraphy and sedimentation.

In the absence of a single comprehensive sequence for Lums Pond, Table 35 synthesizes depositional histories for four (4) principal paleoecological settings in central Delaware. In addition to Lums Pond these include Bay Basin settings (Webb et al. in

Kellogg and Custer 1995); the tidal rivers noted above (Rogers and Pizzuto in Kellogg and Custer 1995); and 7KC 107 (Daniels in Heite and Blume 1995). It was only at site 7KC 107 that a variety of component microenvironments analagous to Lums Pond were sampled. Daniels (1995) recognized the paleoenvironmental significance of synthesizing upland aeolian contexts with the alluvial stratigraphy of the St. Jones floodplain. The Bay Basin settings are most similar to Lums in terms of general physiography because these are the only locales situated on the drainage divide within the High Coastal Plain. Finally, the significance of the Central Tidal Rivers is that they represent composite fluvial settings for the duration of the Holocene and thus index broad environmental transitions in stream morphology and chrono-stratigraphy.

| | DEPOSITIONAL HISTORY | | | | PALEOVEGETATION | CLIMATE |
|---|---|---|---|---|---|---|
| | *Lums Pond* | *Bay Basin Ponds* | *Central Delaware Tidal Rivers* | *Blueberry Hill* | | |
| 0 | Accelerated slope erosion; burial of distal floodplain | rapid accumulation of organics and detrital sediment in seasonally dry basins | brackish wetlands; estuarine settings | undifferentiated swamp/floodplain | European settlement | cool, moist to cool, dry |
| 1000 | | | | | | |
| 1500 | vertical accretion; ponding, palustrine incursions | | primarily interval of tidal transgression; proliferation of palustrine biomes; basin infillings | | Oak-buttonbush (tidal basins) | warmer, drier |
| 2000 | Groundwater posolization, palustrine biomes (seasonal?) | | | maximum extent of swamps; peak aquatic biome | | |
| 2500 | | | | | Pine-oak-grasses-emergents (central rivers) | cool, moist |
| 3000 | Stabilization of concavo-convex floodplain; Entisol | | mud deposition signals palustrine biomes; extensive lateral channel migration;fill erosion | progressive palustrine development; basin infillings Pedogenesis (Bw horizon) in uplands | | warm, moister |
| 3500 | | gradual rise in water table to present levels; Initial sedimentation of organics | | | Oak-buttonbush (tidal basins); Oak-pine & bracken ferns (central rivers) | |
| 4000 | ongoing soil formation in uplands (Bt1); slope retreat | | | | | |
| 4500 | | | | | | |
| 5000 | onset of lateral accretion; fining upward sequence | | | | | |
| 5500 | | | | | | |
| 6000 | extensive local erosion | depositional hiatus (four basin locations); lowered water levels and probable deflation | palustrine muds (wetlands) and sands; channeling, incision, & erosion; limited accretion | vertical accretion of fines; overbanking regime extensive deflation & aeolian deposition on uplands | Highly localized because of lowered water tables & extensive desiccation | warm, dry |
| 6500 | | | | | | |
| 7000 | braided stream | | | | | |
| 7500 | soil formation in uplands (Bt2 horizon) | | | Lateral accretion & stabilization of floodplain; soil formation in uplands (Bt horizon) | | |
| 8000 | | | | | | |
| 8500 | aeolian sedimentation on uplands | | Erosion and reworking of channel sands | High discharge channel gravels; bedded sands | | |
| 9000 | | | | | | |
| 9500 | channeling & mobilization of masses of Pleistocene (Columbia Fm) sediment | | | | Spruce-pine-birch-sedge | cold, dry |
| 10000 | | | | | | |

Table 35. Holocene Landscape Correlations for Central Delaware

Table 34 also incorporates key transitions in paleo-vegetation as measured by pollen and paleobotanic records, as well as climatic shifts derived from recent global and regional

circulation models. Paleovegetation interpretations were generated from systematic coring of the Bay Basin localities (Webb et al. in Kellogg and Custer 1994) and the Central Tidal rivers (Brush in Kellogg and Custer 1994). As illustrated in the table, paleobotanic trends were generally consistent across the Coastal Plain until the Middle Holocene (>6000 BP). Subsequently, diverse plant communities emerged in the basin and riverine settings, presumably in response to localized climatic oscillations and progressive estuarine incursions along the mouths of tidal drainages. Climatic models incorporate recent analyses and reconstructions of the Greenland ice cores (Dansgaard 1981; Stuiver et al. 1995).

The most common manifestation in the geomorphic cycles of all four locations is the Early Holocene interval of erosion. As discussed earlier, realignment of drainages subsequent to the melting of the ice sheets and the resultant massive discharges resulted in widespread resculpting of the landscape. At Lums Pond the cycle is indexed with a high degree of resolution, but analogous high energy stream sediments are recognized at all locations. The erosional cycle is consistent with the inferred transition to a progressively warmer and drier climate. It is also significant that along a latitudinal gradient, the dynamic stream pattern persists to 6000 BP at the more northern locales (i.e., Lums and Bay Basins) while more quiescent (i.e., palustrine) settings appear to emerge in the lower elevations to the south (Central Rivers and Blueberry Hill), presumably in response to the still actively rising sea level between 8500 and 6000 BP. Over this interval sea levels were still depressed by 12-15 m and base level grading and estuarine incursion was relatively rapid. The Early Holocene sequences of Blueberry Hill and Lums are remarkably analogous, each registering the onset of inital deflation followed by an enduring phase of weathering ("Bt horizon") in the uplands. Initiation of the lateral accretion regime along the St. Jones is paralleled by the appearance of the braided stream at Lum Pond Creek (ca. 7000 BP). The transition to a meandering stream at Lums around 5000 BP reflects a "lag effect", again associated with the delay in sea level rise to more northern, High Coastal plain elevations.

By middle Holocene times (after 6000 BP) the depositional sequences are considerably more variable across the region. To a large degree this variability represents the higher degree of stratigraphic resolution accompanying the first widely registered depositional (vs. formerly erosional) geomorphic cycle across the Coastal Plain. Further, at all locations the cycle is indexed by a more complete radiocarbon data base. Generally, a discrete Middle Holocene stabilization cycle is registered between ca. 6000-3000 BP. Regional manifestations are dictated by renewed and increased moisture budgets and depressed evapo-transpiration rates, arguably traceable to the transgressive shoreline and expansion of interior basin biomes. Inter-site comparisons show that uplands locations witnessed soil formation, although the Blueberry Hill data may suggest a renewed phase of weathering ("Bw horizon") while Lums indicates sustained evolution of a deep ("Bt1-Bt2") profile. Evidence for proliferation of palustrine habitats and at least seasonally moister settings takes the form of stabilized floodplains (meandering belts are more confined); at

Lums Pond the basal upward fining sequence (Unit 3a) signifies slowed sedimentation while anaerobic features and geochemical indices point to the initial appearance of the groundwater podsol. Paleo-vegetation communities in the bay basins and tidal ponds begin to diverge with the former featuring oak-buttonwood communities and the latter sustaining oak-pine and bracken ferns. Palustrine settings begin to dominate the central (vs. formerly lower) segments of the the major drainages.

The Late Holocene (<3000 BP) is signalled by the long term emergence of the groundwater podsol at Lums Pond. Since Lums is the highest and most interior setting of the sampled locations, it is hypothesized that aquatic biomes, typically flanking the tidal streams, were finally pervasive everywhere across Coastal Plain. Climatic data converge around a transition to a cooler and moist pulse between 3000-2000 BP (see Stuiver et al. 1995). Tidal transgressions apparently peaked at this time in Delaware (Kellogg and Custer 1994), a phenomenon registered at many locations by increases in rates of sedimentation and dominance of fines. Along the St. Jones, renewed channel migration indicates incursions of the estuary and destabilization of base levels that promoted adjustments in sinuosity. Reinforcing trends of vertical accretion, accelerated organic sedimentation and tidal transgression mark the culmination of the Late Holocene sedimentary environment. More recently, Euro-American settlement and farming practices accounted for accelerated run-off and depositional overhauls that recontoured the landscape on an unprecedented scale, but this realignment was not climatically forced.

The principal Holocene environmental trends characteristic of the Delaware Coastal Plain may be summarized as follows:

1) There is considerable intra-regional discordance in the Holocene depositional chronology of the Delaware Coastal Plain;
2) Discordance is attributable to changing rates in sea-level rise and the variable, highly localized impacts of marine transgressions on ecologically sensitive estuarine and fluvial environments;
3) Despite local constraints, it is possible to segregate large scale regional cycles chrono-stratigraphically: (a) Early Holocene (pre-6000 BP; (b) Middle Holocene (6000-3000 BP); and (c) Late Holocene (<3000 BP);
4) Degree of discordance within the region and between local microenvironments intensifies with time; the Early Holocene record is regionally homogeneous while Late Holocene manifestations are most varied;
5) Along primary drainages, the Early Holocene is almost uniformly recognized by undifferentiated coarse sands and gravels signifying emergence of new channel floors and drainage lines in the wake of post-glacial hydrographic adjustments; erosional surfaces (unconformities) signal the end of this period;

6) In the Uplands, several locations point to an initial Early Holocene phase of deflation (ca. 8000 BP) followed by protracted intervals of weathering ("Bt horizons") that continue into late Holocene time;

7) At the Early-Middle Holocene transition interior locations witness stablization of base levels as braided stream systems give way to meandering systems and lateral accretion regimes;

8) As the Middle Holocene progresses, floodplains stabilize with upward fining systems anchoring drainages and creating differentiated palustrine systems along their flanks; groundwater podsolization emerges as water tables rise and climates become moister;

9) The Late Holocene ushers in cooler climates, but rising sea levels coupled with lower evapo-transpiration rates create complex aquatic/palustrine settings across most of the Coastal Plain; groundwater podsols are the norm and peat bogs and swamps proliferate;

10) Accelerated slope erosion buries landscapes in historic (Euro-American) times altering edaphic balances more drastically that at any time in the Holocene past; these alterations are exclusively attributable to cultural practices and only secondarily to climatics.

It is stressed that these reconstructions are tentative and are based on limited paleoenvironmental sampling of discrete meso- and microenvironments. Radiocarbon dates are lacking and detailed sedimentological analysis have only been undertaken at a limited number of locations. Most sequences are based on paleovegetations sampling and document the considerable variability for the later (i.e., post 6000 BP) Holocene. More comprehensive models can be generated from sites such as Lums Pond and Blueberry Hill where investigators have applied interdisciplinary approaches to sample composite landscapes (i.e., upland as well as floodplains) rather than isolated segments of drainages and wetlands.

## Conclusions

Geoarchaeological investigations at the Lums Pond prehistoric site, 7CNF 18, explored the contexts of buried archaeological components ranging the Archaic to historic periods. While >5,000 years of occupation are preserved, the dominant habitation of the site occurred during Woodland I times. It was, nevertheless, possible to develop a >10,000 year model of landscape history, settlement, and site preservation that was linked to a landscape characterized by dynamic alluvial and aeolian micro-environments and stabilized by periods of soil formation during which occupation peaked.

The present investigations were sufficiently comprehensive to facilitate the following reconstructions:

1) The Lums Pond floodplain emerged from the post-glacial adjustment in hydgrography that pervaded the Delaware Coastal Plain; events were directly related to the southeast flowing drainage net of Dragon Creek;

2) Dated early Holocene deposits (ca. 10,700 BP) attest to a dynamic fluvial environment with a broad channel belt dotted by bogs;

3) Such environments were pervasive regionally; synthesis of evidence suggest that contemporary stream environments began to stabilize around 6000 BP as water tables rose the length and breadth of the Coastal Plain;

5) The geomorphic evolution of the Lums Pond site most directly parallels that of the Blueberry Hill site 7KC107) to the south; both registered synchronous alluvial and aeolian depositional cycles punctuated by long term pedogenesis on uplands;

6) Initial occupations along the Lums Pond floodplain probably corresponded with the initiation of a braided stream around 6000 BP; since this was a dynamic migrating stream evidence for earliest (Archaic) habitation is minimal and confined to isolated segments of the floodplain;

7) Progressive stabilization of the floodplain environment occurred sometime in the middle Holocene (ca. 4500 BP), as the braided stream gave way to a meandering channel registered by a lateral accretion (upward fining) regime; it is probable that point bars formed laterally disjunct landforms and occupation surfaces at this time; these segments are represented by the undulating "3Ab" soil horizons;

8) Groundwater podsolization probably accelerated at this time and ccount for differential depths and dates of soil "3Ab"; Woodland I occupations begin to proliferate on these surfaces;

9) Peak Woodland I occupation was initiated after 3000 BP on the uplands and is registered at the top of the upper Argillic solum ("Bt"); this was a period of optimal climate (warm, moist);

10) At the same time, the alluvial regime passed a threshold moving from a lateral accretion to an overbank regime as channel flow stabilized in its present trench; the "2Ab" marks a long interval of surface stability on the floodplain, and persisted through the end of the Woodland period;

11) Following Euro-american incursions, intensification of soil stripping and unchecked agricultural development produced uncontrolled surface runoff and sedimentation resulting in the burial of the pristine landscape and the buildup of surface veneers (colluvium along the distal floodlain);

12) Most recently, relandscaping of the Lums Pond park has been facilitated by hydrographic engineering that has altered the drainage everywhere in the catchment and created seasonally high water tables and renewed incision of the floodplain.

13) Site formation studies show potential to assist in resolving the long standing controversy surrounding the cultural vs. sedimentary

origins of the purported "D-basin" features; geochemical studies focusing on phosphate fractionation can track inputs of cultural sediments into these features chrono-stratigraphically;

14) Geochemical studies can isolate agricultural from anthropogenic and sedimentary/pedogenic earth matrices on a site specific level, even in the absence of traditional artifact data.

15) Inter-disciplinary studies are especially productive in Delaware because of the long tradition of undertaking such ventures and because of the relatively extensive regional data base.

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