CHAPTER 2. ENVIRONMENTAL CONTEXT

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CHAPTER 2. ENVIRONMENTAL CONTEXT

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ABSTRACT

Geomorphology studies were undertaken in support of Archaeological Data Recovery efforts at Site 36AL480 in Leetsdale, Allegheny County, Pennsylvania. The archaeological site was identified within a 30-acre project footprint. Phase III archaeological excavations were performed at three discrete locations, identified as Areas 1, 2, and 3 on the T-3 (third terrace) landform on the right bank of the Ohio River. The geomorphology team was assigned the responsibility of developing a comprehensive stratigraphy for each of the areas. The team worked in conjunction with the three separate contracting groups that undertook the field work. In addition to developing stratigraphies for the T-3, the geomorphology effort undertook investigations of related landforms in the project area, specifically the site of the Casting Basin flanking the proximal end of the T-3 and a Back Channel 5-6 m below the T-3 surface on its eastern margin. Over the course of work, the geomorphologists concluded that a T-2 was inset into the proximal end of the T-3 within Area 2. This location was added to the list of landforms to be examined.

Four primary objectives were identified in the Scope of Work and subsequent modifications to the contract. The first was to reconstruct the paleo-environmental contexts of the site. The second objective included reconstructions of the site vicinity (integrating the T-3 chronology with those of the Casting Basin, Back Channel, and T-2). That task included developing landform histories, identifying the nature and origins of cultural sediments preserved within the excavation areas; formalizing lithostratigraphic successions; establishing disconformities; documenting weathering patterns; and performing geochemical tests on cultural sediments that interdigitated with natural strata. The third objective required inter-site comparisons to develop a regional model of site formation. This was to be done by comparing the Leetsdale sequence with six other multi-component, deeply stratified archaeological sites. Chronostratigraphic frameworks were to be linked to paleo-climatic models to determine the linkage between alluvial histories and climatic forcing mechanisms. The fourth and final objective was to address a series of eight specific environmental research questions.

Field work proceeded between 2001 and 2003, with the geomorphology team undertaking field investigations initially at Area 3-South and then advancing to Area 1 and finally to Area 2. Efforts concentrated on formalizing the stratigraphies by drawing and sampling diagnostic profiles in each area. Systematic soil-sediment sampling included collection of deep column samples to characterize the changing fluvial conditions registered in the sediment packages and to address the duration (chronology) and strength of weathering in the soils that documented stable landscapes in each of the Areas.

The thematic model for site formation, sequence stratigraphy and environmental context centered on a genetic stratigraphy construct that places climatic variability as the primary cause for variability in patterns and intensity of alluviation since the terminal Pleistocene. In practice the implementation of a genetic stratigraphy rests on the construction of a comprehensive sequence succession that enables the identification of time transgressive events across disciplines (i.e., geology, pedology, archaeology, pollen analysis). This is accomplished with the use of an
allostratigraphic scheme that links sequences of one discipline to another by identifying mutual disconformities.

At 36AL480 six (6) allostra - within a 4 unit allostratigraphic system - were identified as follows (earliest to latest):

1. AU-1 (11,500-6500 B.P.)—linked to basal post-glacial sands of a braided stream
2. AU-2 (6500-3000 B.P.)—tied to initial aggradation of the T-3 by lateral accretion
3. AU-2a (6500-4500 B.P.)—intermittent phases of sustained accretion on the T-3 punctuated by soil forming intervals
4. AU-2b (4500-3000 B.P.)—refers to a cut and fill cycle that resulted in construction of the T-2
5. AU-3 (3000-500 B.P.)—overbanking of the T-2 and T-3 resulting in leveling of surfaces
6. AU-4 (<500 B.P.)—historic landscaping on the T-2 and T-3

The chronology of the 4 unit allostratigraphic system was calibrated on the strength of 104 radiocarbon dates. The Leetsdale model was tested on a variety of scales to demonstrate the utility of the genetic stratigraphy approach. It was successful in explaining recurrent geoarchaeological patterns (i.e., recurrent occurrences of Middle Archaic assemblages in deeper portions of the T-3 sediment columns) on the local level. It was even more accurate in predicting recurrent stratigraphic correlations between prehistoric occupations and particular alluvial or soil horizons. The AU system was also tested for an extensive length of the Ohio River and established clear associations between contemporaneous landforms, strata, and cultural affiliations along a downstream axis.

Geochemical analysis of cultural features vs. control samples isolated particular elements that were diagnostic of human activity. These included Ca, K, Mg, and Zn which were all signatures for activity-specific features. More rigorous phosphate fractionation feature testing underscored that Middle through Late Archaic and Woodland occupations across both the T-2 and T-3 were more likely associated with shorter term hunter-gatherer activity than with more sustained prehistoric habitation across an extensive area (i.e., sheet midden).

Additional on-site observations showed that the Casting Basin location was an aquatic setting during the Early Holocene (until 6000 B.P.) before it was overridden by a migrating Ohio Channel. Conversely, the radiocarbon and pollen data indicate that during the Early Holocene the Back Channel was a former flow line of the Ohio before transitioning to a back channel.

It is concluded that the detailed reconstruction of the Leetsdale paleo-environmental history should serve as the anchor for indexing sequence stratigraphies and chronologies for the Upper Ohio Valley, where integrated landscape and cultural histories have not been developed previously.
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INTRODUCTION

Project Overview

Archaeological Site 36AL480 is contained within a 12-hectare (ha; 30-acre) project area on which the U.S. Army Corps of Engineers (USACE), Pittsburgh District, contracted for geomorphological and archaeological survey prior to the construction of two floatable dam segments (Figures 2.1 and 2.2; see Appendix A). The property spans three terrace surfaces (T1, T2, and T3) flanking the right (north) bank of the Ohio River at Leetsdale, Pennsylvania. Within this tract, the 5 ha (12 acre) area that is identified as Site 36AL480 was deemed eligible for the National Register of Historic Places (NRHP) under Section 106 of the National Historic Preservation Act (NHPA). Initial investigations consisted of Phase I archaeological and geoarchaeological efforts that demonstrated the presence of stratified prehistoric deposits to depths in excess of 3 meters (m) (9 feet [ft]) (Davis 2000; Hardlines 2000). More comprehensive Phase II geomorphological testing across the three terraces verified the preservation of Middle Archaic-age and potentially older deposits more than 5 m (15 ft) beneath the T3 surface and across much of the project area (Vento et al. 2001). Separate Phase II archaeological investigations were implemented between September and November 2002 and consisted of six small block excavations (Fenicle 2003). The geomorphological team examined this study area as well, and the results are integrated into the present report.

Provisional mapping of landform segments during Phase I and II testing, identification of archaeologically enriched soils and sediments, and design concerns of the USACE, provided the basis for the designation of three main areas for Phase III mitigation work (Anderson et al. 2005, 2010; Miller and Marine 2005; Miller et al. 2010). These areas are defined as Area 1, Area 2, and Area 3 South; supplementary mitigation areas are located in the Casting Basin and Back Channel (Figure 2.3).

The southernmost of these areas – Area 3 South – was excavated between June and November 2001 (Anderson et al. 2005, 2010). Investigation of Area 1, to the northeast, followed in 2002, between June and November (Miller et al. 2010). To the northwest, Area 2 was investigated in two separate phases. Initial excavations were undertaken between September 2002 and January 2003. The complex logistics, stratigraphy, and depth of Area 2 required that further investigations of the lowermost (fifth meter) trenches be implemented in May 2003 (Miller and Marine 2005). The stratigraphy of the Casting Basin was recorded during December 2001 (Anderson et al. 2003; Anderson et al. 2005, 2010). Examination of the Back Channel stratigraphy occurred through mechanical trenching in July 2002 (Jones 2006; Schudlenrein et al. 2003). Combined Phase III field excavations, backhoe work, and auger cores extended subsurface probing to depths of 7 m across the composite study area.

This document serves as the report on the investigations and findings of the geomorphological assessment of Site 36AL480 conducted in conjunction with archaeological testing and data recovery. The present investigations were performed by geomorphologists...
Drs. Joseph Schuldenrein and Suanna Selby Crowley from Geoarcheology Research Associates (GRA) and Dr. Frank J. Vento (PG-001831-G) from Clarion University of Pennsylvania (CUP or Clarion) under contract to Greenhorne & O’Mara, Inc. (G&O). Geomorphological investigations during all phases included extensive soil sampling and mapping of landforms, sediment complexes, and critical soil horizons that yielded artifacts and organic material for radiocarbon dating. Taken together, more than 350 stratigraphic profiles from across the main excavation areas, Back Channel, and Casting Basin were examined, described, and recorded; these records are augmented by an archive of nearly a thousand photographs. Over 2,000 soil and sediment samples were taken during the Phase III investigations and more than 500 of these were submitted for advanced laboratory testing. The methodologies and results of these field and laboratory examinations are described and discussed in Sections 2.5 and 2.6 below.

Based on these extensive analyses, this report provides a comprehensive assessment of the environmental context of Site 36AL480. This introductory section begins with a brief description of the 36AL480 project area. It is followed by a discussion of the report format and organization that establishes the structure of this presentation on the geoarchaeology of Site 36AL480. Report requirements were formally identified in a series of documents that include the USACE Scope of Work (June 2001); an Effect Report for the recommended Data Recovery Plan for the site (2000); Guidelines for Archaeological Investigations in Pennsylvania (PHMC 2008); the initial contractor’s proposal (G&O 2000) and acceptance of that document by the USACE (2001); and a modification to that proposal and its approval by the USACE in 2002 (see Appendices L through S for selected documents).

**General Description of Site 36AL480 Project Area**

The Site 36AL480 project area is situated along the north bank of the Ohio River. The downstream margin of the area is situated approximately 400 m (1,310 ft) south of the confluence with Big Sewickley Creek. The investigated landforms extend northward for a distance of 700 m (2,300 ft) (Figure 2.1). The project area is located approximately 24.2 kilometers (km) (15 miles [mi]) downstream from Pittsburgh, Pennsylvania, and is currently situated in a mixed residential and commercial zone. Extensive historic landscaping has obscured much of the original topography and some of the upper sequence stratigraphy.

The primary site surfaces are found on the T3 terrace. These surfaces are approximately 170 m (558 ft) northeast of the modern Ohio River channel and its narrow recent floodplain (T0) to the southwest, and 75 m (245 ft) from a relict Back Channel to the northeast. During the course of geomorphological investigations, four distinct fluvial landforms containing archaeological deposits were identified and examined in detail. These include: 1) a narrow, low-lying T1 terrace remnant situated ca. 4 m (13 ft) above the active river channel, or T0 terrace; 2) a slightly higher and broader T2 terrace ca. 5.5 m (18 ft) above the channel and confined to the northern portion of the project area; 3) the broad T3 terrace which lies ca. 6-7 m (20-23 ft) above the active river channel and is bound to the east by a relict Back Channel zone and to the west by either the lower-lying T1 or T2 terrace scarps; and 4) a low-lying and marshy Back Channel zone immediately east of the T3 terrace within the project area (Figure 2.3).
As noted, much of the 12-ha (30-acre) Site 36Al480 project area has been severely impacted by historic excavation, grading, and filling events; much of this disturbance was associated with the construction and subsequent dismantling of the historic Harmony Brick Works factory (Barse 2003; Davis 2000; Miller et al. 2010). The extensive, but irregular, historic period disturbance underscores the fact that contemporary surface relations do not necessarily correspond to past landform zonations. For this reason, in-field measurements and elevations were indexed directly to the site stratigraphic scheme to facilitate comparisons between sedimentologic bodies. Wherever possible, the terrace complexes were distinguished from each other on the basis of both elevation and stratigraphic relations, removing accumulations of fill as a filter in correlation. More detailed descriptions of regional physiography, climate, and biomes (both recent and Late Quaternary), are provided in Section 2.4.

Report Format and Organization

This Environmental Context chapter of the Site 36AL480 final report begins with a discussion of the research goals and objectives in Section 2.2. A series of eight (8) specific research questions were generated that formed a refined focus of the study. Section 2.3 provides a background context for the research. It is a synthetic overview of previous prehistoric and geoarchaeological investigations conducted at the site between 1999 and 2003. These prior investigations produced a preliminary geomorphological model that was tested and streamlined in the present research effort.

Section 2.4 presents a detailed environmental narrative summarizing the physiography, general geology, drainage, and soils mapping in this portion of southwestern Pennsylvania. This section also includes discussions of climate, Quaternary history, and biotic communities as a prelude to a recently synthesized paleoclimatic history of southwestern Pennsylvania (Vento et al. 2008). The latter is utilized to generate hypotheses linking key alluvial episodes and soil formation phases to the stratigraphy at Site 36AL480.

Section 2.5 presents the overall field, laboratory and analytic approaches to the study, a major component of which is the application of an allostratigraphic framework for integrating the linked landscape and occupational histories at Leetsdale from the late Pleistocene to the present.

The results of field and laboratory investigations from primary excavation of Areas 1, 2, and 3 South, Casting Basin, Back Channel, and Phase II Block 6 are presented in Section 2.6. Sequence stratigraphies for each area are presented using the four-unit allostratigraphic scheme generated for the site. The section concludes with a discussion of anthropogenic components and cultural horizons that intergrade with depositional histories and soil formation chronologies for Areas 1, 2, and 3 South.

Section 2.7 provides an intersite analysis, comparing the Leetsdale Holocene reconstructions with contemporaneous geoarchaeological models generated for the broader Ohio Valley along its downstream axis. A key goal here is to determine if the Leetsdale soil-sediment chronologies and settlement histories correlate with broader trends in the physical and human geography the length of the drainage. A second objective is to expand the
correlations with flanking drainages to the east, including the trunk floodplain and terrace landscapes of the Delaware and Susquehanna drainages.

Section 2.8 is the generation of a new synthetic model focusing on the allostratigraphic construct and offering a baseline for a landscape-based model of prehistoric geography and human ecology at Site 36AL480.

Our collective site-specific and regional geoarchaeological observations are summarized in Section 2.9 together with comprehensive answers to the eight (8) research questions posed in the Research Objectives chapter (Section 2.2). Here we also propose a series of hypotheses that can be advanced for testing in future projects of this size and scope.

A series of comprehensive Appendices (A-T) end the report narrative and provide detailed figures referred to in the text, related geomorphological analyses, and additional data tables.

**RESEARCH OBJECTIVES AND PROJECT GOALS**

**Research Overview**

Informed by the results of Phase I and II testing, the USACE’s overall Phase III data recovery plan at Site 36AL480 was specified in its Effect Report and Recommended Data Recovery Plan (DRP; USACE 2000). Phase III efforts were designed to collect and interpret cultural information relating to prehistoric activities at Leetsdale as part of the compliance guidelines to mitigate the adverse effects on the site as caused by the Lower Monongahela River Project construction (USACE 2000). The DRP articulated five research themes for the prehistoric component of Site 36AL480. These include: 1) site settlement patterning (both intrasite/community studies and intersite analyses); 2) subsistence and seasonality studies; 3) cultural chronology; 4) artifact assemblages and lithic technologies; and 5) environmental context. The archaeological component of the study incorporated the first four themes. Three principal areas of the site – Areas 1, 2, and 3 South – were targeted for excavation and multiple archaeology contractors were engaged to conduct the excavations. The contractors for each area were assigned fieldwork and analyses guidelines to address the research themes for their particular area. Ultimately, a single contractor was given the task of integrating the inter-Area observations to generate a comprehensive site-wide report on the prehistory of Site 36AL480.

The fifth theme of the DRP, Environmental Context, provided the focus of the geomorphological and geoarchaeological investigations. The Phase III geoarchaeological effort was synthetic in scope, insofar as it provided the overarching stratigraphic and paleo-landscape framework to guide the field component of the Area-specific investigations. In practice, the inclusion of a project geomorphology team that oversees all phases of archaeological investigations affords a single point of technical expertise on issues of pedostratigraphy, lithostratigraphy, and chronostratigraphy among the numerous archaeology contractors. This synthetic geomorphological approach to Site 36AL480 offered the opportunity to construct a detailed and carefully articulated intrasite genetic model of landform development and human occupation through the Holocene. Such a model presents
not only an exhaustive intrasite reference for archaeological interpretation of human-landscape interaction, but also establishes a platform for the comprehensive regional intersite comparison of deeply stratified sites of the Archaic and Woodland Periods.

This Environmental Context chapter initially targets the landscape history of the Site 36AL480 project tracts. The present report assembles the key results of geomorphological testing from all previous phases of study, inclusive of the earliest archaeological and geoarchaeological work for the three excavation areas, adjacent locations (Casting Basin and Back Channel), and most recent Phase II (Block 1-6) excavations. The results discussed in Section 2.6 below are structured on the strength of the genetic stratigraphy and a detailed radiocarbon chronology; they provide a model of site formation processes and refined microstratigraphic interpretations.

The balance of this section presents the formal framework for our study. It itemizes the Research Objectives and Questions that emerged in various project documents, including the initial Scope of Work (SOW), interim reports and provisional results, and subsequent modifications to the SOW. These documents include the Effect Report and Recommended Data Recovery Plan (USACE 2000); the initial Scope of Work (USACE 2001); the Pennsylvania Historical and Museum Commission Bureau of Historic Preservation Guidelines For Archaeological Work in Pennsylvania (BHP 1991, 2008); the initial Proposal for the study (Greenhorne & O’Mara 2000); Corps of Engineers Scope of Work, Modification 0001 (USACE 2002); and follow-up proposal for Modification 0001 (Greenhorne & O’Mara 2002) as found in Appendices L-S.

**Research Objectives**

As defined by the Scope of Work issued by the U.S. Army Corps of Engineers (USACE 2001), the geomorphology team conducted its investigations at Site 36AL480 by performing services that included both field studies and follow-up research and analysis (USACE 2001: Section III.B). The collection of both field and analysis data sets targeted four general goals (Greenhorne & O’Mara 2000, 2002; USACE 2000; 2001: Sections A, B.2; 2002), listed below with the report sections that address them.

7. Development of an environmental context for the site conforming to the specifications of the DRP and SOW (USACE 2000; 2001) and the Pennsylvania Historical and Museum Commission Bureau for Historic Preservation guidelines (1991; 2008) (Section 2.4);

8. Synthesis of the environmental history of the site, its depositional sequence, and site formation processes, including the T3 terrace and surrounding landforms. Specific strategies for addressing this objective included:

a. Developing a geomorphic history utilizing formal sequence stratigraphy and concepts (including the lithostratigraphy, archaeological horizons, erosional unconformities, pedostratigraphy, and chronological integration of the cultural/biogeochemical data sets) (Sections 2.3, 2.4, and 2.6);
b. Chronicling Holocene site formation processes (Sections 2.3 and 2.8); 

c. Merging of related environmental data sets (pollen, etc.) (Sections 2.4 and 2.6); and 

d. Integrating pedogenic histories and depositional events with climatic stages, events, or related paleoenvironmental mechanisms (Sections 2.4 and 2.6); 

9. Generation of intersite comparisons through development of a regional stratigraphic model (Section 2.7) which 

a. Compares the sequence stratigraphies and landscape chronologies of Site 36AL480 to six other stratified sites, including three sites in Pennsylvania and three sites in the Appalachian Plateau; and 

b. Refines and links the chronostratigraphic framework and atmospheric circulation models; 

10. Assessment of specific paleoenvironmental research questions which examine particular landscape, paleoclimatic, pedostratigraphic, and lithostratigraphic features of the Leetsdale geomorphic record. These include features that emerged over the course of the sustained investigations of the Leetsdale geoarchaeological studies (see discussion under Research Questions below). 

Research Questions 

As indicated by the DRP (USACE 2000), the Upper Ohio Valley, at the time of initial investigations, required comprehensive study of regional depositional histories and alluvial dynamics. A trunk stream site/landform chronology could potentially assist in understanding the articulation between subsurface archaeological horizons and their relationships with, for example, lower order alluvial stratigraphies of the Upper Ohio. The regional framework for site/landform correlations was missing for the Upper Ohio and it could serve as a necessary benchmark for indexing linked changes in landscape development and occupation both regionally and locally. 

At Site 36AL480, the reconstruction of the Archaic Period landscapes was of particular importance, as Phase I and II testing indicated the presence of extensive and varied occupations spanning most of the Holocene and the entire interval between 8000 B.P. and Euroamerican contact. Moreover, the archaeological record indicated a diverse utilization of the landscape (Anderson et al. 2010; Miller and Marine 2005; Miller et al. 2010) that produced a variably dense and specialized archaeological record both spatially (within and between Areas 1, 2, and 3 South) and through time (with depth in each of the Areas). Identification of numerous nearby stream confluences, a succession of well-drained stream terraces, and an active Back Channel or wetlands zone indicated the potential for diverse micro-environments within close proximity of Site 36AL480. Such niches in the Site 36AL480 vicinity indicate optimal conditions for varying subsistence strategies (e.g., hunting, foraging, fishing), settlement opportunities, and raw material procurement (e.g.,
cobble cherts). Contextualization of those localized environments allowed an understanding of what resources were available to prehistoric inhabitants of the Leetsdale site and how these resources may have changed through time.

While the Phase I and II geomorphological investigations provided an excellent foundation for understanding the environmental context of the Leetsdale occupations (see Section 2.3), numerous issues concerning the environmental setting, Holocene climate change, biotic communities, and soil development sequences required refinement during the Phase III studies. As defined by the Scope of Work (USACE 2001), the geomorphology studies for archaeological data recovery at Site 36AL480 were designed to address several key questions concerning the environmental context of the Leetsdale locality and the T3 stream terrace in particular. These questions were also refined and restated in Contract Modification 0001 (Greenhorne & O’Mara 2002; Appendix O, this document). These questions included:

- How did the environmental setting, including climate, sedimentation, and soil formation on site change during the Holocene? Preliminary indications were that the stream regime changed from braided, to meandering, to overbanking over the broader duration of the Holocene. These tendencies might be registered in the varied patterns and rates of sedimentation along the T3 that have climatic and edaphic correlates (see Appendix O, Question 2). The goal was to examine the long-term modifications archived within the natural soil and sedimentary suites of the Ohio main channel as well as in the adjacent Back Channel zone, which contained preserved and dated paleofloral remains (see Section 2.4 and Section 2.6).

- How do changes in climate, deposition, stream flow, fauna, and vegetation relate to settlement activities that occurred at the site? Time transgressive successions in paleoatmospheric dynamics, paleoprecipitation regimes, and paleotemperature collectively impacted the biotic and human communities within the Upper Ohio drainage area. Careful articulation of Holocene soil-sediment packages integrated with biogeochemical analyses and feature/artifact distribution data provide insight into intrasite settlement and subsistence patterning (see Appendix O, Question 1, 6) (see Section 2.4 and 2.6).

- How did flooding of the T3 terrace affect the archaeological evidence of various occupations? Was there any evidence of scouring present? Reconstruction of the Holocene atmospheric systems and resulting modification to the alluviation regime and duration of surface stability and soil formation would be registered in the dated sequences of soils and variably textured alluvial packages. Disconformities and truncated soils are evidence of sustained erosion or scouring events. Positioned across the T3 landform, each excavation area afforded the opportunity to observe distinct but related depositional histories (see Appendix O, Question 6) (see Sections 2.4 and 2.5).
What were the Holocene climatic, depositional, and environmental histories of the Upper Ohio River Valley in the site vicinity? Broadening the context, the geomorphological investigations addressed the local Holocene environments through examination of the Phase II Blocks (especially Block 6) and Back Channel to better define both the stratigraphic and paleoflora communities (see Appendix O, Questions 4, 6) (see Section 2.6).

Bw/Bt/Btx horizon or soil package date ranges appear more recent than similar soil horizons in the Susquehanna and Delaware River valleys. Does this more recent date range hold true based on the data recovery investigation? If so, what implications does this have for climatic conditions in southwestern Pennsylvania as opposed to central and eastern Pennsylvania? The addition of a regional comparative data set of nearby or analogous deeply-stratified, multi-component sites allows for sequence stratigraphy and especially the soil chronologies of Site 36AL480 to be viewed in sharp relief (see Appendix O, Questions 1, 3, 5). The Bw/Bt/Btx is a potential marker for the duration of stable environments as well as micro-climatic variability in such terrace locations (see Section 2.4, 2.6, and 2.7).

Three additional questions were provided in the Modification Proposal from 2002 that consider the following specific issues:

Was the C Horizon emplaced at 4500 B.P., and recognized at sites locally, traceable to the same large cyclonic storm event, or does the Ab horizon at Site 36AL480 temporally correlate with other late Holocene paleosols found throughout the eastern United States? Soil weathering regimes may be regionally variable and the antiquity of the Ab horizon and its solum is not necessarily a regional manifestation. There is some evidence for a localized erosional event around 4500 B.P. in Area 2 (see Appendix O, Question 3, 5). These questions are explored in Section 2.6.

Does the high sedimentation rate during the Middle Archaic Period correspond with warm and dry episodes associated with zonal atmospheric circulation? Paleoatmospheric patterning corresponds with the Middle Holocene evidence for short term cycles of climatic variability that are of regional significance. Section 2.4 explores this issue in greater detail.

Was the abandonment of the Back Channel zone related to changes in the regime of the river, climate, and associated variability in sediment load? The stratigraphy of Area 1, in particular, highlights the unique alluvial contributions to the larger Leetsdale terrace system. The influence of the relict Back Channel, seen both in terms of its stratigraphy and its paleobotanical archive, is considered (see Appendix O, Question 4) (see Section 2.6).
In conjunction with these stated goals, the geomorphology team addressed several additional issues of concern to the contextualization of the Site 36AL480 environmental archive. These include:

1. Comprehensive review and analysis of all Phase I and II geomorphology work at Site 36AL480 (Section 2.3)

2. Development of an intrasite (i.e., area-specific) landscape model linking Leetsdale landforms and prehistoric occupations (Section 2.6);

3. Synthesis of a site-wide landscape history by merging the prehistoric and landform contexts for each area and landform segment (Section 2.6 and 2.8); and

4. Incorporation of new radiocarbon dates and their integration with the landform history model and site-wide sequence stratigraphy (Section 2.6 and Section 2.8).

These research goals, objectives, and questions shaped the Phase III geomorphological inquiry, focusing necessary attention on the rich archaeological data set which emerged from Site 36AL480 during Phase I and Phase II testing. The previous investigations conducted during the period 1999 to 2003 established a preliminary model of landform development and provided baseline perspectives for the environmental context assessment (see Section 2.3).

**PREVIOUS INVESTIGATIONS, 1999-2003**

**Overview of Geomorphological Investigations, 1999-2003**

Several stages of cultural resource testing (Phases I and II) were conducted across the T1, T2, and T3 surfaces at Site 36AL480 between 1999 and 2003 (Davis 2000; Fenicle 2003; Hardlines 2000; Vento et al. 2001). These early investigations were complemented by geomorphological observations of test units, blocks, and trenches that recognized macro- and micro-topographic features of the local landscape, including the identifications of stream terraces (Schuldenrein et al. 2003; Vento et al. 2001) (Figures 2.4, 2.5). In the field, these stream terraces were broadly (but not always; see discussion on historic landscaping in Section 2.1 and 2.3) distinguished by discernible topographic differences which offset the individual surfaces from one another (Table 2.1). The youngest T1 terrace included surfaces between 211.7-213.5 m (695-700 ft); T2 spanned elevations 214.8-216 m (705-709 ft); and T3, the oldest identified stream terrace at the Leetsdale Industrial Park, ranged from 216.9-218.5 m. The terraces were sub-horizontal treads separated from each other by risers, or sloped steps, with a vertical rise of 0.3-0.92 m (1-3 ft). The discontinuous and unpaired character of the terraces, both upstream and downstream of the study area and on the opposite bank of the Ohio River, indicates that these landforms were created during periods of active lateral channel migration associated with slow down-cutting during the Pleistocene and Holocene (Schuldenrein et al. 2003; Vento et al. 2001; Wagner et al. 1970).

These topographic and morphostratigraphic baseline relations provided a landscape framework and were used in the early geomorphological reports (Schuldenrein et al. 2003;
Vento et al. 2001). Subsequent access to historic maps and digital elevation modeling (DEM) resulted in minor adjustments that affected interpretations of terrace sequencing and stratigraphy, as discussed in Section 2.8.

Table 2.1 Landforms and Absolute Elevations at Site 36AL480

<table>
<thead>
<tr>
<th>Terrace/Landform</th>
<th>Elevation m AMSL</th>
<th>Elevation ft AMSL</th>
</tr>
</thead>
<tbody>
<tr>
<td>T0</td>
<td>207.9</td>
<td>682</td>
</tr>
<tr>
<td>T1</td>
<td>211.7-213.5</td>
<td>695-700</td>
</tr>
<tr>
<td>T2</td>
<td>214.8-216.0</td>
<td>705-709</td>
</tr>
<tr>
<td>T3</td>
<td>216.9-218.5</td>
<td>712-717</td>
</tr>
<tr>
<td>Back Channel</td>
<td>210.3</td>
<td>690</td>
</tr>
</tbody>
</table>

This section reviews the early phases of geomorphological investigations at Site 36AL480. Summaries of the scope and extent of these previous geomorphological investigations are presented first, followed by the provisional interpretations that were generated from these studies. The chapter concludes with a series of landform-based observations and hypotheses that were proposed for testing at the Phase III level of investigation.

Christine Davis Consultants, 1999

A Phase I field survey was conducted by Christine Davis Consultants, Inc. (CDC) between September and December of 1999 (Davis 2000). 53 trenches, 34 shovel test pits, and 60 1-x-1-m units were excavated, encompassing most of the site property and accounting for nearly 150 subsurface tests (Davis 2000: 56-57). Several of these excavations extended to depths of 3 m (9 ft). The descriptions of the mechanically excavated trenches were of limited stratigraphic utility at the outset; with the exception of three additional deep trenches (discussed below), they were not recorded by a geomorphologist. More substantial results emerged during follow-up geomorphology investigations (Vento et al. 2001) when the trench and test unit profiled by CDC were integrated with initial geomorphic observations. Archaeologically, the most critical excavation unit was Trench CD 60 (Figures 2.3), which exposed a feature within a buried soil that was radiocarbon dated to 3620 ± 40 B.P. (Beta-141376; Schuldenrein et al. 2003; Vento et al. 2001:38).

In addition to the testing summarized above, three geomorphological trenches (GT-14, GT-13, and GT-12) were excavated across all three terrace landforms (T1, T2, and T3, respectively) to obtain an initial overview of stratigraphic variability between landforms (Davis 2000:42-50). These trenches were located on the northern end of the future Casting Basin location (Figure 2.3). Lamellar bands, containing interbedded oxidized clay-sands and sands at depths of 3.5-7 m below ground surface (bgs) (11.5-23 ft bgs) produced five bulk soil radiocarbon determinations ranging from 11,700-6600 B.P. (Beta 138051 through 138055), and provided the earliest indications of the depth of the sequence and the potential for registering the terminal Pleistocene-Holocene stratigraphic interface at Site 36AL480 (Davis 2000:117-118; Schuldenrein et al. 2003; Vento et al. 2001:17).
Hand excavation of a single 3-x-3-m block (nine 1-x-1-m test units) was completed by Hardlines Design Company (Hardlines) during February 2000 on the T3 landform (Unit BHE-1; Figure 2.3). Four strata were observed to a maximum profile depth of 1.3 m (4.2 ft bgs). The stratigraphy consisted of:

- an uppermost historic fill and plowed surface horizon (Fill and Ap);
- an underlying cambic soil horizon (Bw);
- a weakly developed second generation (sub-Ap) horizon (2AB); and
- an underlying, strongly developed argillic horizon (2Bt).

Three features were observed; these included a post mold and a basin-shaped circular hearth. A circular area of fire-reddened soil with charcoal flecking was also identified, as was a noncultural tree root stain (Hardlines 2000:24-25). In 2002, Hardlines dated a single feature, Feature 3, which produced a radiocarbon date of 2940 ± 40 B.P. (Beta-177992). More than 350 lithic artifacts were recovered from the test units and the features and, in conjunction with diagnostic tools, the data confirmed the presence of a Late Archaic occupation within the Site 36AL480 project area (Hardlines 2000:25-26).

Field investigations for the follow-up geomorphological studies were coordinated by Gray & Pape, Inc. (G&P) and were undertaken over the interval of February 3-11, 2000 (Vento et al. 2001). The scope of work included a pedestrian surface reconnaissance of the project corridor and the excavation and mapping of 15 deep backhoe trenches along five transects (Transects 1-5; Figure 2.4). An additional set of deep units consisted of two freshly excavated tests outside those transects (Trench 6-1 and Trench 7-1), three deep trenches from the CDC study (GT-12, GT-13, and GT-14), and two deep archaeological tests from the former testing phases (CD-60 and BHE-1). Transect locations were aligned with breaks in surface topography and high concentrations of archaeological materials, as determined by initial Phase I work. Based on field relations, surface elevations, and subsurface stratigraphies, the terrace associations for the 20 transect-based and supplementary deep units are summarized in Table 2.2.
Table 2.2 Location of Test Trenches by Landform (1999-2000)

<table>
<thead>
<tr>
<th>Landform</th>
<th>Elevation m ASL</th>
<th>Trenches</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>211.7-213.5</td>
<td>Trench GT-14; Trench 7-1</td>
</tr>
<tr>
<td>T2</td>
<td>214.8-216</td>
<td>Trench GT-13; Trench 4-1; Trench 5-1; Trench 5-2</td>
</tr>
<tr>
<td>T3</td>
<td>216.9-218.5</td>
<td>Trench GT-12; Trench 51/Unit 60; BHE-1; Trench 1-1; Trench 1-2; Trench 2-1; Trench 2-2; Trench 3-1; Trench 3-2; Trench 4-2; Trench 4-3; Trench 4-4; Trench 5-3; Trench 6-1</td>
</tr>
</tbody>
</table>

Over the course of geomorphological testing, more than two dozen cultural features were identified. Of these, nearly all were of prehistoric origin and one was a portion of a historic brick/limestone foundation. The majority (n=22) of the prehistoric features consisted of thin, burnt earth and charcoal stains of irregular shape. These features, generally devoid of artifacts, were tentatively interpreted as surface fires or hearths (Vento et al. 2001) and are similar to features defined as hearths at the St. Albans site in West Virginia (Broyles 1971). The geoarchaeological interpretations from the Gray & Pape study (Vento et al. 2001) were the most comprehensive generated for Site 36AL480 prior to the Phase III excavations and provided the chronological, stratigraphic and paleo-landscape underpinnings (baselines) for the models developed in the present work. Landform relations across the project area were largely generated from the observations produced during this phase of the work (Figure 2.5).

ASC Group, Inc., 2003

In fall 2002, concurrent with data recovery in Areas 1 and 2, the ASC Group, Inc., undertook Phase II block excavations within the Leetsdale project area on the archaeologically rich T3 terrace. Five units (designated Blocks 1-5) were located in a north-south alignment along the eastern edge of the project area adjacent to the former Back Channel (see Figures 2.3 and 2.5). These five blocks were intended to define the horizontal extent of the site along the crest of the T3 surface and its distal margins. The final block (Block 6) was a very large deep test, excavated both mechanically and by hand, that was completed to determine the vertical depths of the prehistoric occupation and to aid in extending the stratigraphies developed for Area 1, Area 2, and Area 3 South. The geomorphology team had a limited window of opportunity to examine the stratigraphy at the Phase II excavations.

Excavations for Blocks 1-5 extended to 3 m (9.8 ft bgs) and were then profiled (Fenicle 2003). The Block 6 stepped excavations reached a depth of 6 m (19.6 ft bgs). Subsequent manual coring under the supervision of the geomorphological team was extended to reach a total depth of 7 m (23 ft bgs) where gravels were identified and the potential for prehistoric preservation was obviated.
Blocks 1, 2, and 5 yielded prehistoric artifacts. The stratigraphy across Blocks 1, 3, 4, and 5 was largely consistent, with a fill mantle overlying a thick package of stacked AC/C horizons underlain by a weakly developed 2BC horizon. Block 2 and Block 6 featured a solum with a moderately well-developed Bw horizon formed above thin AC/C couplets. The AC/C couplets from the other blocks more closely resembled the pedogenic horizonation registered in the upper 3 m (9.8 ft bgs) in Area 1 and Area 3 South. A single cultural sediment matrix, Feature 1 from Block 1, returned a radiocarbon date of 3370 ± 40 B.P. (Beta-177514). That cultural context was close to the location of Hardlines Feature 3 which, as noted earlier, was radiocarbon dated to 2940 ± 40 B.P. (Beta-177992). The Late Archaic to Transitional period occupations bracketed in the uncalibrated 3500-3000 B.P. time range are chronostratigraphically consistent with dated features from Area 1 South derived from analogous upper lamellar sands (AC/C horizons).

In Block 6, the soil profile consisted of a fill capping a Bw horizon, which in turn overlaid lamellae of alternating incipient A and C horizons. The lamellae extended to approximately 3 m (9.8 ft bgs). Between 5 and 6 m, (16.4 and 19.7 ft bgs), lenses of organic rich gleyed soils were indicative of water table movement and earlier Holocene hydromorphic environments. River gravels, as noted above, were encountered at 7 m (23 ft bgs). Block 6 was devoid of artifacts, although a probable hearth (Feature 3) was identified at approximately 1.9 m (6.2 ft bgs).

Geoarchaeological observations at Blocks 1-6 were not entirely consistent with observations made at the distal end of Areas 2 and 3 South. Principally, observations suggest that sediment contributions to the upper T3 terrace were derived from Back Channel flooding. Sub-industrial fill sediment sequences were capped by either a Bw horizon or the AC/C couplets that extended variably to depths of 1-2 m (3.3-6.6 ft bgs), and occasionally truncated a Middle Holocene BC horizon. Since these lamellar sands largely slope to the east, it can be inferred that the relict Back Channel, rather than the main stem of the Ohio River, was the source of alluviation. This geomorphic process is consistent with the development of a natural levee.

Detailed documentation for the geoarchaeological investigations at Block 6 are presented in Section 2.6. An interpretive synthesis, focusing particularly on the emergence of the Back Channel as a major source of later Holocene alluviation, is integrated into the model for the site history and chronology (Section 2.6 and 2.8).

Phase I and Phase II Cultural Chronology

To establish the Site 36AL480 cultural chronology, samples for radiocarbon dating were collected from features in buried contexts as well as noncultural terrace deposits and soil horizons. A total of 21 radiocarbon ages were reported from these early investigations (Davis 2000; Fenicle 2003; Schuldenrein et al. 2003; Vento et al. 2001:38; see Section 2.6 discussion and Appendix B for a complete listing of radiocarbon dates). Of this set, 14 were taken from charcoal in cultural contexts and six from natural horizons (soils or sediments). Dateable specimens from natural horizons were extracted from bulk organic material as well from free (dispersed) carbon/charcoal. The strategy was to isolate horizons that were either equivalent to human occupation or that marked buried surfaces (indicating landform
stability) or environmental breaks (suggesting possible channel migration or terrace erosion) in the overall sequence.

Figure 2.6 presents the distribution of radiocarbon dates, cultural and noncultural, as they were recognized in 2003 (Schuldenrein et al. 2003). This diagram illustrates the known range of dates from natural contexts that spanned the uncalibrated interval 11,500-3500 B.P. Clear evidence for human occupation was identified by the determinations in the encircled cluster which spanned the period 6500-3000 B.P. Figure 2.6 shows that 17 of these 20 dates (85 percent) were obtained from surfaces underlying the T3 terrace, thus underscoring the antiquity and high level of prehistoric sensitivity for that landform (Schuldenrein et al. 2003:3.3-3.4). Establishing the archaeological sensitivity of the Leetsdale landform was an early and significant objective of the preliminary geomorphological investigations (Schuldenrein et al. 2003: Figure A20).

These early landform dates demonstrated the potential for subsurface deposits which could contain evidence of human occupation from the Paleoindian or Early Archaic through Transitional Archaic and extending into the Early Woodland period. Preliminary evidence, based on the most reliable charcoal assays, converged around the preponderance of Middle through Late Archaic occupations within a 4 m (13ft bgs) depth. Phase I work also recovered datable materials possibly confirming the age of later Woodland occupations (Davis 2000). The analysis of samples from noncultural terrace deposits and soil horizons made it possible to develop timelines integrating terrace and floodplain developments with archaeological occupations (Schuldenrein et al. 2003; Vento et al. 2001).

**Initial Geomorphological Modeling, 1999-2003**

In 2001, and in modified form in 2003, a comprehensive overview of the landform relations, stratigraphy, and archaeology at Site 36AL480 was presented as a schematic transect cross-cutting the T2 and T3 landforms (Figure 2.7) (Schuldenrein et al. 2003: Figure 3A.3 revised from Vento et al. 2001: Figure A18). This diagram synthesized the observations from available geomorphic and archaeological exposures; it linked similarly developed soils of comparable age across the Leetsdale landforms, predominantly the T3 terrace. Excavation Area 3 South, Area 3 (northern end), and Area 2 were illustrated in their approximate landscape positions. Trench descriptions were presented in detail in Vento et al. (2001) and summarized again in Schuldenrein et al. (2003). Early in the geomorphological examinations, it became clear that suites or packages of related soils and sediments appeared in exposures across the T3 terrace; deep sections from the T2 profiles revealed strata, and especially soils, at weaker stages of development but with related radiocarbon ages or diagnostic artifact material. These sections were interpreted during the initial geomorphology investigations and served as an excellent guideline for subsequent Phase III investigations.

During Phase I and II work (excluding the ASC Group Phase II testing in 2003), it became necessary to develop a site-wide generic stratigraphy model as both a heuristic device and as a tool for managing the interpretation of soils and sediments visible across the range of landform segments and exposures available on site. Its organizing principle was a site-wide framework that accommodated the variability of geomorphic process, soil
formation, and prehistoric occupation through time and also facilitated a comprehensive model of site formation for the greater Leetsdale landscape.

In geological stratigraphic terms, the units of the model were considered allostratigraphic; they are “mappable…[bodies] of sedimentary rock defined and identified on the basis of bounding discontinuities” (North American Commission on Stratigraphic Nomenclature [NACSN] 1983:865; see also NASCN 2005:1578). While soils can be problematic for identifying surfaces of erosion because of their localized nature and expression, “the upper boundary of a surface or buried soil may be used as a boundary of an allostratigraphic unit” (NASCN 2005:1578; see also discussion in Holliday 2004:76).

In this study it was recognized that, in many cases, buried soil horizons were disconformities and often marked surfaces in which fragile A horizons had been stripped away by erosion. On the terraces, the best developed and extensive horizons (either Bw or Bt) were identified as those most appropriate for separating allostratigraphic units on the site-wide level. Across landforms which did not feature soil formation, allostratigraphic units allowed for the recognition of events that were contemporaneous but which did not leave the same evidence of occupation or of natural events. At Site 36AL480, one example of allostratigraphic equivalence was a floodplain deposit in Area 1 radiocarbon dated to ca. 4000 B.P. and a Late Archaic midden in Area 3-South. Both were found on top of the eroded surface of Allostratigraphic Unit 2 (AU-2). Since these sediments were coeval and had accumulated on the same eroded surface, they both belonged to Allostratigraphic Unit 3 (AU-3). Four allostrata with preliminary date ranges were recognized at Site 36AL480 prior to data recovery excavations in 2003 (Figure 2.7). From bottom to top, these allostratigraphic units (AU) were:

AU-1 Basal sequence of coarse sands, often greater than 2 m thick, capped by sequences of thin, short-term organic soils (AC horizons); these contained the oldest prehistoric deposits that were radiometrically dated to at least the interval 7000-6500 B.P. (Middle Archaic) with non-cultural deposits as old as 11,700 B.P. (Early Holocene);

AU-2 Overlying cambic (Bw), argillic (Bt), or fragic (Btx) subsoils (A horizons were typically stripped), 0.8-2.2 m thick, that developed on finer grained (silt and clay sized) flood deposits and were deeply weathered; sub-soil was thickest in Area 2 and had “stacked” prehistoric features preserved within the brown clay matrix of the soil; the features dated to the interval 6500-3000 B.P. (Middle Holocene);

AU-3 A subsequent series of thin flood deposits capped by shorter term Inceptisols (AB-Bw-C), 1-2 m thick, containing Late Archaic through Woodland deposits; these deposits were deepest in Area 3 South, radiometrically dated from 3000-1500 B.P., and were thin, nearly absent, or truncated by historic fills in the highest terrain of Area 2 (Late Holocene);

AU-4 Irregular caps of historic fill consisting of lead-contaminated construction debris and landscaping sediment (historic). This sediment was stripped locally from the investigation areas prior to excavation.
At depths of 5-7 m (16.4-23 ft bgs) (AU-1), depending on terrace location, gravels marking the Pleistocene/Holocene boundary were recognized. These were signaled by coarse sands and gravels within deeply gleyed and oxidized sandy clay matrices. Immediately beneath the zone of oxidation and reduction, well-rounded coarse gravels and boulders separated the top of the Pleistocene outwash.

The T2 terrace (Figures 2.5 and 2.7), which was not as widely investigated, contained the same basal coarse sands (AU-1) identified in the T3 terrace. This was initially signaled by Phase I geomorphological investigations at GT-13 and GT-14 (see Figures 2.3 and 2.4) that showed lateral continuity of the coarse sands across the entire set of investigated landforms. The coarse AU-1 sands formed the ancient channel bed of the Ohio River during the late Wisconsin glaciation (ca. 11,500 B.P.) when it migrated across the valley floor. On the T2 terrace, however, the AU-1 appeared to have been disconformably overlain, and in places scourred, by sediments of a much younger sequence of autogenic events; these emplaced moderately well-sorted sands of the same age as the AU-3 from the T3 terrace. While the intervening Bw/Bt/Btx horizons of AU-2 were absent, it was not clear if this was a function of scouring over the long history of the landform or due to its depositional setting on the active, proximal margin of the flood zone in an area which was more frequently affected by overbanking events. The uppermost T2 alluvial sediments appeared as sets of fining-upward sands of probable late prehistoric (upper Late Archaic-Woodland) age. Thus, while the T3 elevations were approximately 217 m (712 ft) and T2 elevations were approximately 215 m (705 ft), it was proposed in the geomorphological models of 2001 and 2003 that the upper 2 m of sediment on each landform were coeval. That these capping sediments were as much as 2 m lower in elevation on the T2 terrace reflected the fact that flooding was more frequent and sustained on that surface; discharge on T3 surfaces required higher energy floods that were also less frequent during the later prehistoric period.

During Phase II investigations, testing along the distal end of the T3 terrace extended into a relict Back Channel of the Ohio River (Trench 7-1) with an elevation of 212.3 m (conforming to a T1 position). Within Trench 7-1, at a depth of 2.8 m (9 ft) below a surface elevation of 213.5 m above sea level (asl) (Figures 2.4 and 2.5), organic sediments extracted from the stratigraphic column produced a radiocarbon determination of 3570 ± 70 B.P. (Beta-141381; Vento et al. 2001:38), signifying the date after which the channel was abandoned as a primary stem for the Ohio River. Overlying sediments of dense, organically enriched, strongly mottled silts and clays previewed the location’s potential for preserving critical pollen and paleoenvironmental data which were later obtained during Phase III investigations of Area 1 (see Section 2.6 for detailed discussion of results of this study).

The composite archaeological and natural stratigraphies depicted in Figure 2.7 established guidelines for assessing expectations of archaeological preservation by prehistoric component. The cambic, argillic, and fragic subsoils (AU-2) were the most pervasive context for archaeological associations and were preserved exclusively on the T3 terrace. The uniquely deep, firm, and red soil was a signature for well-articulated features of lower Late Archaic age (i.e., post-5500 B.P.). Earlier occupations were potentially associated with AU-1, but the distributions of that allostratum were diffuse and irregular, reflecting both less intense occupation of the landform during the early Holocene as well as a less stable landform situated in a near-levee position to the then-active river channel. Later
prehistoric materials from the upper Late Archaic through Woodland periods were more firmly linked to weak/moderately developed soils (generally weak A horizons and cambic B horizons) formed on cyclic flood deposits capping the T3 terrace (AU-3). These were present primarily in Area 3 South and the northern end of Area 2. Elsewhere, coeval deposits were truncated by historic and modern grading and land-filling activities (AU-4).

By 2003, Figure 2.8 was presented as an archaeological sensitivity map constructed on the basis of vertical and lateral distributions of artifacts, features, and radiocarbon ages (Schuldenrein et al. 2003:Figure 3A.5; Vento et al. 2001:Figure A21). The time lines were conflated to show areas of high sensitivity for locations predating and postdating 5000 B.P. The map was patterned around the spatial distribution of the AU-2 in which the cambic/argillic/fragic horizon was effectively a marker horizon separating the earlier prehistoric materials (lower Late Archaic and earlier = AU-1) from the later assemblages (upper Late Archaic to Woodland = AU-3). As was demonstrated, the oldest materials were concentrated in an ovate area bracketed by Trenches 3-2, 4-4, and 4-3 and subsumed by the Casting Basin and Area 2. This was the only location featuring intact and deeply buried Inceptisols that housed dated deposits (features) of Early-Middle Archaic age. Figure 2.8 also showed the distributions of the densest later prehistoric (i.e., upper Late Archaic/Transitional, and probably Woodland) complexes within the stacked Inceptisol sequences of AU-3. The densest feature concentrations and most intact archaeological horizons were preserved within the well-developed soils of AU-2. That allostratum extended across Area 1, Area 2, Area 3, and the eastern third of the Casting Basin.

It was argued that the single most sensitive portion of the site was that in which both the Late Archaic/fragic soil (AU-2) and Middle Archaic/Inceptisol (AU-1) associations overlapped (Schuldenrein et al. 2003; Vento et al. 2001). This segment of the site had the highest likelihood of preserving the oldest, near continuous succession of multicomponent deposits. It was defined as an ovate area measuring approximately 60 m (196 ft) along the linear axis and 40 m (131 ft) east to west and was centered on Trench 3-2 and Area 2 (Figure 2.8). This became the zone of intense archaeological investigation during Phase III mitigation.

In summary, the Phase I and II archaeological and geomorphological investigations demonstrated the following:

- The T3 terrace was likely to contain the oldest archaeological materials as well as the widest range of preservation settings;
- There was high expectation for buried archaeological features and discrete assemblages within one of the two to three Inceptisols capping the top of the T3 landform;
- The deep and well-developed soils of the T3 terrace contained one of the richest and most unique preservation settings in which soil “overprinting” had occurred on vertically stacked archaeological features; this setting was observed in the central portion of the T3 landform in the vicinity of Area 2;
The oldest archaeological deposits on the T3 terrace were contained in AU-1 floodplain deposits (Area 2) which began accumulating at the end of the Pleistocene;

The T2 basal (i.e., middle Holocene) deposits were interpreted as higher energy deposits and were less likely to contain intact archaeological materials. It was deemed probable that later Archaic and younger materials were contained within the upper soil-sediment packages;

Soils identified on the T3 terrace had cross-cut the landform and extended onto the T2 terrace. This was true for the upper meter of the T3 landform, where soils were considered time equivalent to the lower Inceptisols on the T2 terrace;

The Back Channel was a potentially rich locus for obtaining pollen and paleoenvironmental data for the past 4,000 years, coincident with most intensive cultural activity on site; and

The (proximal) T1 terrace was an amalgam of historic and recent contaminated fills which had no potential for prehistoric archaeological resources.

This set of observations informed the geomorphological investigation conducted in conjunction with the Phase III data recovery at Site 36AL480. During the course of those investigations, detailed information regarding the environmental record of Leetsdale and the surrounding region was gathered and interpreted. These data and observations are summarized in the following section.

SITE 36AL480 ENVIRONMENTAL OVERVIEW

Overview

This section provides a comprehensive environmental overview for Site 36AL480. It includes discussion of the physiographic, geologic, geomorphic, and biotic components of the present and paleolandscapes, as well as general climatic conditions of the late Pleistocene through modern periods. Taken together, these data provide a more detailed platform from which to examine the ecology of occupation at Leetsdale. As summarized in Vento et al. (2001) and Schuldenrein et al. (2003) and expanded upon here, both the regional and site-specific elements of the environmental record inform the geomorphological and geoarchaeological reconstructions for Site 36AL480.

Since a major emphasis of the geoarchaeological synthesis is linked to a model of climatic forcing, the present section concludes with a summary of broad relationships between late Quaternary climatic episodes and their generic expressions in the Leetsdale stratigraphic record. The baseline stratigraphy developed during the Phase II geomorphology study (Vento et al., 2001; Schuldenrein et al., 2003) served to index key changes in the landform chronology per the working allostratigraphy (see also Section 2.3) and to frame
these sequences in terms of regional climatic trends. A more rigorous assessment of the convergence of landscape histories, climate chronologies, and the archaeological record is developed in Sections 2.6 through 2.8.

**Physiography**

Geologically, the Site 36AL480 study area is situated within the Pittsburgh Lowland Section (also referred to as the Unglaciated Appalachian Plateaus) of the Appalachian Plateaus physiographic province (Briggs 1999; Thornbury 1965). The Appalachian Plateau province extends northeastward from Alabama into New York. The northwestern boundary of the province in Pennsylvania is the prominent scarp in Erie County that drops 90-180 m (300-600 ft) to the Eastern lake section of the Central Lowland Province (Briggs 1999). Structurally, the units within this province consist of gently folded Devonian through Permian age (416-251 Ma [mega-annum, or million years ago]) sedimentary rocks, that display shallow dips of less than 5 degrees to the south/southeast or south/southwest, while strike varies between 60-85 degrees east (Briggs 1999; Edmunds et al. 1999).

The southeastern boundary is defined by the Allegheny Front, an imposing escarpment which overlooks the more varied, linear, and structurally developed Ridge and Valley physiographic province. The Allegheny Front marks an abrupt change in the style of deformation. The strata here turn up abruptly, while beyond they are heavily folded and faulted (Briggs 1999).

On the extreme northeastern boundary of the province is the Wyoming Valley prong of the Ridge and Valley Province. This boundary separates a belt of Pennsylvanian age (318-299 Ma) rock on the west from Mississippian age rock of the Pocono Mountains to the east. Surface rocks of the foreland plateau extend from Pennsylvania into Kentucky, and consist largely of Pennsylvanian age continental and coal-bearing strata. These strata conformably overlie Devonian (416-359 Ma) and Mississippian (359-318 Ma) strata and are succeeded conformably in West Virginia and southwestern Pennsylvania by Permian age (299-251 Ma) lithologies (Berg et al. 1980; Thornbury 1965; Walker and Geissman 2009).

The Pittsburgh Low Plateau section, which includes the Site 36AL480 project area, is the largest section within the Appalachian Plateaus province, totaling 16,800 km2 (6,500 mi2). The section is sharply offset to the east by the west flank of Chestnut Ridge and to the north by the Glaciated Pittsburgh Plateau section. Base levels are developed in the mostly homogeneous bedrock, shale, and subordinate sandstone, but are locally affected by dominant sandstone, siltstone, and limestone (Briggs 1999). Most strata in the Pittsburgh Low Plateaus are gently folded, with dips in excess of five degrees rarely exceeded; folds decrease in amplitude to the northwest. Anticlines and synclinal folds are subdued, reflected by correspondingly minimal and linear topographic highs and lows (Berg et al. 1980; Briggs 1999; Lebold 2005). Jointing is an important structural control on stream channel orientation with many deep and incised streams exhibiting long straight segments. The entrenched character of the regional streams (e.g., upper Allegheny, Monongahela River, Youghiogheny River, and Clarion River) is a function of uplift and subsequent rapid down-cutting in response to Quaternary epierogeny (broad landform uplift). The streams in the section are consequent and exhibit a dendritic (branching) drainage pattern. Glacial outwash terraces
and benches are common along trunk streams, such as the Ohio and Allegheny, which served as outlets for glacial meltwaters. The overall aspect of the Pittsburgh Low Plateaus section is one of broad, rolling interfluves separated by relatively narrow steep-walled, and moderately incised valleys (Briggs 1999; Kaktins and Delano 1999). The ridge tops across the region occur at nearly the same accordant elevation and reflect an erosional surface of late Mesozoic to early Cenozoic age (70-60 Ma) (Briggs 1999).

Local topography of the upper Ohio River is pronounced. Upland elevations exceed 300 m (1,000 ft), and terraces are inset into the excavated bedrock valley (Berg et al. 1980). Maximum T3 terrace elevations are 216-219 m ASL (712-717 ft). The valley itself is considered to be mature, dissected by numerous secondary streams and creeks, typified locally by Big Sewickley Creek that are part of the extensive Ohio River watershed (see Figures 2.1 and 2.2).

**General Geology**

Bedrock lithologies in the vicinity of Site 36AL480 represent a diverse range of Pennsylvanian age (318-299 Ma) sedimentary facies, dominated by the Allegheny and Conemaugh Groups (Berg et al. 1980; Briggs 1999) (Figure 2.9). To the north of the project area, there are local outcrops of the older Allegheny sedimentary sequence. During this period, there was a general eastward shift of marine conditions, which introduced a series of shallow marine transgressions into western Pennsylvania. This is registered by the distributions of limestone (e.g., Vanport Limestone) and shales signifying depositional environments ranging from shallow marine shelf, marine carbonate banks, coastal marshes and swamps, lagoons, and distributary deltas that graded into alluvial plain fluvial distributaries and interdistributary flood basins (Edmunds et al. 1999). These formations contain the majority of the mineable coal seams in the state (PADEP 1999).

The younger Pennsylvanian-age bedrock outcrops, visible across much of the general project area, are from the Glenshaw Formation of the Conemaugh Group (Briggs 1999; Lebold 2005). The Glenshaw locally caps the upland ridges/drainage divides and is characterized by cyclic sequences of shales, sandstone, marine limestones/shales, irregular thin red beds, freshwater limestone beds, and persistent coals (e.g., Freeport and Kittanning seams). The base of the Glenshaw Formation (or Conemaugh Group) is mapped along the bottom of the upper Freeport Coal at elevations in excess of 520 m (1,700 ft) (Lebold 2005). The Glenshaw Formation’s greatest thickness is 115 m (375 ft) to the east of the study area in Somerset County, Pennsylvania (Briggs 1999; Lebold 2005).

The distinguishing feature of the Glenshaw Formation is a series of widespread marine units, including in ascending succession: Brush Creek, Pine Creek, Woods Run, and Ames. Each marine zone incorporates both a limestone and shale facies (Berg et al. 1980; Busch and Rollins 1984). Thicknesses of the generally well-bedded units are lithologically dictated and range from a fraction of an inch to as much as several feet (in some of the sandstones). The shales are typically thin and fissile, while the limestones are well-bedded to nodular. Upon prolonged weathering, the formation accounts for landforms dominated by rolling ridges and hills of medium relief (Lebold 2005). Steeper natural structural dips have produced deeper, narrower stream valleys separated by broad-topped, steep-sided divides.
Natural slopes are moderately stable except in those areas where red beds crop out. Terrain featuring Glenshaw landforms is typically associated with good surface drainage (Briggs 1999; Edmunds et al. 1999; Kaktins and Delano 1999; Lebold 2005).

It should be noted that none of the limestone units in the immediate project area contain chert suitable for lithic stone tool manufacture. The Brush Creek limestones to the south in Greene and Fayette Counties, as well those in northern West Virginia, contain cherty facies which were utilized extensively by prehistoric populations in the region (Eisert 1974; Lothrop and Cremeens 2003; Payne et al. 1981; Stevenson 1906; see also Appendix C).

The Glenshaw Formation is consistently overlain by the Casselman Formation of the Conemaugh Group (Berg et al. 1999; Briggs 1999; Lebold 2005). The Casselman is a heterogeneous unit composed primarily of alternating layers of shale, siltstone, sandstone, and thin, impure freshwater to brackish water limestones. In addition, the Casselman beds may contain thin, non-persistent coal seams and underclay beds; minor red beds, though thin, can be found in the lower part of the formation. Thicknesses range from 72 m (236 ft) (Washington County) to as much as 160 m (525 ft) along the Berlin syncline in Somerset County, Pennsylvania (Briggs 1999).

The Conemaugh Group is overlain by rock of the Monongahela Group that extends from the base of the Pittsburgh Coal to the base of the Waynesburg Coal. The group is divided into the Pittsburgh and Uniontown Formations. The Monongahela Group is dominated by limestone, dolomitic limestone, calcareous mudstones, shales, and thin bedded siltstones, most of which were deposited in low-energy environments (Briggs 1999; Edmunds et al. 1999). Nodular chert suitable for stone tool manufacture occurs within limestone of the Uniontown Formation (Briggs 1999; Edmunds et al. 1999; Lothrop and Cremeens 2003; see also Appendix C).

Depositional environments of the lower interval of the Glenshaw Formation were alluvial plains interspersed with large isolated (coal) swamps, complex fluvial channels, and freshwater lakes (Skema et al. 1982). Sedimentation during the upper part of the formation consisted of a series of at least seven rapid, short-lived, eastward marine transgressions that resulted in the establishment of a shallow-marine coastal plain and associated lower delta plain across all of western Pennsylvania (Busch and Rollins 1984; Donahue and Rollins 1974). By the beginning of deposition ascribed to the Monongahela Group, the northeastern end of the Appalachian Basin was effectively severed from any marine connection. The general environment at this time was that of a relatively low-energy alluvial plain containing widespread coal swamps and freshwater lakes (Edmunds et al. 1999).

**Drainage and Hydrology**

The rugged topography of Allegheny County is mature, dissected by numerous consequent and insequent rills, runs, and streams, which are part of the Ohio River drainage basin. Prior to navigation controls, the principal drainage line, the Ohio River, exhibited a nominal gradient of almost 2 m per kilometer (10 feet per mile) with an average discharge of 590 m³ per second (20,800 ft³ per second) (Kaktins and Delano 1999; USGS n.d.). As noted
previously, these drainage lines and their tributaries feature consequent streams that have developed a dendritic drainage pattern on an older plateau surface (Thornbury 1965) (Figure 2.10). In places, Quaternary uplift has caused entrenchment along some of the major river valleys (e.g., upper Allegheny, Clarion, Casselman, and Monongahela Rivers) (Shepps et al. 1959). Impacts on the drainage evolution are rooted in epierogenic effects, including regional upwarping and rock fracturing. Such controls on drainage may also be exogenic (derived externally) and related to past climates (Kaktins and Delano 1999).

Presently, flows or discharges along the Ohio River and its major tributaries (Big Sewickley Creek adjacent to the Site 36AL480 project area) can vary significantly. Low flow is typically a late summer and early fall (USGS n.d.) phenomenon, while high discharge is more frequent in late winter and early spring because of snowmelt or more effective precipitation (Hoyt and Langbein 1955). Flood recurrence data indicates that the primary site landform, the T3 terrace, lies just within the mapped elevation of the 100-year flood event. The Sewickley Gaging Station (207 m ASL [680 ft] elevation) along the Ohio River recorded over 68 years of discharge data (USDA n.d.). Over this interval, the largest single discharge occurred on March 18, 1936, with a stream flow of 16,200 cubic meters per second (574,000 cubic feet per second) and a gage height of 10.5 m (34.75 ft) (Moseley 1939); the latter is 10.6 m (35 ft) above the present river level. Other high discharge events which would have inundated at least part of the T3 terrace include the 1943 (gage height 8.35 m [27.39 ft]) (Moseley 1944); 1972 (gage height 7.45 m [24.42 ft]); and 1996 (gage height 10.2 m [33.34 ft]) floods (NOAA 2008, 2009). Several other inundations have extended to over 6.7 m (22 ft) above gage height 207 m (680 ft) (USGS n.d.).

Today, as in the past, flooding along the Ohio River results from storms of three basic types (Noren et al. 2001; Vento and Rollins 1989; Vento et al. 2008). First are cyclonic storms, produced by the converging inflow of warm air from the Atlantic Ocean within the warm sector (between the cold and warm fronts) of slow-moving mid-latitude cyclones embedded within a cool season meridional flow regime (Bond et al. 2001; Carbone 1982). Floods of this type can be especially large if they are augmented by snowmelt and/or saturated soil conditions. Second, south/southeastern tropical storms and hurricanes produced sizeable recent floods over both small and large portions of the basin (Chapman and Shackleton 2000). Over the last 150 years, seven large regional floods (1903, 1936, 1955, 1972, 1975, 1996, and 2004) were caused by intense tropical cyclonic storms (NOAA 2009). These events typically eroded and/or laid down sediment on low terraces bordering the major drainage lines (Henderson and Vega 1996). Third, localized but intense summer and autumn thunderstorms caused significant upstream flooding over small watersheds (Knox 1983; Vento and Rollins 1989). These would have had limited effects on the Ohio main stem, but would have impacted Sewickley Creek, possibly even affecting the course of the drainage line. Finally, some local drainages (e.g., Oil Creek at Franklin, Pennsylvania) may have been inundated because of melting ice jams during late winter and early spring (Vento et al. 2008).

Review of hundreds of alluvial profiles in Allegheny County converge around the probability of significantly more frequent, higher magnitude events of bankfull discharge over the last 150 years than prior to the European contact (Vento and Rollins 1989). This
was especially notable for tributary streams. Increased inundation is likely a function of several factors, including: 1) increased land cover of impervious materials (roofs, pavement, and cement) due to urbanization; 2) higher surface availability of deforested lands (timber, agriculture, strip-mines and pasture); and 3) the size of area served by storm sewers. Since flooding frequency and magnitude is a function of rainfall/runoff relations, urbanization is largely accountable for increased inundation, as well as the diminished lag time between peak rainfall and maximum discharge (Vento et al. 2008).

**Mapped Soils**

The soils within the 12-ha (30-acre) Leetsdale Casting Basin project area are mapped as the Urban Land-Rainsboro-Philo Association and specifically the Urban Land series (USDA 1981). Urban Land refers to soils which have been severely modified and impacted by historic activities (roads, buildings, utility lines, etc.). Prior to historic impact, however, these soils would have been mapped to the Allegheny Variant, Rainsboro, or Philo series. In examining small isolated upstream and downstream segments of the Ohio River, which exhibit fewer disturbances, it appears that the T1 and T2 terraces at Leetsdale are best assigned to the Philo series, while the higher T3 terrace is associated with the Rainsboro series (USDA 1981).

Philo soils are described as coarse loamy, mixed, active, mesic Fluvaquentic Dystrudepts, typically very deep and moderately well-drained on flood plains. They formed in recent alluvium derived mainly from sandstone and shale. Permeability is moderate to moderately rapid. Slope range is 0-6 percent. The mean annual precipitation in the Leetsdale area is about 109.2 cm (43 in) and the mean annual temperature is about 11 degrees Celsius (52 degrees Fahrenheit). The potential for surface runoff is low or very low, and permeability is moderate to moderately rapid. A seasonally fluctuating water table rises to within .5-1 m (1.5-3 ft) below the soil surface. Diagnostic horizons and features in this pedon are an Ochric epipedon, specifically a Cambic (Bw) subsoil. It also has a Udic soil moisture regime and Fluvaquentic features (e.g., irregular decrease in organic carbon and low chroma) (USDA 1981).

Rainsboro soils are fine silty, mixed, superactive, mesic Oxyaquic Fragiudalfs. Rainsboro soils are deep, moderately well-drained and formed on high stream terraces, some of which lie more than 92 m (300 ft) above the present river channel. Permeability is moderate to rapid depending on texture and the presence or absence of well-developed fragic features within in a clay-rich soil (Btx) or a proper silty fragipan (Btx). Slope ranges from 0-5 percent. These soils are associated with areas having mean annual precipitation of about 99 cm (39 in), and mean annual temperature of about 11 degrees Celsius (52 degrees Fahrenheit; USDA 1981).

**General Climate**

Allegheny County has a cool and humid, temperate climate (USDA 1981). Precipitation is distributed through the year with a slight maximum in May, June, and July. Seasonal soil water budget deficits typically occur during late August, September, October, and early November as a result of decreased effective precipitation. There may be wide
fluctuations of precipitation within a given year. Although Allegheny County receives an average of 1066 mm (42 in) of rainfall per year, it has experienced extremes of 89 cm (35 in) to as much as 142.2 cm (56 in) (USDA 1981).

The months of December, January, and February frequently have temperatures below freezing. Unofficial recordings as low as minus 34 degrees Celsius (minus 29 degrees Fahrenheit) have been recorded in certain localities. Late spring, summer, and early fall temperatures are warm and sometimes even hot, but average around 18 degrees Celsius (65 degrees Fahrenheit). The average length of the growing season is 116 days. Typically, May 27 is the date of the last freeze in spring and there are occasional surges of several hour freezes in mid-September. These ephemeral extremes are found where valley inversions exist and air drainage is retarded in restricted valleys. Daily changes of temperature during the winter and early spring cause frequent freezing and thawing of the ground, most commonly on south and west slopes, which have little or no vegetative cover (USDA 1981).

In the Koppen Climate Classification system, Allegheny County is considered a Humid Continental (Dfa) climate. This category is characterized by frequent weather changes associated with the passage of migratory pressure systems, most notably during the cool season. Significant climatic oscillation is associated with the regional location within the global westerly wind belt that explains for both high diurnal and seasonal variability (Vento et al. 2006; USDA 1981).

Temperature

The warmest months occur during the summer season, while the coolest temperatures occur during winter. Over the long term, the warmest month is July, which is only slightly warmer on average than August. Average summer temperatures exceed 32 degrees Celsius (90 degrees Fahrenheit) only occasionally for most of the region but may be expected to occur for short durations during July and August in Pennsylvania (USDA 1981). Average winter temperatures are fairly low with all three winter months recording below freezing normals. Diurnally, low temperatures during the cold season may dip below zero degrees Celsius (32 degrees Fahrenheit) with regularity. Occasionally, the diurnal high temperature may remain below the freezing mark. Coldest temperatures are usually the result of migratory anticyclones that move into the region when persistent jet stream troughs extend over eastern North America. The typical progression of such events includes passage of a fairly strong mid-latitude cyclone embedded within the jet stream flow. As the cyclone, and more particularly the cold front, progresses through the area, winds shift from southwesterly to northwesterly. Such veering indicates onset of the anticyclone that follows the temperatures through nighttime radiational cooling (loss of diurnally stored terrestrial radiation) (Vento et al. 2006; USDA 1981).

In terms of the circulation systems, the most extreme heat waves are accompanied by relatively dry conditions that result from a persistent anticyclone blocking pattern over the North Atlantic Ocean. Such blocking inhibits the migration of mid-latitude cyclones through the region, in addition to providing low level subsidence that inhibits convective precipitation. However, normal summertime conditions are somewhat humid as a result of warm air advection from the southwestern North Atlantic and the Gulf of Mexico. This flow
is stimulated by the strength and position of the North Atlantic Subtropical High pressure cell (STH). This semi-permanent atmospheric feature reaches maximum strength and poleward position during the peak summer months. The STH occurrence results in high regional humidity levels (50-70 percent at eight p.m. readings) although not nearly as high as humidities recorded in the southern United States (Vento et al. 2006).

In examining the detailed temperature data for Pennsylvania restricted to the period 1895-1991, there is an apparent high degree of inter-annual variation above and below the long-term average temperature of approximately 11 degrees Celsius (52 degrees Fahrenheit). The early record was typically below normal, while the middle portion remained above normal. The last half of the record shows primarily depressed (sub-normal) temperatures until the onset of a slight warming trend during the late 1980s and early 1990s. However, statistical testing revealed no long-term trends of any kind. The Chow statistical test for changing variance supports the qualitative assumption of a decrease in temperature variability through the time-series (Vento et al. 2006).

Detailed analysis reveals that a statistically significant decrease in variability began in the early 1940s and continues through the recent record. Such a change is inherently related to jet stream variability. Leathers et al. (1991) denote a statistically significant change in longwave (jet stream) amplitude beginning in the late 1950s and continuing through the recent record. They show that in approximately 1958, the polar jet stream increased in amplitude over North America. Because of the continental distribution of mountains and oceanic currents, the jet stream has shown persistent troughing over the eastern United States since that time. This accounts for both the latter record decrease in temperatures and the decrease in variability as seen in the time-series (Leathers et al. 1991).

Precipitation

In western Pennsylvania, the wettest months are July and August, which both normally record 102 mm (4 in) of precipitation (USDA 1981). The totals are largely associated with convective precipitation generated from the high average temperatures and the influx of moist air on the lee side of the North Atlantic STH. Evapotranspiration also acts as a moisture source, as ET rates are typically highest during the warmest months (Vento et al. 2006). However, elevated ET rates may quickly deplete soil moisture storage, especially during the latter portion of summer. Therefore, ET is likely an important source of water vapor for only early summer convective processes. The high ET rates through summer are also responsible for vegetative stress. Even though the highest precipitation totals are achieved during the summer months, the totals are not high enough to offset the amount of summer ET during July and August throughout the region. Also, a three- to four-week dry period is normal for the region as longwave blocking patterns become established in the North Atlantic (described above). Such blocking is normally associated with strengthening and migration of the STH during early summer. Large-scale moisture advection into the region does not occur until after the STH becomes entrenched in its poleward position (Vento et al. 2006).

The driest month on record is February, which typically records 73 mm (2.9 in) of precipitation (USDA 1981). This “dry” period occurs as the jet stream adjusts to its typical
wintertime position. The normal position for the jet stream during the winter months includes a moderate to highly amplified ridge over the western United States, and a moderate to highly amplified trough over the eastern US. This results in reduced and colder temperatures for much of the east coast. Precipitation is generated by mid-latitude cyclones in the deepest portion of the jet stream trough because of upper atmospheric speed divergence (venting) and cyclonic wind shear. The cyclones usually migrate through the trough and dissipate into the downstream ridge, typically located over the North Atlantic Ocean where it has significant impact on the east coast (Vento et al. 2006).

Because mid-latitude cyclones represent the primary precipitation forcing mechanism for western Pennsylvania, they are inherently linked to the jet stream. Therefore, it is prudent to briefly examine the annual characteristics of jet stream variations.

The jet stream represents a thermal boundary between cold polar-induced air to the north and warm equatorial-induced air to the south. The jet stream gains its energy from the thermal contrast associated with the latitudinal thermal gradient. During the winter months, the latitudinal thermal gradient reaches a maximum as the pole is shrouded in perpetual darkness. At this time, average jet stream location dips equatorward as the atmosphere seeks to balance the extreme latitudinal thermal inequalities (Bond et al. 1997). In the height of winter (February), average jet stream position is along the northern Gulf of Mexico. Cyclones generated in the jet stream trough typically develop over the western Gulf of Mexico where a steep local-scale thermal gradient exists between the relatively cold continent and the warm waters of the Gulf. This region in the atmosphere has produced some of the most extreme mid-latitude cyclones on record (Chapman and Shackleton 2000). Once formed, the Gulf Lows migrate up the east coast of the United States between the Appalachian range and the coast, bringing copious precipitation in the form of rain, sleet, freezing rain, and/or snowfall, depending upon a particular areas location to the center of the low. Dissipation typically occurs over the New England states (Vento et al. 2006).

During the spring months, jet stream position shifts northward as the polar region warms with increased solar incidence through the Arctic Circle. Average jet stream position is typically located over the middle portion of the United States (the trough is located over the northern Gulf States, Tennessee, and Kentucky area). Cyclogenesis usually occurs with regularity over Colorado (Crowley and North 1991). These Colorado Lows skirt through the trough region over the Gulf States and finally northeastward, where dissipation typically occurs into the downstream ridge located over the New England states (Vento et al. 2006).

Summertime mid-latitude cyclones usually originate in Alberta, Canada, as the jet stream retreats to its most northerly position near the United States-Canadian border. During this time, the polar region receives constant diurnal insulation that raises temperatures to comfortable levels. The Alberta Clippers that form during these times are relatively weak as compared to Gulf and Colorado Lows. They typically migrate across the northern tier and occlude over the extreme northeastern United States and southern Canada. Such migration occasionally produces mid-latitude cyclone induced precipitation in Pennsylvania and an influx of cooler drier air even during July and August (Vento et al. 2006).
Irrespective of the sources of the mid-latitude cyclones, they invariably affect the northeastern United States, which serves as the occlusion region. Long periods of unbroken cloudiness and light precipitation are normal during the cool season, as one mid-latitude cyclone dissipates and another progresses into the region (Vento et al. 2006).

Summarily, this examination of modern atmospheric dynamics—particularly jet stream position, precipitation patterns, and long-term temperature variability—is pivotal for calibrating systematic variation of the Late Quaternary paleoclimatic record. In our subsequent discussion, we attempt to merge an understanding of circulation variability to the proxy measures of climatic change signaled in the alluviation and soil forming chronologies of the Leetsdale stratigraphic record. These, in turn, assist in framing the linked histories of environmental change and occupation at Site 36AL480.

**Quaternary History and Fluvial Geomorphology**

The Late Cenozoic (pre Pleistocene) topography and drainage patterns of the Appalachian Plateau were much different from those of today. Topographic relief was much lower and drainage direction was dominantly north and northwest (Beynon and Donahue 1982; Ray 1965; Wagner et al. 1970) to basins ultimately occupied by the Great Lakes (Figure 2.11). Data supporting this northwestward drainage flow is based primarily on the northward slope of the upland surface, as well as the occurrence of deep, glacially buried, river valleys with gradients to the northwest. The diversion of the present upper Ohio drainage to the Gulf of Mexico was considered to be affected by Pleistocene glaciation (Kaktins and Delano 1999). There is no clear date for establishment of the northward drainage other than that it must have occurred after the end of the Permian (250 Ma). This is the moment when the youngest Appalachian basin sediments were deposited, but long enough before the Pleistocene stream reversal for the development of fairly wide, mature valley bottoms, now filled and buried with glacial drift (Benson and Thompson 1987; Kaktins and Delano 1999). At this time, prior to the Pleistocene reversal, the present Ohio River did not exist. In fact, two main river systems drained the western Appalachian Plateau (Thornbury 1965; Vento and Rollins 1989).

The Teays Mahomet River flowed from the piedmont area of Virginia and West Virginia northwest into Ohio, Indiana, and Illinois (Beynon and Donahue 1980; Kaktins and Delano 1999). Final drainage was either through the pre Great Lake Basins or the Mississippi River (Beynon and Donahue 1980). The other drainage network was the Monongahela Beaver to which the Ohio River and Lower Allegheny were tributary. This system drained the Allegheny Plateau and flowed north into what is today the Lake Erie Basin (Leverett 1934).

During this time, the relatively flat land surface was uplifted and the plateau rivers responded by incising their valleys (Figure 2.12). What is left today of this nearly level, erosional surface is a sequence of flat-topped hills or summits with elevations of between 360–430 m (1,200 1,400 ft) ASL. As incision slowed, a second terrace level was created. This terrace surface is commonly termed the Worthington Erosion surface and typically occurs along the major river valleys at elevations between 330-350 m (1,080 1,140 ft) ASL (Vento and Rollins 1989).
Following establishment of the Worthington surface, a second period of incision occurred along the Ohio and Allegheny Rivers. Eventually, as incision slowed, lateral channel migration occurred forming a well-defined wide valley floor. The remnants of this early flood plain now lie 275 m (900 ft) ASL, or 61 m (200 ft) below the Worthington Erosional Surface and 91.5 122 m (300-400 ft) below the Allegheny Peneplain. This relic valley floor has been termed the Parker Strath, from a typical occurrence near Parker, on the Allegheny River in northern Armstrong County (Vento and Rollins 1989). The present Allegheny River and its associated tributaries from Olean, New York, to Pittsburgh, Pennsylvania, were once three separate rivers: a Lower, Middle, and Upper Allegheny (see Figure 2.11). The Lower Allegheny began at the Clarion River and flowed south to join the ancestral Monongahela River at Pittsburgh (Figure 2.13). The Middle Allegheny course drains through present day Oil City and Franklin and then northwest, along what is now French Creek, to the ancestral Erie Basin. In New York State, the Upper Allegheny flowed through the present site of Olean and into the ancestral Erie Basin just south of Dunkirk, New York (Shepps et al. 1959).

Although five major glacial advances and retreats are recognized in the United States (Richmond and Fullerton 1987), only the last two advances (Illinoian and Wisconsin) can be clearly demonstrated to have reached northwestern Pennsylvania (see Figure 2.13). Sediments of the pre Illinoian (before 310,000 B.P.) advance are not present south of the mapped Illinoian drift sheet and, hence, have been extensively reworked by later glacial advances and retreats (Crowl and Sevon 1999; Flint 1971). As the Illinoian (310,000 B.P.) glaciers advanced into northwestern Pennsylvania, the ice sheet blocked the north flowing streams causing ponding (lake formation) episodes to occur. However, by the time Illinoian ponding occurred in the Monongahela River, or shortly afterward, the course of the modern Ohio River had been created by a breach of the drainage divide near New Martinsville, West Virginia (Hamel 1987). With the onset of the Wisconsin ice advance about 70,000 years ago, glacial meltwaters once again filled the Ohio and Allegheny valleys (Wagner et al. 1970). These major drainage outlets were packed with glacial outwash that in places reached a thickness in excess of 115 m (e.g., along French Creek). These Wisconsin-age (22,000 to 14,000 B.P.) deposits are often termed the first bottom (late Wisconsin outwash) and second bottom (early Wisconsin outwash) soils along the Allegheny and Ohio Rivers at Pittsburgh (Crowl and Sevon 1999; Wagner et al. 1970).

During the terminal late Pleistocene (11,000 B.P.) and early Holocene (10,000 to 9000 B.P.), drainage systems responded to: 1) increased evapotranspiration; 2) a thicker vegetative cover; 3) a lowered base level; 4) warmer temperatures; and 5) a decrease in discharge and accompanying sediment load. Consequently, the Ohio and Allegheny Rivers, as well as their major tributaries (e.g., Clarion River, Redbank Creek, French Creek), adjusted their channels by incising Wisconsin valley-fill deposits (Crowl and Sevon 1999; Wagner et al. 1970). The result was the emergence of several Wisconsin-age terraces currently at varying heights (3.5-9 m [10-30 ft]) above the active river channels (Figure 2.13). The lowermost terraces are typically mantled (often unconformably) by a variably thick package of fine-grained, vertical, accretionary deposits of Holocene age, and/or historic fill. The T1, T2, and T3 terraces mapped within the Site 36AL480 project area are correlative with these persistent low terraces previously identified along other segments of
the Allegheny and upper Ohio river valleys (Schuldenrein et al. 2003; Vento et al. 2001; Wagner et al. 1970).

**Biotic Communities**

The Late Quaternary successions of paleobiotic communities are key barometers of both landscape and climatic change. In this section, broad trends in the transition from late glacial to postglacial paleobiotic communities are examined, ultimately exploring the more subtle biotic transitions characteristic of the Holocene. The sections on paleoflora, and especially Holocene flora, are emphasized in some detail, since pollen and paleobotanic studies were undertaken in concert with the geomorphological investigations at Site 36AL480, specifically in the Back Channel, Casting Basin, and Area 3 South (see Figure 2.5; Johannessen 2003; Jones 2006). In the following sections, the natural vegetation chronologies at Site 36AL480 are stressed, insofar as they have implications for both regional and local ecological reconstructions. More comprehensive interpretations, formally linking the bio-stratigraphies to the allostratigraphic model, are developed in Section 2.6.

**Paleoflora**

Evidence for Late Quaternary glaciations (84,000-73,000 B.P.) is registered far to the north of the Site 36AL480 project area. That expansion was followed by a long interglacial/interstadial stage with accompanying soil formation at approximately 30,000 B.P. The major advance of the Laurentide ice sheet took place during the late Wisconsin stage, about 22,000 B.P., and culminated in a maximum ice movement at approximately 18,000 B.P. (Crowl and Sevon 1999). The ice sheet was in full retreat once again by 10,000 B.P. (Barry 1983). Interglacial/interstadial climatic conditions were again established, but with a lengthy, slow transition characterized by several pulses, which lasted from ca. 15,000-10,000 B.P. (Watts 1980a; 1983:300).

While the margin of the late Wisconsin ice sheet was positioned to the north, the effects of glaciation in the form of periglacial landforms and features are present throughout the region. Typical landscape features include rock fields, shale chip rubble zones, rock streams, alluvial fans, and asymmetric valleys. According to Watts (1979), lands lying within 65 km (40 mi) from the full maximum glacial limit consisted of tundra, dominated by boreal forest and jack pine forest ecotones. Pollen assemblages from late glacial deposits in the eastern United States contain high quantities (up to 40 percent) quantities of sedge, indicating tundra environments (Bartlein et al. 1984; Davis 1983; Davis et al. 1975; Delcourt 1979; King 1980).

A number of late Wisconsin age floral localities in Pennsylvania (e.g., Rose Lake, Crider's Pond, Longswamp, Tannersville Bog, and Corry Bog) have provided important information on the composition of the probable floral community present in the general project area during the full glacial (Woodfordian Stade) and also during the final retreat of the late Pleistocene ice sheets (Cotter 1983; Cotter and Crowl 1984; Karrow et al. 1984). The information presented herein draws on localities throughout the state, but in proximity to the glacial margin.
At approximately 13,000 B.P., the principal floral taxa at Crider's Pond in southcentral Pennsylvania included jack pine (Pinus banksiana), fir (Albies sp), birch (Betula sp), and alder (Alnus rugosa). These taxa replaced the species poor spruce (Picea sp) woodland recorded for the glacial maximum (18,000 B.P.). A similar floral community invaded the spruce (Picea sp.) dwarf birch (Betula glandulosa) association at Longswamp in southwestern Pennsylvania (Watts 1979), where gray birch (Betula populifolia) was also present (Watts 1983:306).

Additionally, investigations at Corry Bog in northwestern Pennsylvania, by Cotter (1983), Cotter and Crowl (1984), and Karrow et al. (1984), indicate that the spruce pollen zone in Pennsylvania occurs between 14,250 and 11,250 B.P. Cotter (1983) and Cotter and Crowl (1984) state that the herb pollen zone lasted from 18,500 to 14,250 B.P. and that the basal age of the spruce pollen zone of sites near the Woodfordian drift border of Pennsylvania is approximately 14,250 B.P., rather than the 12,600 B.P. as suggested by Karrow et al. (1984). Watts (1983:307) notes that clear differences exist between the floral history of the periglacial region to the south (i.e., Longswamp and Crider's Pond) and that of the region which was ice-covered (i.e., Tannersville and Corry Bogs). The grass-dominated tundra flora at unglaciated Longswamp is paralleled by sedge dominated pollen floras at Tannersville Bog, which was located at the edge of the ice margin. Since Tannersville Bog is outside the drift border, in what must have been an ecotone similar to that of Site 36AL480, it presently offers the best reconstruction of what probable taxa were present within the general study area during the period 25,000 to 10,000 B.P.

At the end of the Pleistocene at Tannersville Bog, the demise of sedge, aspen (Populus tremuloides), green alder (Alnus crispa), and invasion of trees in the sequence spruce (Picea sp.), fir (Albies sp.), jack pine (Pinus banksiana), gray birch (Betula populifolia), and pitch pine (Pinus rigida) can be demonstrated to have occurred between 13,000 and 9000 B.P. (Watts 1983:307). At 12,000 B.P., spruce woodland replaced tundra in western Maryland, western and central New York, and southern New England (Davis 1983). The appearance of spruce over such a wide area indicates both the rapid migratory speed of spruce and a climatic amelioration at 12,000 B.P. that allowed spruce to grow in regions where it was previously limited by climate (Davis 1983:179).

These paleofloral data suggest that the population of each tree species behaved independently of other taxa in response to climatic change (Watts 1983:307). Davis (1969) notes that the recolonization of trees from their southern habitats into the northeast was a relatively slow process. At Rodger's Lake in Connecticut, glacial ice had retreated and tundra was present for over 2,000 years before the invasion of spruce (Picea sp.), although the latter was already present in unglaciated Pennsylvania during the recession of the ice margin (Davis 1969).

Following glacial retreat (circa 14,000 B.P.), the boreal forest associated with the glacial maximum gave way to a mixed conifer-northern hardwood forest assemblage (Delcourt and Delcourt 1985) during the Bølling-Allerød interval (12,500-11,000 B.P.). In the following Inter-Allerød-Younger Dryas transition at 11,000 B.P., climate in the northeast interior deteriorated significantly and was associated with rapid broad scale changes in vegetation régime and dynamic temperature fluctuations (Bartlein et al. 1984; Davis 1983).
While there is no evidence of glacial ice advancing into the United States associated with the Younger Dryas (11,000-10,000 B.P.), cold, dry climate conditions and boreal forests were present in western Ohio during the period 10,800 B.P. to 10,000 B.P. (Wright 1987). Bernabo and Webb (1977) estimated that pollen in southwestern Pennsylvania at 11,000 B.P. consisted of about 30 percent spruce, 20 percent pine, and slightly less than 10 percent oak and herbs.

**Paleoflora at Site 36AL40**

While the overriding majority of pollen assemblages recovered from Site 36AL480 were of Holocene age, a single locality—the Casting Basin—(see Figure 2.5 for location) provided a sample of Pleistocene origin (Jones 2006). The lag gravels of AU-1 were striking, insofar as conifer pollen was wholly absent from the collected sample at that provenience. Deciduous forest taxa, including Carya, Fagus, Fraxinus, Tilia, and Ulmus are slightly elevated (Figure 2.14). A single charcoal specimen within the lag gravels was dated to 36,270 B.P. ± 320 (Beta-176078). While the determination was dismissed as contaminated and too young (Jones 2006), the sediment was judged to be of Pleistocene or earliest Holocene in age. The lack of boreal forest elements and elevated quantities of mesic woodland taxa are consistent with an earlier interglacial pollen distribution. Present interpretations are that high proportions of grasses and Ericaceae pollen are consistent with heath formation, but the lack of conifers and abundance of hardwood taxa may point to forested woodland (Jones 2006). The heath glen reconstruction may be favored, since nearly all terminal Pleistocene or earliest Holocene cores recovered in Pennsylvania have produced pollen profiles dominated by fir, spruce, or pine pollen—species absent from the Casting Basin sample.

**Holocene Flora**

By 10,000 B.P., forests of variable composition expanded across the northeast and much of the Ohio River Valley was probably within the northern fringe of expanding deciduous forests (Delcourt and Delcourt 1983, 1985). Evidence of the establishment of the deciduous forests on the Ohio is indicated by pollen spectra present at the Gallipolis Lock and Dam site, downstream of Site 36AL480, where paleofloral analysis reveal that a mixed mesophytic forest had been established by 9000-8500 B.P. (Fredlund 1989). Estimated temperature increases during the early to middle Holocene are three times greater than recent Holocene fluctuations, with the Holocene climatic optimum occurring approximately 8000-6000 B.P. (Webb and Bryson 1972). During the early Holocene, there is evidence for rapid increases in boreal plant species and populations on the Appalachian Plateau in response to the northern retreat of the Laurentide ice sheets (Maxwell and Davis 1972). Klippel and Parmalee (1982) note that, even with this warming trend, the climate during the early Holocene was considerably cooler than at present on the Allegheny Plateau with conditions most closely resembling more northerly boreal forest regions. Bernabo and Webb (1977) note that by 9000 B.P. however, the pollen in southwestern Pennsylvania consisted of almost no spruce, 30 percent pine, 35 percent oak, and slightly less than 10 percent herbs, indicating the northward retreat of the boreal forest.
Fredlund (1989) reports that after 5750 B.P., the structure of the forest communities surrounding the Gallipolis site became more homogeneous, dominated by xeric oak-hickory stands more typical of western mesophytic forest types. By 4000 B.P., the influence of meridional circulation increased over the mid-continent and brought about the beginning of our current climate regime (Delcourt and Delcourt 1985). On the basis of analysis of 62 pollen cores in the northeastern United States (e.g., Buckles Bog in western Maryland, Crystal Lake in western Pennsylvania, etc.), Bernabo and Webb (1977) conclude that by 4000 B.P., regional forests were comprised of no spruce, 10 percent pine, 40 percent oak, 15 percent birch, and less than 10 percent herbs. According to Davis (1983:179), by about 2000 B.P. (regionally between 5000-1000 B.P.), boreal elements of floral and faunal communities began to diversify again, a phenomenon suggestive of the onset of cooler climatic conditions. This cooling trend appears to continue even into the present.

It is interesting to note that also during the late Holocene there is clear evidence for increasing local disturbance of vegetation, probably in response to human land use (e.g., horticultural and agricultural activities). At the Gallipolis site, the pollen record shows increasing local disturbance of vegetation beginning around 4850 B.P. (Fredlund 1989). Supporting data from the study of pollen and wood charcoal from Cliff Palace Pond in Jackson County, Kentucky, shows a forest dominated by fire-tolerant taxa such as oak and chestnuts at around 1250 B.P. (Delcourt et al. 1998).

**Holocene Flora at Site 36AL480**

The pollen sequence at Leetsdale is extremely informative for the Holocene succession, largely based on time-transgressive distributions assembled from the coring program in both the Casting Basin and the Back Channel (see Figure 2.5; Jones 2006). Phytolith analysis provided additional information on the Holocene vegetation communities (Appendix T).

In the Casting Basin, Jones (2006) notes that stratigraphically ordered pollen samples from 208.03 m and 208.30 m, dating to 7080 B.P. and 5870 B.P. respectively, underscore consistent middle Holocene arboreal and plant distributions (Figure 2.15-2.17; see also Figure 2.14). The landscape was dominated by an oak-hickory-beech woodland, nearly identical to that of the present. Other significant taxa include Castanea (chestnut), Tsuga, low spine Asteraceae, and grasses. In addition to hemlock, other gymnosperms are Picea, Pinus, and Juniperus/Thuja (juniper or arbor vitae). The low occurrence of these pollen types suggests transport. Evidence for hemlock pollen is compelling for local distribution in hollows and ravines. These pollen types represent species found in the Leetsdale area today, and argue for largely similar forest communities. The most significant difference between mid-Holocene and modern forests is the absence of chestnut trees due to the early twentieth-century chestnut blight, which removed this important species from the Eastern Woodlands. Additional elements of the woodland environment include Acer (maple), Betula (birch), Carpinus (hornbeam), Fraxinus (ash), Juglans (walnut), Ostrya (hop-hornbeam), Platanus (sycamore), Salix (willow), Tilia (basswood), and Ulmus (elm). Low spine Asteraceae represent species growing along the river margin, rather than weedy field taxa. Cyperaceae (sedge family) pollen is also low, suggesting a riverine, rather than a marshy, setting.
Back Channel pollen assemblages came from two trenches, BHT-1 and BHT-3 (Figures 2.5, 2.18-2.19). Phytoliths were recovered from BHT-1 and Area 3 South (Jones 2006). The pollen profiles were most informative and internally consistent for the middle to late Holocene, the interval 4500-2000 B.P. (see also Jones 2006: Figures 5.3, 5.5, 5.7, and 5.8). It should be noted that earlier out-of-sequence dates referenced on the graphics are probably a product of old carbon contamination, possibly derived from Pennsylvanian age coal and spores. The most reliable dates in the Back Channel, specifically the middle to late Holocene dates referenced above, came from identifiable carbon pieces and visibly enriched humic contexts, viewed both in the field and over the course of preliminary lab processing.

In general, the Back Channel pollen assemblages are dominated by Carya and Quercus, along with Fagus and Tsuga (Figures 2.18-2.20). Other significant taxa include Acer, Alnus, Betula, Castanea, Juglans, Platanus, and Ulmus, all common taxa in the Eastern Woodlands. Additional woodland taxa noted in the samples include Carpinus, Fraxinus, Ostrya, Prunus, Robinia, Salix, and Tilia. A forested environment is also represented by several non-arboreal types, including Apiaceae, Rubus, and Urtica. Collectively, the middle to late Holocene profiles confirm a homogeneous forested environment, dominated by oak, hickory, and beech trees. This environment is nearly identical to that found in the vicinity today. There are no significant temporal variations in forest species composition, suggesting that climatic variations during the period of sediment deposition were minimal.

The most prominent element of some climatic variation is Poaceae pollen. Its presence may signify either drying trends or protracted intervals of site abandonment. Additionally, economic or subsistence forest plants possibly utilized by Late Archaic residents are represented by Carya, Castanea, Celtis, Fagus, Juglans, Prunus, Quercus, Rhus, Sambucus, and Vitis. Exploited aquatic plants growing near the Back Channel slough include Cyperaceae and Typha, and disturbance taxa of economic significance such as Cheno-Ams, Poaceae, Polygonaceae, and Rubus. Variation in the latter distributions, between test localities BHT-1 and BHT-3, may be the product of variable human and resource activities, or even landscape impacts over the course of the Late Archaic through historic occupations. Phytolith assemblages show an increase in forest indicators in the Back Channel until 2500 B.P., at which point grasses are more widely represented. This trend is paralleled by increased sedimentation and siltation in the Back Channel. Ongoing siltation reflects progressive anthropogenic impacts to the landscape, probably including erosion of the terrace flanks, which proceeded well into the historic period.

Finally, the phytolith record from the single terrace locale sampled, Area 3 South, indicated a heavily forested landscape during the late Pleistocene-early Holocene. This period was followed by a change to more diverse forest and grass sample population, signifying a turn to gradual, and then more pronounced, drying over the course of the middle Holocene. Phytoliths of the upper terrace strata include almost exclusively non-arboreal taxa, pointing to either or both anthropogenic impact and climatic influence. The collective evidence of the cultural paleobotanic record is examined in greater detail in Section 2.6.
Modern Flora

The study area is located in the mixed mesophytic forest region, which covers a majority of the Glaciated and Unglaciated Allegheny Plateau (Braun 1950; Davis 1976, 1983). The mixed mesophytic biome is considered the most complex and the oldest association of the Deciduous Forest Formation and is a community in which the dominant trees of the arboreal layer are communities of beech (Fagus grandifolia), tuliptree (Liriodendron tulipifera), basswood (Tilia heterophylla, Tilia heterophylla var. Michauxii, Tilia floridana, Tilia neglecta), sugar maple (Acer saccharum), chestnut (Castanea dentata), sweet buckeye (Aesculus octandra), red oak (Quercus borealis var. maxima), white oak (Quercus alba), and hemlock (Tsuga Canadensis) (Braun 1950:40).

A survey of the contemporary Leetsdale floral communities was undertaken by Jones (2006), chiefly in the vicinity of the Casting Basin and Back Channel. Dominant vegetation featured Poaceae (grasses), Ambrosia (ragweed), Cirsium (thistle), Chenopodium (goosefoot), Amaranthus (pigweed), Plantago (plantain), Medicago (medick or alfalfa), Rhus typhina (staghorn sumac), Urtica (nettles), and small stands of scrubby trees, including Prunus (cherry) and Quercus (oak). In the Back Channel, key arboreal elements include Ulmus (elm), Fraxinus (ash), Quercus, Prunus, Acer spp. (sugar maple type and box elder), Ailanthus (tree-of-heaven), Cornus (dogwood), and Fagus (beech). Other species are Platanus (sycamore), black walnut (Juglans nigra), Robinia (black locust), and Salix (willow).

Additionally there are isolated trees and small stands of sumac (Rhus glabra), locust (Gleditsia trianacanthos), sugar maple (Acer saccharum), wild cherry (Prunus serotina), and red and white oaks (Quercus borealis and Quercus alba) (Schuldenrein et al. 2003; Vento et al. 2001).

Non-arboreal elements in the area include Rhus toxicodendron (poison ivy), Urtica, Rubus (blackberry), Podophyllum (may-apple), Impatiens (touch-me-not), and Smilacina (false Solomon’s seal). The vegetation in the Back Channel area is characteristic of the vegetation typical of the deciduous woodlands of this region.

Invasive plants from the Old World include Ailanthus, introduced as an ornamental species into North America in the eighteenth century. The tree flourishes in disturbed industrial and urban settings. Plantago and Medicago are two weeds that were also introduced from Europe, at least by the eighteenth century. The latter has been widely planted as a forage plant. Both plants have escaped cultivation and are widely distributed. Castanea dentata (American chestnut) was once a major component of the Eastern Woodlands, but was largely eradicated by the chestnut blight in the early twentieth century, as mentioned above.

Industrial and historic re-contouring has altered the surfaces in much of the terrace vicinity. Naturally occurring plants consist of perennial grasses and weeds, deciduous and coniferous trees, deciduous and coniferous shrubs, and woody vines (USDA 1981; Vento 2007, 2008). In these locations, the vegetation consisted almost entirely of grasses and low scrubs.
Paleofauna

During the late Pleistocene, the development of open grazing lands and boreal forests would have supported a wide array of mammals adapted to cool climates (Cleland 1966). Evidence suggests that these types of biomes along the glacier's southern margins were exploited by megafauna indigenous to these areas, specifically the woodland musk ox (Ovibos moschatus), mastodon and woolly mammoth (Mammut sp.), barren ground caribou (Rangifer tarandus), giant beaver (Castoroides sp.), and moose-elk (Cervacles scotti) (Cleland 1966: 91-92; Prufer and Baby 1963:55; Ritchie and Funk 1973). Recent studies at Sheridan Rockshelter in Wyandot County, Ohio, note the presence of flat headed peccary and giant beaver at 11,060 B.P. and 10,850 B.P., respectively. The dates for these now extinct fauna overlap the date on a Clovis age bone point recovered during excavation of the rockshelter (Redmond and Tankersley 2005).

The Pleistocene fauna of the United States can be characterized as a combination of extinct mega-vertebrates and extant temperate mega-vertebrates and micro-vertebrates, in association with now disjunctive large and small northern species (Semken 1983:192). The Holocene fauna of central Ohio is generally composed of the second category. Semken (1983) states that this reduction in the number of species has led authors (Martin 1967; Martin and Webb 1974; Semken 1974) to regard the Holocene biotic record as impoverished as compared to the high species densities characteristic of the late Pleistocene (Graham 1979). This faunal change is used to define the Pleistocene/Holocene transition. Clearly, the megafauna of the late Pleistocene suffered massive extinction and were replaced by smaller animals that filled the emerging faunal ecological niches. Within the general Site 36AL480 project area, the response time of various vertebrate species to deglaciation and subsequent climatic change was highly variable from one species to another (Guilday 1965a, 1967, 1971, 1982; Guilday and Parmalee 1965; Guilday et al. 1966, 1977). However, in a fashion similar to the pollen record for the Midwest and Northeast, the concept of a vertebrate transition within a few hundred years after deglaciation appears valid (Semken 1983).

Holocene Fauna

Due to the absence of identifiable vertebrate remains within the Phase I, II, and III archeological inventories at Site 36AL480, specific biotic reconstructions cannot be made (Anderson et al. 2005, 2010; Barse 2003; Davis 2000; Fenicle 2003; Hardlines 2000; Miller and Marine 2005; Miller et al. 2010). The faunal inventory utilized by the aboriginal inhabitants of the project area, however, may be inferred from other dated, regional paleontological and archaeological sites which have yielded information concerning Holocene age vertebrates in Pennsylvania (Guilday 1965a, 1967, 1971, 1982; Guilday and Parmalee 1965; Guilday et al. 1966, 1977). However, in a fashion similar to the pollen record for the Midwest and Northeast, the concept of a vertebrate transition within a few hundred years after deglaciation appears valid (Semken 1983).

The mammalian vertebrate fauna from Hosterman's Pit, Pennsylvania, dated at 9290 B.P., is modern in every aspect (Guilday 1967). This is in direct contrast to the 11,300 B.P. fauna from Unit B of the New Sinkhole No. 4 which lies ca. 80 km (50 mi) to the north (Guilday et al. 1964; Vento and Rollins 1989). The latter contains a strong boreal component represented by the northern bog lemming (Synatomys borealis), collared lemming (Dicrostonyx hudsonius), yellow cheeked vole (Phenacomys intermedius), and the arctic...
shrew (Sonex arcticus). A similar boreal fauna assemblage was identified at Bootlegger Sink, York County, Pennsylvania (Guilday et al. 1966). Based on the above dates of 9290 B.P. and 11,300 B.P., the change from a boreal to near contemporary faunal community must have occurred within this 2,000-year interval in central Pennsylvania (Guilday 1971). Arguments are bolstered by the Unit A fauna at New Paris Sinkhole No. 4, which contains a large number of temperate species and overlies the older, strong boreal taxa represented by Unit B fauna at the site (Guilday et al. 1964; Vento and Rollins 1989).

Based on his observation of a number of sites, Guilday (1967:232) notes that all zooarchaeological faunas from the northeast during the last 6,000 years contain taxa which are essentially modern. The longevity of the Eastern Woodlands Holocene record is confirmed by 11 superimposed strata (11,300 B.P. to 700 B.P.) at Meadowcroft Rockshelter in southwestern, Pennsylvania (Adovasio et al. 1977, 1985), as well as the Archaic to recent period (8920-490 B.P.) faunal succession at Sheep Rock Shelter in southeastern Pennsylvania (Guilday and Parmalee 1965).

The only evidence of the "climatic optimum" or "Hypsithermal Climatic Event" between 5500 and 3500 B.P. in the eastern forests is at the Lamoka Lake Site, New York (Guilday 1965b). Evidence for warming at Lamoka is based on the presence of fox squirrel (Sciurus niger) and the box turtle (Terrapene carolina), each of which reflects a warming trend and perhaps a reduction of the closed canopy deciduous forest at that time (Guilday 1965b; Vento et al. 2008).

Modern Fauna

Allegheny County supports a wide range of terrestrial, avian, and riverine fauna. However, the contemporary fauna do not necessarily represent the full range of species that were available for exploitation by aboriginal populations during the late Pleistocene or Holocene. A cursory examination of late Pleistocene through Recent (12,500 B.P. to Present) faunal remains statewide indicates that considerably more species would have been available for aboriginal exploitation in the past than are now present, though population densities and distributions would have varied from what is seen today (Dent and Kauffman 1985; Guilday 1982; Vento et al. 2008).

White-tailed deer (Odocoileus virginianus) is the most abundant large mammal in the region. White-tailed deer are generally considered a forest species, but they more typically prefer edge or ecotonal zones which combine areas of brush, young trees, and open meadow/pasture-lands. In pre-Columbian periods, deer were probably distributed throughout the region at densities of approximately 5 to 10 individuals per square kilometer (Hay et al. 1985:4). In the fall, this deer population congregated at localities which were heavy in mast (nut) production. For the winter months, deer distribution was largely conditioned by the severity of weather. During moderate winters, a more even distribution over valley floors, hills, and ridge tops was maintained. Severe cold and snow, however, would have forced deer into sheltered coves and valleys. During the spring and summer, an even distribution was again established (Hay et al. 1985; Taylor 1956).
Black bear (Ursus americanus) can be found throughout the more mountainous and less populated areas of the county. Black bears were probably distributed at a density of approximately one adult bear for every 13-39 forested square kilometers (sq km; 5-15 forested sq mi) (Hay et al. 1985; Kordeck 1973). Beech, sugar maple, and birch constitute their primary food supply, supplemented by acorns, black cherries, and blueberries. During the fall and summer, preferred ranges encompass steep terrain with dense understory. Thus, most bears occur to the east and north of the study area in less urbanized, higher elevations (Roger McPherson, personal communication 2003).

Fur-bearing animals are found in nearly all regions and on most soil types in the county. These principal fur-bearing taxa include: raccoon (Procyon lotor), opossum (Didelphis marsupialis), striped skunk (Mephitis mephitis), eastern spotted skunk (Spilogale putorius), wood chuck (Marmota monax), gray squirrel (Sciurus carolinensis), muskrat (Ondatra zibethicus), gray fox (Urocyon cineroargenteus), red fox (Vulpes fulva), eastern cottontail (Sylvilagus floridanus), and beaver (Castor canadensis) (Adovasio et al. 1977; Scheirer 1969).

Game fish species in streams and rivers included brook trout (Salvelinus fontinalis), rainbow trout (Salmo gairdneri), brown trout (Salmo trutta), bluegill (Lepomis macrochirus), sunfish (Lepomis megalotis), crappie bass (Micropterus punctulatus), largemouth bass (Micropterus salmoides), smallmouth bass (Micropterus dolomieui), muskellunge (Esox masquinongy), pickerel (Esox niger), yellow perch (Perca flavescens), and channel catfish (Ictalurus punctatus) (Adovasio et al. 1977; Scheirer 1969).

Most of the avifauna in western Pennsylvania consists of songbirds rather than gamebirds (Scheirer 1969). However, several types of gamebirds are native or present in the project areas on either a permanent or seasonal basis. These include: wild turkey (Melagris gallopavo), American woodcock (Philohela minor), ruffed grouse (Bonasa umbellus), and Canadian geese (Branta sp.), as well as a large number of ducks (Anas sp.), which stop to rest and feed on lakes, ponds, and rivers during annual fall/spring migrations. During pre-Columbian times, wild turkey densities were probably on the order of four to six per sq km (8-13 individuals per sq mi). Ideal habitats for turkey were those containing mature oak forests with white oaks predominating. These conditions were found mainly on valley floors and lower valley slopes (Scheirer 1969).

Paleoclimatic Models, Mechanisms, and Sequences

The dynamics of terminal Pleistocene glacial and inter-glacial cycles are complex with respect to the timing and manifestations of cold and warm climate transitions and their impacts on ancient landscapes and paleo-ecology. The following discussion explores current paradigms in climate theory and modeling as a background to understanding the relationship between climate and the mechanisms that fashioned the changing physical geography at Leetsdale since the terminal Pleistocene and through the various stages of the Holocene. Higher resolution sequences for the Holocene climatic succession are pivotal in explaining the intricate landform histories preserved in the geomorphic record of the terrace and flood plain settings at Site 38AL480.
The most recent large-scale glacial maximum occurred between 22,000 and 14,000 B.P. and deglaciation took hold over the interval 14,000-10,000 B.P. Presently, the North American continent is within the Holocene interglacial which began about 10,000 B.P. While climatic evidence and climate-based reconstructions draw from a broad range of environmental proxy data (Crowley and North 1991), climato-stratigraphies are insufficiently precise to allow for calibration of millennial-scale cycles of the Holocene. Thus for present purposes, the general Blytt-Sernander climatic sequence is employed to order late Pleistocene/Holocene environmental change in the mid-Atlantic region (Figure 2.21). The Blytt-Sernander record, developed through the twentieth century, subdivides and describes the episodes of the terminal glacial and current interglacial periods (Vento and Rollins 1989; Vento et al. 2008; Zeuner 1952). Figure 2.21 is a regional construct or baseline for western Pennsylvania, developed by one of the present authors and colleagues, that applies the Blytt-Sernander cycles to vegetation communities, fluvial histories (indicative of intervals of geomorphic dynamism), soil chronologies (signifying periods of landscape stability), and archaeological periods pervasive across the region (Vento and Rollins 1989; Vento et al. 2008). This model is applied for establishing the regional paleoenvironmental baseline for Site 36AL480 (this chapter) and eventually for structuring the integrated landscape and occupation histories on site (through allostratigraphy; see Sections 2.6 and 2.7).

The model centers on the recognition of paleoclimatic transition and the processes and proxy indicators explaining such transition. Accordingly, numerous techniques are used to reconstruct the paleoclimatic history, beginning with the terminal Pleistocene/Holocene interface (ca. 14,500 B.P.; see Figure 2.21). An organizing principle of any explanation of climatic transition and sequencing are the mechanisms, periodicity, and cycling of climatic forcing.

**General Climatic Forcing Mechanisms**

Long-term climatic changes, such as those associated with the shift from the last glacial interval to the Holocene, are related most directly to perturbations in the Earth’s orbit and axis, and the consequent changes in the amount of solar radiation reaching the planet’s surface. For late Quaternary climates, long-term celestial axial orientation (precession) cycles (19,000-23,000 years) and axial tilt (obliquity) cycles (41,000 years) are particularly important (e.g., Grootes and Stuiver 1997) to climatic change.

Shorter-term climatic Dansgaard-Oeschger (D/O) and Bond cycles, on millennial scales of about 1,500 years and 6,100 years respectively, have also been recognized in proxy records from ice or sediment cores taken from oceans and continental lakes (Benson et al. 2003; Bond 2005; Bond et al. 1997; Burns et al. 2003). It is not yet clear how the shorter term cyclical variations may relate to the celestial mechanics which drive the longer precession and obliquity cycles, although there is suggestion that they are related to variations in solar output itself (e.g., Björck et al. 2001; Bond et al. 2001; Denton and Karlén 1973; Finkel and Nishiizumi 1997; Kodera 2002; Rahmstorf 2003). A number of possible explanations for the cause of these shorter cycles, particularly the D/O cycles, have been posited, including the effects of volcanic eruptions and catastrophic floodwater outflows that reduced or enhanced the underlying solar-based climate cycles (e.g., Broecker et al. 2003;
Regardless of the specific causal mechanisms, it is becoming increasingly clear that the transitions between the steady-state conditions that characterize these millennial-scale cycles are relatively abrupt, often on the order of a decade or less. In the North Atlantic, and apparently throughout the Northern Hemisphere (e.g., Benson et al. 2003; Burns et al. 2003; Courty and Vallverdu 2001; Grafenstein et al. 1999; Gupta et al. 2002; Leuschner and Sirocko 2000; Noren et al. 2002; Schulz et al. 1999; Sirocko et al. 1996; Wilkins and Currey 1997), the D/O cycles are synchronous and take a characteristic form (Alley et al. 1997). As noted, they average about 1,500 years long and are initiated with a rapid (i.e., decadal) rise in temperature (five to eight degrees Celsius [zero to 14 degrees Fahrenheit] during the glacial period; one to three degrees Celsius [two to five degrees Fahrenheit] during the Holocene). These cycles gradually return to moderate conditions over the course of approximately one thousand years and end with a rapid return to very cold temperatures prior to the start of the subsequent warming event that initiates a new cycle. Currently, nine cycles have been recognized in these detailed core records spanning the last 12,000 years (e.g., Bond et al. 1997).

Although environmental change in the mid-Atlantic region is correlated with millennial-scale cycles, as recorded in the ice core records (e.g., Willard et al. 2005), all of the identified Holocene cycles have yet to be recognized within the general Site 36AL480 project region. Other, even shorter, climatic cycles—such as those of the El Niño-Southern Oscillation and the North Atlantic Oscillation—range in duration from decades to several centuries. The attendant signals are preserved in a variety of proxy records and may also be related to variation in solar output (e.g., Berger and von Rad 2002; Chapman and Shackleton 2000; Clement et al. 2001; Gagan et al. 2004; Grafenstein et al. 1999; Kunzendorf and Larsen 2002; Menking and Anderson 2003; Takahashi et al. 2003). These shorter cycles are within the range of variation of most radiocarbon dates, but records of these events are difficult to calibrate internally and to correlate with environmental events and archaeological successions.

Ultimately, the chronology of the more complete and chronologically well-controlled North Atlantic core records may index the cycles of environmental change in the mid-Atlantic region. However, there are some slight chronological variations of 50 years or less between the marine and ice core records (Rind and Overpeck 1993). Variability may be due to depositional discontinuities and differences in chronological techniques (Denton and Karlén 1973). Perhaps more importantly, there appears to be a significant spatio-temporal lag in the response of vegetational communities to the climate change events recorded in the North Atlantic records (Viau et al. 2002). While response times are short, consistently less than 200 years and often less than 100 years, it is probable that there is a lag between the North Atlantic core-based climate record and alluvial sequences in Pennsylvania (Williams et al. 2002; Vento and Rollins 1989).
Late Pleistocene Climate Sequence (22,000-10,000 B.P.)

Depending on geographic location, the last glacial maximum occurred between 22,000 and 14,000 B.P. (Crowley and North 1991). Regionally (north of 40 degrees 27 seconds north latitude and 79 degrees 57 seconds west longitude, the location of Pittsburgh), placement of the glacial maximum at 18,000 B.P. is widely accepted (Crowl and Sevon 1999; Sevon and Braun 1997). This period is referred to as the Wisconsinan in North America and is viewed as the time of the earliest Paleoindian occupations of western Pennsylvania (Adovasio et al. 1985). The largest accumulation of ice in eastern and central North America was termed the Laurentide ice sheet, which extended from the eastern flank of the Rocky Mountains to the Atlantic shore and from the Arctic Ocean to the Missouri and Ohio Rivers (Crowley and North 1991). This ice sheet may have been linked directly to the smaller Cordilleran ice sheet in northwestern North America and indirectly to the Fennoscandian ice sheet in northwestern Europe through a thicker Arctic Ocean ice shelf (Broecker 1989; Denton and Hughes 1981). The overwhelming weight of the ice mass vertically displaced the underlying continental crust by as much as 700-800 m (2,300-2,600 ft). Isostatic rebound is ongoing in many locations as a result of deglaciation and the association or effects of these isostatic movements with terrace formation are only now being considered (Vento and Rollins 1989).

Laurentide thickness varied between 3,500 m and 4,000 m (11,500-13,100 ft) (CLIMAP 1976, 1981). To the north of the Site 36AL480 study area, the Illinoian and then Wisconsinan ice sheets may have attained a thickness in excess of 400 m (1,300 ft). This estimate is based upon the occurrence of till deposits on the high ridgetops and the ice thickness versus gradient needed to override the preglacial topography (Crowley and North 1991; Shepps et al. 1959). The generation of such a large ice sheet required ocean evaporation on the order of 50-60x10^6 km3 of water, and effectively lowered mean sea levels more than 120 m (390 ft) (Fairbanks 1989). With the expansion of the Laurentide ice sheet, atmospheric circulation patterns adjusted equatorward. The ice sheet caused expansion of the circumpolar vortex which caused equatorward adjustments in polar fronts and sea ice (CLIMAP 1976, 1981). Such adjustments caused dramatic changes in North Atlantic Ocean circulation which had significant impacts on northern hemisphere climates (Crowley and North 1991).

Presently, the northeast North Atlantic is seasonally ice free to 78 degrees north latitude (the Norwegian Sea). During the last glacial maximum, the polar front migrated to approximately 45 degrees north latitude (Ruddiman and McIntyre 1981). North of this point, sea ice was present through winter. As such, a substantial region (120 degrees west longitude [Washington State] to 90 degrees east longitude [Central Asia] and above 45 degrees north latitude) was covered by ice and/or tundra. At elevations greater than 2,000 m (6,500 ft), substantial ice expansion occurred by 18,000 B.P., as evidenced by lowered snow lines of approximately 1,000 m (3,300 ft) (Crowley and North 1991). This equates to an overall global temperature decline of 5 to 6 degrees Celsius (nine to 11 degrees Fahrenheit) (Bonnefille and Riollet 1988). Proxy records also indicate a reduction in summer ablation, or seasonal depletion of the glacier through calving or ice melting (Cooke and Hays 1982).
Substantial changes of climate occurred in areas bordering the ice sheet (Watts 1983; Wright 1987), including significant areas of Ohio and Pennsylvania. Tundra extended south of the ice margins, but this region was spatially limited as compared to that which occurred in Europe (Péwé 1983). Instead, in North America, spruce-pine boreal forests replaced most tundra, except in a zone immediately adjacent to the ice sheet (Davis 1983). It is estimated that the mean position of the polar front boundary was at approximately 34 degrees north latitude (an area including Texas, Mississippi, South Carolina), that represents a position about 1,930 km (1,200 mi) south of the current Canadian polar front boundary (Delcourt 1979; Delcourt and Delcourt 1983). South of 34 degrees north latitude oak-hickory forest and local prairie vegetation dominated (Delcourt and Delcourt 1985). This situation, in conjunction with recorded low lake levels from as far away as Florida, support the notion of overall ice age aridity (Crowley and North 1991).

Surface air temperatures were reduced approximately 10 degrees Celsius (18 degrees Fahrenheit) near the Laurentide ice sheet (Flint 1971; Barry 1983). Temperature flux south of the ice sheet was more severe in winter than summer and this likely stemmed from outbreaks of polar air off the ice sheet.

Not surprisingly, most of the planet was drier during the last glaciation under those climatic conditions, with patterns varying by latitude. Declines in precipitation were approximately 50 percent below present values in high latitude regions (above 60 degrees), for instance, while in some southerly areas, increases in precipitation occurred (Beer et al. 1985). In the mid-latitudes, this situation was associated with the development of pluvial lakes in the Great Basin of western North America. The lakes formed from a combination of lower overall temperatures which reduced mean evaporation rates, increases in precipitation and/or meltwater runoff, and blockage of drainage systems (Benson and Thompson 1987; Brakenridge 1978; Grosswald 1980).

Changes in wind direction and speed were also noted from the glacial distribution of eolian features in North America (Wells 1983). Mean wind directions at present are from the southwest. During the last glaciation, the mean direction was from the northwest, which advected cold air directly from the ice sheet and created a significant effect on cooling and evaporation rates south of the ice sheet (Sarnthien et al. 1981). Global surface wind speeds were approximately 20-50 percent greater than present. This induced a strong effect on ocean circulation and sea ice formation (Crowley and Parkinson 1988).

Ice cores suggest CO2 levels of about 200 ppm (Barnola et al. 1987) and methane concentrations were about 2 percent less than present values (Stauffer et al. 1988). The latter reflects increased aridity as wetlands are a primary source of methane (Matthews and Fung 1987). Since both gases are greenhouse gases, climate feedbacks accounted for a global temperature reduction of about 1.5 degrees Celsius (2.7 degrees Fahrenheit), or about 40 percent of the glacial/interglacial signal (Crowley and North 1991).

Deglaciation marks the most rapid climate change recorded in the geologic record (Prest 1969). Residual remnants of the Laurentide ice sheet lasted until 7000-6000 B.P. in northern Canada. However, most ice disappeared over a 5,000-year period between 14,000 and 9000 B.P. (Mix and Ruddiman 1985). The major phase of deglaciation occurred from
14,000-13,000 B.P. (Bryson et al. 1969; Mix and Ruddiman 1985). Abrupt warming occurred approximately 13,000 B.P. followed by a climate reversal at 11,000 B.P. (the Younger Dryas in Europe), then another abrupt warming at 10,000 B.P. (Broecker 2006; Broecker et al. 1988). A third step took place at about 8000 B.P. with the final outflow of the Laurentide ice occurring from Hudson Strait and Hudson Bay (Mix and Ruddiman 1985) into the North Atlantic, with ablation of the ice sheet triggering rapid changes in mean sea levels (Fairbanks 1989).

During the Younger Dryas (11,000-10,000 B.P.) and at the time of late Paleoindian to Early Archaic occupations in western Pennsylvania, temperatures were reduced, which generated equatorward displacement of the North Atlantic polar front (Dincauze and Mullholland 1977; Eisenberg 1978; Fiedel 1999; Fitting 1968). Cooling was especially strong in the circum-subpolar North Atlantic (Bond et al. 1997). The cool period may have been triggered by meltwater-induced changes in air-sea circulation (Broecker 1989). Proglacial lakes, many of them dammed, caused catastrophic release of discharge in certain areas (Benson and Thompson 1987). This is best exemplified by the Lake Missoula, Montana, dam burst, which is the largest flood recorded in the geologic record. The result caused widespread channeled scablands (Buetz 1923).

Early deglaciation meltwater in the mid-continent also discharged through the Mississippi River (Broecker et al. 1988; Kennett and Shackleton 1975). However, by about 11,000 B.P., ice sheet ablation had opened up the St. Lawrence River drainage network (Broecker et al. 1988). The outflow caused a low salinity lens in the subpolar North Atlantic, which depressed sea surface temperatures further (Ruddiman and McIntyre 1981). The lens affected deep sea mixing and diminished North Atlantic deep water production (Fairbanks 1989). This condition triggered atmospheric circulation changes in the Atlantic, which resulted in decreased atmospheric convection (Folland et al. 1986). Such changes led to climate feedbacks which ultimately cooled the hemisphere (Crowley and North 1991).

**Holocene Climate Sequence (10,000 B.P. to Present)**

Following the final retreat of the Wisconsinan ice sheets (Laurentide in eastern and Cordilleran in western North America), drastically different climatic and circulation patterns began to characterize the mid-Atlantic region (Crowl and Sevon 1999). The early to mid-Holocene (10,000-4500 B.P.), encompassing the Pre-Boreal, Boreal, and the Atlantic climatic episodes, was warmer than the previous five millennia, even with Laurentide ice sheet remnants present in high latitudes (see Figure 2.21). Warming was seasonal, mainly summer increases in temperature over annual increases. This interpretation is based on latitudinal displacements of vegetative zones in eastern North America (Crowley and North 1991; Davis 1983; Davis et al. 1980). Streams during this period stabilized their channels and developed a meandering (versus braided) channel habit, indicating that the early and middle Holocene was a time of active flood plain aggradation (Scully and Arnold 1981; Schuldenrein 2003; Vento and Rollins 1989).

In western Pennsylvania, the pine-oak forests of the late Pre-Boreal and Boreal episodes (ca. 10,000-8000 B.P.; see Figure 2.21) of the region, which replaced the late Pleistocene stands of spruce and pine, were most likely composed of fir, white pine, oak,
hemlock, alder, and birch (Davis 1969, 1983). The absence or low percentage of certain species (e.g., chestnut, beech, hickory) during this time may have been more a function of migration lag from their southern Appalachian refuge than an indication of unfavorable climate (Davis 1983). Changes in forest composition in the northeast around 10,000 B.P. suggest that the opening of the Holocene was marked by near-modern climatic conditions (Carbone 1976; Davis 1983), an observation largely verified by the pollen studies in Leetsdale (Jones 2006). Soon afterward, at least by 9000 B.P., the climate was warmer than today (Davis 1983). This Hypsithermal period (5500 to 3500 B.P.) is identified by Bartlein et al. (1984) and King (1980). The expansion of white pine, an excellent temperature and moisture indicator, spanned both upland and lowland elevations in the northeast (Davis 1983).

Brief but measurable centennial-scale cooling events punctuated the Pre-Boreal (10,000-9200 B.P.) and Boreal (9200-8000 B.P.) climatic episodes and were associated with the release of fresh water from Lake Agassiz (which covered portions of Minnesota, North Dakota, and the Canadian provinces of Ontario, Manitoba, and Saskatchewan) into the Hudson Straights, and ultimately to the Labrador Sea. These events appear to have impacted the salinity of the North Atlantic, the rate of movement of warm water from southern latitudes, and the associated atmospheric circulation patterns (Barber et al. 1999; Teller et al. 2002). Of these events, the “8.2 cal ka event” at approximately 7700 B.P. or earlier, is apparent in several high resolution, well-dated records, including: the Greenland ice cores (Alley et al. 1997; Johnsen et al. 2001); speleothems in Ireland (Baldini et al. 2002); and tree rings and lacustrine sediments in northern and eastern Europe (Klitgaard-Kristenson et al. 1998; Veski et al. 2004). These records suggest the event lasted 100-200 years (Johnsen et al. 2001).

Due to the limited duration of the event, there is some debate as to its effect on climate, fluvial dynamics, and associated vegetation changes. One might argue that even a 200-year-long event may be a causal agent in environmental change when acting in concert with other mechanisms (e.g., solar fluctuations). Given that it is a centennial-scale event, the environmental and vegetation changes it caused may have persisted for some time after the event ended. Many studies, particularly those of lower resolution, emphasize multi-centurial climatic change centered on 8200 cal B.P. (Dean et al. 2002). Rohling and Palike (2005) argue that the vast majority of high resolution climate proxy records indicate the events started at or before 8400 cal B.P., and most imply an age before 8500 cal B.P. They contend that it would be erroneous to attribute all climate anomalies around 8000 cal B.P. to the “8.2 cal ka event.” They suggest that climate deterioration between 8500 and 8000 cal B.P. is more likely part of a broad pattern of longer term anomalies during the Holocene probably related to solar fluctuations (Rohling and Palike 2005).

Aside from such climatic anomalies, the cultural history coincident with the Boreal episode (9200-8000 B.P.) in the Northeast shows trends consistent with the northward retreat of coniferous forests, which contained relatively few food resources compared to the abundance of nuts, berries, and herbs produced in deciduous forests (Stoltman and Baerreis 1983). Human populations occupying the coniferous forests of Pennsylvanina (prior to 10,000 B.P.) had to depend largely on riverine resources, with the exception of those groups that utilized woodland caribou. These riverine resources would have been impacted by changes
in alluviation and aggradation patterns along the terrace landforms. Within the upper Ohio River basin, the early Holocene (10,000-8000 B.P.) was a time of active alluviation/aggradation. Assuming that both base level transitions and tectonic controls were minimal, the most likely cause of this phase of alluviation was the expansion of tributary streams supplying an increase in sediment yields to the river and its main tributaries, as well as a change to zonal atmospheric circulation patterns.

Runoff and sediment yields are the principal determinants of the physical properties of alluvial channels and flood plains. The frequency and magnitude of water and sediment yields are adjusted to climate, vegetative cover, and physiography (Knox 1983). Knox's (1983) classic paper entitled, “Responses of River Systems to Holocene Climates,” discusses the adjustments of river systems as they relate to the direct effects of climatic events (storms and floods) and the indirect effects of vegetation as it controls runoff and erosion. Knox (1983:26-41) proposed that fluctuations in the atmospheric circulation pattern (i.e., jet stream) from zonal (deamplified west to east flow), during the Pre-Boreal (10,000-9200 B.P.), and Boreal (9200-8000 B.P.) climatic phases, to mixed zonal-meridional (amplified flow, allowing cross-latitudinal advection), during the Atlantic (8000-4500 B.P.) through Pacific (1000-750 B.P.) climatic phases, were responsible for changes in stream regime. These transitions included variability in flood magnitude and thresholds marking the passage from aggradation to incision.

Since most of the Eastern Woodlands region was forested through the Holocene, the responses of streams to environmental change may be more closely related to climatic controls than to broad-scale changes in vegetative cover (Knox 1983:22). Carbone (1976) shows that modern floral assemblages were present in the mid-Atlantic region by approximately 9000 B.P., allowing comparison between early Holocene and present alluvial responses. The Knox hypothesis is supported in the present climate in that overbank deposition is primarily controlled by the frequency and magnitude of individual precipitation events (primarily linked to cool-season mid-latitude storms), and/or repeated and frequent precipitation events over short durations with related runoff. The application of Knox's view provides a basis for consideration of a climatically controlled forcing mechanism accounting for both the timing and duration of depositional, erosional and soil-forming cycles of the type registered consistently in the Leetsdale profiles. The underlying assumption here is that vegetation covers were relatively uniform.

Alternatively, Langbein and Schumm (1958) emphasized the strong influence of vegetative cover on surface runoff and subsequent bankfull discharges. They argued that contemporary environments, where mean annual precipitation is about 300-500 mm (12-20 in; arid landscapes) and about 800-900 mm (32-35 in; forested landscapes), represent thresholds that limit fluvial response to climate change. Below 300-500 mm (12-20 in), there is little vegetation and hence rapid surface runoff. In forested areas, which receive over 800 mm (32 in) of precipitation, little overland flow occurs, even from relatively large storms. To date, there is no strong evidence for the replacement of forest by prairie vegetation in the mid-Atlantic region (even during the warm and dry Sub-Boreal climatic phase at 4500-3000 B.P.) (Vento and Rollins 1989). The vegetation based argument is that changes in forest communities were apparently of secondary importance to climate change in affecting fluvial responses.
Following the Boreal episode, the Atlantic (8000-4500 B.P.) represents a return to warm and moist conditions. At this time, the Midwestern United States was approximately two degrees Celsius (4 degrees Fahrenheit) warmer than present with most of the increases associated with the summer season (Bartlein et al. 1984; Webb 1985). Warm waters penetrated into higher latitudes during this period (Hays et al. 1976) and such conditions ultimately led to wetter climate regimes.

At 8000-7700 B.P., the pollen record for the upper Ohio, upper and central Delaware, and Susquehanna River drainage basins shows a rapid decrease in pine and an accompanying increase in both oak and hemlock (Davis 1983). This shift in the pollen spectra was likely the result of a change from the warmer and drier conditions of the Pre-Boreal and Boreal climatic episodes (10,000-8000 B.P.) to moister conditions during the Atlantic episode (8000-4500 B.P.) (Bartlein et al. 1984; Davis 1983).

After the dissipation of the Laurentide ice sheet during the early Atlantic climatic phase (ca. 8000-6000 B.P.; Bryson et al. 1969; Prest 1969), the large differential in summer temperatures between central Canada and the southern United States no longer existed (Knox 1983:30). The strength of the summer's westerly circulation was greatly weakened, which allowed for the deep penetration of both polar and tropical air masses. Although Knox (1983) and Vento and Rollins (1989) argue for the prevalence of a more meridional circulation regime during this period, it is more likely that zonal conditions prevailed, with the mean jet stream trough increasing in latitude and allowing warmer and wetter air masses to occupy the region.

A seasonal analogy occurs during the present-day summer and autumn seasons. During the warm season, the high latitudes heat greatly (compared to the cool season) in the presence of nearly constant insolation from very long day lengths. This greatly reduces the thermal gradient which promotes zonal flow conditions. Cyclonic storms are less frequent, weaker, and shorter in duration than during meridional flow periods. This promotes more stable precipitation regimes characterized by fewer large precipitation (flooding) events.

Evidence of long-term landscape stability resulting from less frequent flooding events is observed in regional stratigraphies at archaeological sites dated to the Atlantic climatic episodes. For instance, radiocarbon dates from basal buried A horizons at Shawnee Island (ca. 8000 B.P.; Dent and Kauffman 1985) are among the horizons which support this hypothesis. When present, the buried A horizon is then overlain by a rather thick package of fine-grained overbank deposits, which documents a lengthy episode (8000-4500 B.P.) of continuous low magnitude flood deposition induced by strong zonal atmospheric circulation. Throughout the region, a thick, moderately well-developed B horizon attests to this episode of slow, but continuous, vertical accretion during the Atlantic climatic phase (Vento and Rollins 1989; Vento et al. 2008).

The prevailing forcing mechanisms of upper-atmospheric flow suggest that the long-term flood plain stability present throughout the 3,500-year Atlantic climatic episode stems from zonal flow conditions. It is climatically plausible that warming conditions and Laurentide ice sheet ablation forced a net poleward adjustment in the mean polar jet stream as documented by Bartlein et al. (1984), King (1980), and Watts (1979). The adjustment to
this new flow regime likely occurred in an abrupt fashion (Wendland and Bryson 1974) with fluvial systems responding directly to the climatic change and indirectly to the slower associated vegetation shift (Knox 1983). As Knox (1983) suggests, vegetation would transition to the new climatic forcing within a period as short as 50-200 years.

By 4500-3000 B.P., there was a return to warmer and drier, and in areas, cooler and drier climates indicative of the late middle Holocene. This episode, known as the Sub-Boreal or neoglacialation, stimulated the initiation of North Atlantic circulation patterns similar to those of the present (Ruddiman 1968).

Increased frequency of cyclonic storms after the Atlantic episode, (but perhaps beginning as soon as 6000 B.P.) and resultant high alluvial deposition, fits with data from the upper Ohio River drainage basin (Vento and Rollins 1989; Vento et al. 2008). Stratigraphic evidence, in the form of coarse-grained vertical and lateral accretionary deposits especially along the first-, second-, and third-order streams within the basin, documents the increased occurrence of large storms certainly after 5000 B.P. (Vento 2007, 2008; Vento and Rollins 1989; Vento et al. 2008). Similar stratigraphic evidence in the northern Midwest supports the idea of more frequent large floods after 5000 B.P. (Knox et al. 1981). The increased rates of overbank deposition along the major drainage lines, and more active lateral channel migration and incision along their tributary streams, precluded the development (and/or preservation) of cumulic A horizons during this Sub-Boreal climatic phase (4500-3000 B.P.; Vento and Rollins 1989).

At present, it appears that the incision of the Pre-Boreal and Boreal (10,000-8000 B.P.) valley fill deposits in most areas of Pennsylvania stream basins is coincident with increasing meridional circulation patterns, resulting in more frequent, strong cyclonic storms (Grissinger and Murphey 1981; Vento et al. 2008). This episode of middle Holocene incision and flooding may be responsible for the general paucity or near absence of in situ Paleoindian, Early Archaic, and Middle Archaic sites in low terrace contexts along the majority of the streams in these basins. Archaeological sites such as Shawnee Minisink, Shawnee Island, Smithfield Beach, Cremard, Memorial Park, High Bank, Piney Island, and Canfield Island are somewhat unique in that they contain intact artifact-bearing remnants of those late Pleistocene through Atlantic climatic episodes in fine-grained overbank deposits (Vento and Rollins 1989).

By 3000 B.P., the mean climate abruptly transitioned to warm and moist conditions. The Sub-Atlantic (3000-2000 B.P.) and Neo-Atlantic (1500-1000 B.P.) climatic episodes mark successions to warm/moist and cool/moist to warm/moist conditions, respectively. It is likely that the effects of meridional circulation and the associated cyclonic and convectional storms were much reduced during these late periods (Vento and Rollins 1989; Vento et al. 2008). A subsequent return to more abundant hemlock pollen from its low levels during the warm/dry Sub-Boreal (4500-3000 B.P.) indicates lowered rates of evapotranspiration and more effective precipitation (Davis 1983).

Cooler and moister climatic episodes, such as the Scandic (2000-1500 B.P.) and Pacific (1000-750 B.P.), effectively impeded A horizon preservation as a result of frequent large floods. Rapid vertical accretion seems to be associated with more intact sola and
certainly the sealing of Cambic B horizons and coarse-grained C horizons (autogenic units) on low terraces within the region. This may be a result of an increase in tropical storm (hurricane) frequency and/or more frequent cool season flood events associated with more meridional flow conditions (Vento and Rollins 1989; Vento et al. 2008). Precipitation from intensive low pressure cells, such as the 1955 and 1972 tropical cyclone-induced floods, could have been rather common during these climatic phases as the atmosphere approached modern flow characteristics (NOAA 2009). Prior to 6000 B.P., blocking effects induced by the presence of the Laurentian ice sheet would have precluded such tropically induced flood events (Vento and Rollins 1989).

During the Neo-Boreal, or “Little Ice Age” (750-200 B.P.), cooler conditions returned to the northern hemisphere (Crowley and North 1991; Vento and Rollins 1989). This moderate glaciation followed the warmest part of the Holocene. There were two main cool stages about 100 years in length, primarily during the seventeenth and nineteenth centuries; the coldest decades occurred during the mid-late 1600s and early through late 1800s. Much of this period overlaps with the development of meteorological instruments which began in the early 1700s (Crowley and North 1991). The “Little Ice Age” was predominantly a winter phenomenon, expressed as winter cooling and marked summer droughts in North America. Southward shifts in mean circulation regimes were common during the cool season. Temperatures were about one to one and a half degrees Celsius (two to three degrees Fahrenheit) lower than present (Allison and Kruss 1977; Lamb 1977; Zhang and Crowley 1989). Over North America, a more meridional circulation regime was the norm, and it is similar to that which is presently dominant (Crowley and North 1991).

Paleoenvironmental Contexts

This section summarizes and synthesizes paleo-environmental data and sequencing most relevant to the regional and immediate environment of Site 36AL480. Components most heavily drawn upon are the climate-vegetation dynamic (with emphasis on the pollen record), climate-geomorphic relations, chronology, and broader implications for human settlement trends based on changing environmental zonation through time.

Paleoenvironments of the Upper Ohio and Neighboring Regions

As noted, the project area lies within the Unglaciated Appalachian Plateaus section of the mixed mesophytic forest region (Braun 1950). Extant secondary forests of the Ohio River drainage basin are composed of mesophytic species such as beech, white and red oak, sugar maple, ash, and walnut. However, the prehistoric forest was not only different from the modern forest in many respects, but was also in a state of gradual change for at least 8,000 years following the retreat of glacial ice. Watts (1979) has examined the pollen record for central Appalachia and the New Jersey Coastal Plain and has divided the post-glacial era into four periods: 1) the late Pleistocene, influenced by the proximity of the glacial front and ending about 13,000 B.P.; 2) the early Holocene, characterized by the in-migration of tree species from refugia in the south, ending about 9000 B.P.; 3) the Hypsithermal, a warm, dry period lasting until 3500 B.P.; and 4) the late Holocene environment, during which a relatively stable primary forest became established (Miller, et al. 2004; Watts 1979). It is noted that this is a broader climatic construct than the Blytt-Sernander scheme described
earlier, but it accounts for greater variability and facilitates interpretations of larger scale paleoenvironmental trends that might be more unequivocally registered in the stratigraphic record.

Pollen data suggest that glacial ice began its final melt and retreat between 15,000 and 14,000 B.P. (Watts 1979). At Longswamp, immediately south of the ice front, tundra vegetation with grasses, ericaceous shrubs, and dwarf birch was present, suggesting a cold, dry, and windy environment. In the Site 36AL480 study area, during maximum glacial advance, it is likely that similar vegetation dominated. As the glacier retreated, temperatures increased and organic soil horizons developed. Watts (1979) suggests that mosaic vegetation communities of this period would have featured stands of spruce, dwarf shrubs, and wet meadows in permafrost-free zones. Tundra pockets would have been extended across permanently frozen sites. This environment would have presented little in terms of edible plant resources for human populations. However, large, cold-adapted herbivores, such as mastodon, buffalo, and caribou, were available as human prey (Miller et al. 2004).

After 13,000 B.P., the climate and vegetation of the study area species ranges expanded northward due to increasing temperatures. Webb and Bartlein (1988:6) define the period between 12,000 and 9000 B.P. as a period of decreasing influence of the ice sheet and increasing influence of summer solar radiation. During this period, the modern vegetation gradient from northeast to southwest first appeared (Webb and Bartlein 1988). Fir, jack pine, paper birch, and white pine were among the earliest immigrants to the area, advancing from glacial-period refugia in the south. Hemlock was present in the study area by 9600 B.P., and oak was also present at a relatively early date. Beech and hickory appear in the pollen record by about 7500 B.P. Chestnut, an exceedingly slow migrant, was not found in the study area until approximately 5500 B.P. Many of the arboreal species that became established at this time represent food resources that yielded fruits and nuts, known to have been utilized both by humans and by faunal species hunted by humans, such as deer, elk, bear, and small mammals (Davis 1976; Miller et al. 2004).

A world-wide reversal of the warming climate appears to have occurred during the early Holocene, although there is debate as to its extent and cause. The Younger Dryas (11,000-10,000 B.P.), as described above, is characterized by an expansion of boreal taxa including spruce, fir, larch, paper birch, and alder (Peteet et al. 1990; Kneller and Peteet 1999). At Alpine Swamp, in northern New Jersey, radiocarbon dates place the boreal expansion between 11,000 and 10,000 B.P. (Peteet et al. 1990). In contrast, the pollen record at Browns Pond in the central Appalachians of Virginia suggests a brief cold reversal at 12,260 B.P., possibly correlating with the Older Dryas identified in Europe. But, there is no climatic reversal evidenced between 11,000 and 10,000 B.P., suggesting that the Younger Dryas cooling may not have extended as far south as Virginia (Kneller and Peteet 1999).

Older interpretations of the pollen record converged around the concept that the environment of 10,000 years ago resembled the modern Boreal forest, and was dominated by pine and without the deciduous food-bearing species that were abundant in the forest after 5000 B.P. (Fitting 1968; Ritchie 1979). More recent data shows a post-glacial proliferation of deciduous elements such as oak in pollen profiles. This is taken as evidence of the colonization, at least locally, of deciduous components in the early Holocene forest (Davis et
Delcourt and Delcourt (1980) show the presence of conifer-hardwood forests in the mid-Atlantic region at 10,000 B.P. In addition to conifers and oak, these forests included cold-adapted, mesic species such as birch, elm, ash, ironwood, maple, and beech. Oak and hickory pollen are well-represented at 10,000 B.P. in a core from Browns Pond (Kneller and Peteet 1999). The presence of carbonized grape, plum, and hackberry in a Paleoindian hearth at the Shawnee Minisink site on the Delaware River indicates that understory vegetation common in the temperate forest was present by this early period (Dent and Kauffman 1985).

Thus, by 10,000 B.P., the region consisted of forest canopy which contained a substantial component of temperate hardwoods. Deciduous hardwoods and their related understory species likely occupied favorable topographic and edaphic niches and initially occurred as patches within a predominantly coniferous forest. Eisenberg (1978) suggests that during the early post-glacial period, oak was also adapted to drier upland sites where soil formation was more advanced. In the southern section of the modern conifer-hardwoods found on the Appalachian Plateau, deciduous species have migrated northward along major valleys and their tributaries (Braun 1950). There is also evidence for an early to mid-Holocene immigration of deciduous species along stream valleys from glacial refugia in the south (Miller et al. 2004).

Faunal data also support the presence of a forest with a strong component of temperate species. Guilday (1982) has identified a Holocene fauna including six species of large mammals (deer, elk, mountain lion, timber wolf, bear, and bison) and a variety of small mammals such as rabbits and squirrels, and birds such as grouse and passenger pigeons (Guilday et al. 1964; Guilday 1967). Faunal resources were diverse during the early Holocene, including both those adapted to boreal and those adapted to deciduous forests (Eisenberg 1978). Guilday et al. (1977) note that the distribution of fauna depended on biotic gradients related to variations in topographic and edaphic conditions. Eisenberg (1978) cites evidence of mammoth and white-tailed deer co-occurring in the Northeast. The temperate forest faunal remains and pollen dating to ca. 11,300 B.P. at Meadowcroft may have been the localized result of favorable temperature and moisture regimes within the Cross Creek drainage (Adovasio et al. 1985).

Pollen evidence also signals the passage to warmer and drier climates (than present) over the period between 9000 and 5500 B.P. Within this timeframe, the data for the Hypsithermal is strongest in the Midwest where pollen profiles argue for advance of the prairie eastward into Illinois, reaching its maximum extent at about 7000 B.P. (Bartlein et al. 1984; King 1980). In the eastern United States, evidence for a warmer, drier period at this time, summarized by Graetzer (1986), includes a peak in grasses at Bear Meadows in Centre County, Pennsylvania (Kovar 1965), and xeric vegetation on the Cumberland Plateau in Tennessee (Delcourt 1979). Davis et al. (1980) point to an increase in the altitudinal range of hemlock and white pine as evidence of a warmer, drier period between 9000 and 5000 B.P. in New England. Watts (1979), in his examination of pollen diagrams in the mid-Atlantic region, supports the hypothesis of a warmer, drier climate between 8500 and 5500 B.P. (Miller et al. 2004).
Effects of the warmer, drier climate included a decrease in the number of low-order streams, lower water volume in streams generally, a decrease in biomass on ridges, and a lowering of the water table (Graetzer 1986; Watts 1979). Evidence, provided by correlations of pollen core data with pollen from surface samples from known vegetation types, suggests that the overall composition of the vegetation did not change radically (Bradstreet and Davis 1975). However, changes in hydrology and decreases in productivity would likely have had some effect on the distribution of prehistoric populations. Specifically, upland areas would have become relatively less attractive, whereas major riverine areas such as the Ohio, Delaware, and Susquehanna flood plains and terraces would have been relatively more attractive (Miller et al. 2004).

Although there is some disagreement regarding the occurrence of a mid-Holocene climatic optimum in the Northeast, there is still greater disagreement regarding the climate following 5000 B.P. A number of researchers have presented evidence in support of environments affected by severe climatic fluctuations, including a warm, dry, or xerothermic, period between 5000 and 2600 B.P. (Carbone 1976; Custer 1988; Curry and Custer 1982; Vento and Rollins 1989, Vento et al. 2008). Joyce (1988) notes that researchers have presented a variety of dates within this period for the proposed xerothermic. Curry and Custer (1982) argue that the xerothermic corresponds to the warm, dry conditions of the late Atlantic/Sub-Boreal (8000-4500 B.P. and 4500-3000 B.P., respectively) period in the Blytt-Sernander construct. Other researchers hold that although there were undoubted fluctuations in temperature and moisture after 5000 B.P., these were no more than low amplitude fluctuations of short duration (Beckerman 1986; Joyce 1988; Watts 1979).

Impacts on vegetation were likely minimal and the composition of the forest, as a result, was similar to the present day forest in many respects (Miller et al. 2004). Custer (1984, 1988) points to a decrease in hemlock and an increase in hickory evidenced in many of the major pollen studies of the northeastern United States. Hickory, in this sense, is considered an indicator of relatively dry conditions. However, as both Custer (1988) and Carbone (1976) remark, the inability to identify pollen to the species level renders such an interpretation problematical. Mesic species of hickory exist (Carya cordiformis, Carya ovata) and are common in the modern biota (Joyce 1988). Most xeric hickory species also grow and thrive on moist fertile soils. The sudden and synchronous decline of hemlock across a wide range of latitudes, cited as an indicator of dry conditions, is strongly supportive of disease rather than climatic change as the cause (Bhiry and Filion 1996; Davis 1983; Watts 1979, 1983). Likewise, pollen profiles do not exhibit significant increases in non-arboreal pollen, such as grasses, amaranth, and chenopod that would suggest a significant decline in overstory vegetation resulting from decreasing precipitation and increasing temperatures (Miller et al. 2004).

Carbone’s (1976) quantitative analysis of data from the Shenandoah Valley is often cited to support the proposition that warm and dry conditions were present in the mid-Atlantic during the late Holocene. The study followed a statistical methodology developed by Webb and Bryson (1972), based on modern pollen samples and modern climatic data from 73 sample locations in the Midwest. Carbone (1976) applied this methodology to raw data from Hack Pond, located in the Shenandoah Valley of Virginia, to project a warm, dry period that culminated around 4350 B.P. (Carbone 1976; Miller et al. 2004). This period
involved “increased temperatures, increased desiccation, and moisture stress” (Carbone 1976:106). It is not clear, in Carbone’s discussion, at what time temperature and precipitation reached modern conditions, although Carbone states that “the climatic shifts of the last 4,000 to 5,000 years can be better understood as perturbations of the modern pattern rather than as actual long-term shifts” (Carbone 1976:107). Problems in projecting the effective spatial ranges (from the Midwest eastward) and timing of climatic change for this widely utilized model stem from ecological variability, on both regional and localized scales (Miller et al. 2004).

Alluvial stratigraphy has also been cited as evidence for warm, dry conditions in the late Holocene. Increases in overbank deposition rates have been cited to account for increased runoff resulting from decreased vegetative cover. Such interpretations are based in part on Knox’s (1972) study of the morphology of stream channels and flood plains in southwestern Wisconsin. Knox interprets increased alluviation prior to 6000 B.P. as resulting from a warm, dry period in which climate was primarily influenced by dry westerly winds. This period is well-documented in the pollen profiles of the Midwest, which indicate an eastward migration of the Midwestern prairie prior to 6000 B.P. (King 1980). Following 6000 B.P., Knox theorizes that increasing rainfall and vegetation would have resulted in a decrease in the magnitude and frequency of peak stream flows, thus decreasing overbank deposition. Knox notes that the period of greatest sediment yield during the climatic evolution from humid to arid to humid conditions would have occurred at the end of the warm, dry period, during which vegetation was at a minimum, but rainfall had increased (Miller et al. 2004). Here again, there is the problem of projecting mechanisms (climatic or otherwise) onto alluvial depositional trends between regions.

Nevertheless, studies of alluvial stratigraphy in the mid-Atlantic region do indicate that overbank deposition was rapid during the period between approximately 5000 and 3000 B.P. Vento and Rollins (1989) and Vento et al. (2008) have identified rapid vertical accretion in the Ohio and Susquehanna River basins, consisting of sediments with Late Archaic and Transitional Period cultural material. Scully and Arnold (1981) found evidence of increasing vertical accretion in the upper Susquehanna Basin after 4900 B.P. Schuldenrein (2003) has found somewhat similar, although slightly more subdued, trends along the Delaware. Carbone (1976) points to the rapid deposition of culturally sterile, sandy clay loam between 5000 and 2700 B.P. as an indication that vegetation cover was at a minimum as a result of increased temperatures and decreased rainfall (Miller et al. 2004).

Hydrological studies cast additional light on the link between sediment yield, climate, and vegetation cover. Langbein and Schumm (1958) demonstrated that the magnitude of precipitation decrease needed to affect substantially the sediment yield and flood size is quite large. Their data show that precipitation declines for a forest to grassland transition would result only in a 30 percent increase in sediment yield. Late Archaic and Transitional Period overbank deposition apparently increased to at least this degree, yet there is no evidence in pollen profiles of grassland vegetation during this period (Vento and Rollins 1989; Vento et al. 2008). Data presented by Knox (1972) indicate that changes in mean annual precipitation have little effect on flood size above 65 cm (25.5 in) mean annual precipitation. Modern precipitation in the Susquehanna, Delaware, and Ohio River basins is approximately 89 cm (35 in) annually (Vento et al. 2008). Thus, for decreased rainfall to affect either the sediment
yield of drainage basins or the magnitude of overbank flooding, arid conditions would have been required. As noted above, there is no evidence of vegetation changes in the late Holocene pollen data of the mid-Atlantic region that would indicate a change to arid conditions. At most, the pollen data cited as evidence for a warm, dry period would indicate a shift in overstory composition involving an increase in xeric species. However, as noted above, this interpretation of the pollen profile is not irrefutable (Miller et al. 2004).

Vento and Rollins (1989) and Vento et al. (2008) accept the hypothesis of a warm, dry Sub-Boreal (4500-3000 B.P.), and they attribute rapid vertical accretion to changes in atmospheric circulation patterns. Based on Knox's (1983) discussion of the effects of zonal vs. meridional circulation, Vento et al. (2008) and Joyce (1988) point to an increase in meridional circulation that resulted in more frequent cyclonic storms, causing more frequent overbank flooding. Miller et al. (2004) indicates that such an interpretation does not depend on an overall decrease in precipitation and/or decrease in vegetation to explain the increase in alluvial deposition. Although there are, at present, no independent supporting data for this interpretation, the hypothesis is not in conflict with the pollen data as is the hypothesis of severe climatic change (Miller et al. 2004).

Miller et al. (2004) further note that there is no conclusive evidence of a widespread warm, dry climate such as that hypothesized by Carbone (1976) and Curry and Custer (1982) for the period between 5000 and 2600 B.P. Rather, data suggest that modern levels of temperature and precipitation prevailed in the eastern United States and the Ohio River drainage basin in general. Cyclonic storms, as evidenced by flood scouring and the deposition of coarse-grained material on the flood plain, likely occurred with greater frequency than in the previous period. Flood plain and terrace soils supported mesophytic species such as beech, oak, tulip tree, ash, sugar maple, and walnut. Upland soils supported forest communities dominated by chestnut, hickory, and oak. The late Holocene forest differed from the modern forest primarily in age structure; the late Holocene forest featured tree communities of variable ages, but featured internal gaps caused by falls of senescent trees and in various stages of regeneration. These gaps supported a variety of edible resources that grew best in the open, including berries such as blackberries, raspberries, and a variety of tubers that would have been available subsistence resources (Miller et al. 2004).

Holocene Climate and Alluviation History at 36AL480

The major shifts in atmospheric circulation, and consequently climate, in the mid-Atlantic during the late Pleistocene and through the Holocene, impacted the fluvial regime and the landscape architecture of the Ohio River and its terrace system. Locally, such changes are registered in both the landform configurations and in the stratigraphic record at Site 36AL480. Table 2.3 reviews the major time periods discussed in this section, highlighting the general expressions of regional climatic change. Further, it summarizes the primary soil and depositional changes as observed in stratigraphic exposures from Phases I, II, and III archaeological and geomorphological investigations. The allostratigraphic scheme outlined earlier is utilized to distinguish key transitions in the alluvial history registered on the primary (T3) landform. The correspondence between allostrata and climatic episodes is a measure of the degree of causality between local stream histories and larger scale climatic trends and forcing mechanisms.
<table>
<thead>
<tr>
<th>Geologic Period Climatic Episode</th>
<th>Dates (14C)</th>
<th>General Features</th>
<th>Leetsdale Stratigraphic Record</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late Pleistocene Late Wisconsin</td>
<td>18,000-14,000 B.P.</td>
<td>Shifting atmospheric circulation, precipitation patterns, and temperature fluctuations as climate warmed; massive ablation of the ice sheets and extremely coarse sands and gravels filled stream valleys.</td>
<td>Deep gleyed silts and clays resting on heavily oxidized very coarse sands and gravels at approximately 207 m NVGD and below as seen in the Casting Basin, Back Channel and deep auger tests within the excavation areas.</td>
</tr>
<tr>
<td>Younger Dryas</td>
<td>11,000-10,000 B.P.</td>
<td>Brief return to colder conditions, greater effective precipitation, active lateral channel migration, and high stream discharge.</td>
<td>Basal lateral accretion deposits reflecting high stream velocities; Leetsdale T3 likely a mid-channel island within a braided channel pattern (AU-1).</td>
</tr>
<tr>
<td>Holocene Pre-Boreal</td>
<td>10,000-9200 B.P.</td>
<td>Warming trend generally, colder and drier episodically; lateral deposits alternating with vertical accretion, some surface stability, and deep soil development (early-Holocene); retreat of spruce-pine forest and rise of fir-oak-birch stands.</td>
<td>Lateral accretion deposits shifting toward vertical accretion as stream channel develops a meandering aspect. Thick accumulation of sands with in situ weathering above basal gravels (AC-C) in Areas 2 and 3.</td>
</tr>
<tr>
<td>Boreal</td>
<td>9200-8000 B.P.</td>
<td>Warmer and drier conditions; establishment of meandering channel pattern and accumulation of finer overbank deposits. Brief cooling “8.2 cal ka event”</td>
<td>Continued accumulation of fine sands/silts and formation of incipient A horizons across landform. Indications of initial occupation of the T3 (Early-Middle Archaic?)</td>
</tr>
</tbody>
</table>
Table 2.3 Summary of Paleoclimatic Chronology in the Mid-Atlantic and Specific Stratigraphic Expressions at Site 36AL480.

<table>
<thead>
<tr>
<th>Geologic Period Climatic Episode</th>
<th>Dates (14C)</th>
<th>General Features</th>
<th>Leetsdale Stratigraphic Record</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlantic</td>
<td>8000-4500 B.P.</td>
<td>Warmer and wetter; vertical accretion sustained as channel trench stabilizes; slow, continuous development of cumulic A and cambic/argillic/fragic B horizons.</td>
<td>Deeply developed cambic/argillic B horizons in Areas 2 and 3, and Phase II Block 6, minimally Area 1 (AU-2). Primary Middle to Late Archaic occupations (all areas).</td>
</tr>
<tr>
<td>Sub-Boreal</td>
<td>4500-3000 B.P.</td>
<td>Warm, dry climate; large, high energy storms renew vertical deposition on high stream terraces (T3) and lateral accretion across valleys. Periodic incision of stream channel against existing older terraces seen regionally.</td>
<td>Initial deposition and aggradation of terrace near Back Channel, Area 1; weakly developed incipient A horizons on fine to medium sands (AC-C); deeply inset erosion of T3 near Area 2; abandonment of Back Channel as primary channel line and its establishment as an overflow chute.</td>
</tr>
<tr>
<td>Sub-Atlantic</td>
<td>3000-2000 B.P.</td>
<td>Warm, moist climate; reduced storm circulation; flood plain stability (T3 surface) and long-term surface horizon development.</td>
<td>Buried A horizons of Area 3 and neighboring backhoe trenches from 2000 signal terminal construction of T3 and aggradation of T2.</td>
</tr>
<tr>
<td>Scandic</td>
<td>2000-1500 B.P.</td>
<td>Cool, moist; related to higher tropical storm frequency causing renewal of high energy flood events overtopping highest stream terraces.</td>
<td>Thin, overbank deposits (related to most prominent flooding events) developing weakly into A-B packages. Examples include Ap-Bw and BC horizons from Area 3 (AU-3).</td>
</tr>
<tr>
<td>Neo-Atlantic</td>
<td>1500-1000 B.P.</td>
<td>Warm, moist; surface stability on terraces.</td>
<td>Possible Woodland period cultural alterations of flood plain.</td>
</tr>
<tr>
<td>Geologic Period</td>
<td>Dates (14C)</td>
<td>General Features</td>
<td>Leetsdale Stratigraphic Record</td>
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<tr>
<td>Pacific</td>
<td>1000-750 B.P.</td>
<td>Cool, moist; renewed alleviation with increased tropical storm appearance possible.</td>
<td>Possible Woodland period cultural alterations of flood plain.</td>
</tr>
<tr>
<td>Neo-Boreal “Little Ice Age”</td>
<td>750-200 B.P.</td>
<td>Cool, moist to cool, dry</td>
<td>Late Woodland to Historic Contact</td>
</tr>
<tr>
<td>Historic/Modern</td>
<td>200 B.P. to present</td>
<td>Warm, moist.</td>
<td>Lead-contaminated historic fills (AU-4).</td>
</tr>
</tbody>
</table>

The earliest stratigraphic sequences at Site 36AL480 are observed from the late Wisconsin, during the period of significant deglaciation (after 14,000 B.P.). At this time, rapid and extreme climatic change occurred, triggering massive ablation of the ice sheets over a 5,000-year period. Along the Ohio River at Pittsburgh, more than 24.4 m (80 ft) of glacial outwash filled the valley bottom zone as the Laurentide glacier began to retreat northward. Locally, the surface of these basal late Wisconsin outwash deposits at Leetsdale are observed at a nominal elevation of 207 m ASL (679 ft), some 2.5 m (8 ft) above the thalweg of the Ohio River prior to navigation controls (Wagner et al. 1970).

During the late Wisconsin (18,000-14,000 B.P.), the river habit was braided with numerous anastomizing channels. At this time it was probable that a relict Back Channel zone was created at Leetsdale and that the T3 terrace landform essentially stood in the river channel as a medial channel bar. Cultural materials from this period are both scant and undiagnostic at the site, although several hand-augered cores and deep backhoe trenches have pierced the surface of the late Wisconsin gravels in the Casting Basin and archaeological excavation areas (Schuldenrein et al. 2003; Vento et al. 2001; Vento et al. 2008).

Slightly later, at the time of the Younger Dryas cooling event (11,000-10,000 B.P.), greater effective precipitation in the Ohio River valley favored active lateral channel migration and higher stream discharges. The top of the basal sands and gravels, which consistently underlie early Holocene-age vertical accretion deposits at Leetsdale, are dated to approximately the Younger Dryas and, hence, would correspond to the terminal Paleoindian or earliest Archaic. The renewed dynamism of the Ohio River fluvial system (especially deposition and channel migration along the trunk stream) at this time may in part be responsible for the general paucity of recorded pre-Clovis and Clovis sites along low terrace contexts. In addition, many possible sites of this time frame would have been eroded as a result of early Holocene flood events or channel migration episodes. Several radiocarbon dates ranging between 13,000 and 10,000 B.P. from the basal lateral accretion deposits in the project area roughly correspond to the end of the Bolling-Allerod through the Younger Dryas, documenting this episode of high flow velocities and more effective precipitation.
(Schuldenrein et al. 2003; Vento et al. 2001; Vento et al. 2008). Preliminary indications are that the end of the Younger Dryas marked a threshold shift from dominant lateral accretion to overbanking, as vertical accretion began to stabilize the early Holocene flood plain, currently the T3 terrace. However, periodic lateral shifting of channel lines was still ongoing during that period.

As discussed above, the Holocene stratigraphic record preserves several shifts in local warming and cooling events. At Site 36AL480, any stratigraphic evidence of the earliest Pre-Boreal change (10,000-9200 B.P.) is sealed within the basal gravelly coarse sands typically encountered within 7 m (23 ft) of the ground surface of the T3 terrace. That interval has no unique stratigraphic or depositional signature that was recognized in the current investigations. However, the Boreal (9200-8000 B.P.) warming trend is interrupted by the “8.2 cal ka event” (brief climatic deterioration). It is interesting to note that at Site 36AL480 the thick package of sands (unaltered flood sands expressed as alternating AC-C horizons and cyclic couplets; associated with AU-1), dating from roughly 10,000-7000 B.P., may in fact result from this period of climatic deterioration. In terms of floodplain geography, the most likely interpretation for deposition of these sands, which cap the basal late Wisconsin-age lateral accretion deposits, is that, during the early Holocene, the T3 terrace landform was situated within 2.5-3 m (8-10 ft) of the active river channel in a proximal or medial channel bar position.

During the Pre-Boreal (10,000-9200 B.P.) and Boreal (9200-8000 B.P.) episodes, the Ohio River near Leetsdale established a clear meandering channel habit and began the long phase of Holocene aggradation. The basal sands and gravels deposited during the Younger Dryas (11,000-10,000 B.P.) are overlain by fine-grained overbank deposits emplaced during the warmer and drier climatic conditions of the Pre-Boreal and Boreal. On the T3, the pedostratigraphic units that date from the Pre-Boreal to Boreal are principally comprised of variably thick, fine to medium grained sand lenses (C horizons), the upper parts of which show some evidence of incipient in situ weathering and soil development. These capping AC horizons document relatively short intervals of flood plain stability during rather rapid aggradation of the T3 landform. The emplacement of these stacked AC-C horizons essentially spans the period of time from the end of the Younger Dryas at 10,000 B.P. to roughly 7000 B.P. (AU-1), during the middle of the Atlantic climatic episode (8000-4500 B.P.). By 7000 B.P., the T3 landform had aggraded sufficiently above the active channel of the Ohio River and an ancillary artery (now in-filled as the Back Channel), such that the flow velocities diminished by an order of magnitude, depositional suites transitioned to an abundance of suspended load and alluviation patterns trended to overbanking. The lower BC/Bw/Bt/Btx horizons encountered in some of the geomorphology test trenches during 2000 (Vento et al. 2001), and during excavations in Area 3 South and Area 2, corresponded with stabilization of the T3 terrace at this time (Schuldenrein et al. 2003).

During the Atlantic episode (8000-4500 B.P.) at Site 36AL480, incipient A horizons formed between 4 and 6 m (13 and 20 ft) below ground surface in Area 3 South and Area 2. These weakly developed paleosurfaces are analogous to equivalent soil and sediment packages at trunk stream terraces sites such as Memorial Park, Shawnee Island, Point State Park, Cremard, and French Creek as discussed above, which also demonstrated cumulic and incipient A horizons from the first half of the Atlantic period.
It is, however, the more strongly developed paleosols associated with the Bw, Bt, and Btx horizons in Areas 2, 3 South, and in associated trenches (Schuldenrein et al. 2003; Vento et al. 2001) that weathered down-profile and within overbank alluvium during the Atlantic climatic episode (8000-4500 B.P.). These horizons represent the primary construction phase as well as subsequent weathering and stabilization interval on the T3 terrace (part of Allostratigraphic Unit 2). The aggradation and initial weathering phases correspond to the roughly 3500-year duration of the Atlantic period. This thick, moderately well-developed B horizon is also seen regionally. Several bracketing radiocarbon dates, between 4800 and 4200 B.P. from a large number of excavated sites in Pennsylvania, indicate at least a several hundred year period of warm/moist conditions and flood plain stability (decreased rates of overbank discharge) for the end of the Atlantic climatic episode. At Site 36AL480, such a late to middle Holocene-age paleosol, signaled by a well-developed cumulic A horizon, is noticeably absent. Its absence is likely more a function of variables such as the local valley morphology, occurrence of the active Back Channel supplying sediment to the terrace, and height and distance of the terrace from the active river channel.

At Site 36AL480, the Sub-Boreal episode (4500-3000 B.P.) documents a period of rapid terrace aggradation, especially in those areas adjacent to the relict Back Channel. In Area 1, for example, more than 1 m (3.3 ft) of lamellar sands comprised of incipient AC horizons overlain by coarser grained C horizons sands were emplaced within 1,000-1,500 years. The large number of Transitional Archaic features in Area 1 that were preserved within this 1-m-thick package of stacked AC-C couplets consistently occurs on or within the AC portion of the couplet. The oxidized AC horizons document brief episodes of terrace stability prior to deposition of the next autogenic event. The absence of these lamellar sands to the north and west in Area 2 and Area 3 South argues for their deposition from a formerly active flood chute rather than from the Ohio River main stem. Deposition of these lamellar sands appears to have stopped prior to 3000 B.P., given the occurrence of a thick cumulic A horizon in Area 3 South, and the occurrence of a Bw horizon overlying the lamellar sands in Area 1 and in the Phase II excavation Blocks 1-6 from 2002. It is significant that following a localized erosional event in the southern portion of Area 2, resumption of T3 aggradation, generally by finer sands, is dated to the Sub-Boreal transition (at 4500 B.P.) above a disconformable surface marked by lamellar sands.

Furthermore, geomorphologic testing in the Back Channel zone and a series of dates between 4500 and 3500 B.P. argue for significant landscape differentiation at around the same time. At that point, the Back Channel still served as a seasonal overflow chute and perhaps a longer term outlet for floodwaters. The decline of hemlock during the Sub-Boreal (4500-3000 B.P.) lends support to the assignation of warm-dry conditions during this time. The absence of well-developed cumulic A horizons and associated flood plain instability during this period, as expressed in the soil stratigraphic profiles from Leetsdale, can also be attributed to these conditions.

The transition from the Sub-Boreal to the Sub-Atlantic (3000-2000 B.P.) climatic episode is registered by long-term A horizon development above an obviously elevated and stabilized flood plain. It remains unclear as to whether or not the thin accumulation of fills (1-2 m) attesting to construction of the T2 is dated to that transition or not, but it occurred within several hundred years of the change. The proliferation of thinly separated and/or
welded buried A horizons in the central and southern portions of the T3 landform (Areas 2 and 3) clearly document a period of relative stability on the primary site landform beginning at approximately 3000 B.P. (Schuldenrein et al. 2003: Figure 4A.1; Vento et al. 2001: Figures A5 and A6). Later, cooler and moister climatic phases such as the Scandic (2000-1500 B.P.) produced the Ap, AC, Bw, and BC horizons that cap the 2AB horizon from Trench 2-1, for instance, in the vicinity of Area 3 South (Vento et al. 2001:Figure A5) and the truncated Bw/BC horizons in Area 1 and Area 2 at Leetsdale (AU-3). Unfortunately, due to extensive historic disturbance and recent stripping of the upper soil package, much of the latest Holocene vertical accretion deposits are either missing or disturbed, thus limiting a more detailed pedostratigraphic interpretation.

Pollen studies indicate that high percentages of grass, vetch, and chenopodium (both pollen and seed) occur in alluvial deposits less than 2,000 years old, and are often associated with various types of disturbance events (Jones 2006). Their occurrence here may either register significant late aboriginal impacts on the terrace, or attest to accelerated deforestation followed by establishment of these pioneering taxa. Scully and Arnold (1981) have suggested that native populations may have been an important geomorphic agent as there is evidence for burning, clearing, and cultivating of forest lands before larger scale European farming took hold. The reported high percentages of Ambrosia and Rumex pollen in the C3a zone may be attributable to aboriginal clearing. The occurrence of ubiquitous charcoal flecks in the late Holocene alluvium at numerous sites in the region may reflect increased aboriginal utilization and occupation of the valley bottoms during this time.

Finally, much of the Contact, Historic, and very late Holocene flood histories (AU-4) have been removed at Site 36AL480 by recontouring of the landscape by Euroamericans, particularly as documented by the Harmony Brick Works in Area 1 (Miller et al. 2010). The limited number of soil profiles at Leetsdale that do contain soils of late Holocene age, as well as other studied profiles within the region (e.g., Leetsdale Sewerage Treatment Renovation project), indicate increased flood activity during the period 750 B.P. to present (Vento 2007, 2008). This increased flood frequency may reflect higher stream discharges during the cool and wet “Little Ice Age” (750-200 B.P.) and also from historic deforestation events, which allowed for greater rates of surface runoff and associated higher stream discharges.

The alluviation and supplementary paleocological histories from Leetsdale and the surrounding regions provide a deep and rich archive of information on human occupation of a dynamic landscape. Further evidence of this environmental context was collected during the Phase III investigations in Areas 1, 2, and 3 South. The following section summarizes and describes the field and analytical methodologies employed by the geomorphology team at Site 36AL480.

**Phase III Geomorphological Field and Laboratory Methodology**

The considerable baseline geoarchaeological data produced during the Phase I and II testing (see Section 2.3) helped to guide the methodological approach to the Phase III archaeological investigations at Site 36AL480. By methodology, we refer to both the theory
underlying the stratigraphic framework of field observation, analysis, and site interpretation and to the practical techniques and applications of data assembly and analysis. The importance of the Phase III stratigraphic framework cannot be segregated from the methodology of data collection and analysis, insofar as that framework was consistently refined in response to the expanding data bases generated by both the archaeological and geomorphological investigations. Moreover, the refinements in our understanding of the stratigraphy also produced modifications to in-field data collection (in some cases) and in analysis protocols (in many others).

Accordingly, this section of the report is organized in four sub-sections as follows:

- **Chronology and the timeline for data recovery efforts.** The presentation highlights the major services provided by the geomorphology team while on site and during post-field analyses.

- **Summary of the major geomorphological concepts and stratigraphic nomenclature** underlying the genetic stratigraphy model that ultimately governed the interpretations offered in this study.

- Description of the program of complementary field and laboratory techniques utilized to structure and maximize recovery of data.

- **Assessment of the inductive utility of the Leetsdale geoarchaeological model** to facilitate regional and extra-regional comparisons with deeply stratified, multi-component alluvial sites in the Appalachian Plateaus Physiographic Province (Section 2.7).

**Chronology of Phase III Data Recovery Efforts**

As described in Section 2.1, the Phase III geoarchaeological data recovery program began with systematic investigations at Area 3 South in 2001 (Anderson et al. 2010). The program was expanded to Area 1 over the course of 2002 (Miller et al. 2010), while Area 2 efforts began in 2002 and were completed in 2003 (Miller and Marine 2005). Concurrently, examination of six Phase II block excavation units proceeded during the summer and fall of 2002 (see Figure 2.3; Anderson et al. 2003; Fenicle 2003). It should be noted that by 2001 the Phase II report concerning geomorphology had been released and presented a provisional chronostratigraphy spanning all of the major Areas (i.e., the T3 terrace; Vento et al. 2001: Figure A-17). That document provided the initial guide for subsurface excavations for the archaeological contractors as they began work. Following the 2001 field season, the geomorphology team issued an interim Phase III report that proposed the initial allostratigraphic scheme based on observations and limited laboratory results for Area 3 South only (Schuldenrein et al. 2003).

In July 2002, Drs. Schuldenrein and Vento accompanied project palynologist Dr. John Jones in a joint effort to extend deep test excavations in the vicinity of the Back Channel through excavation of four deep backhoe trenches (see Figure 2.3). Detailed descriptions, drawings, and photographs were completed to record the soil and sediment
profiles. The geomorphology team collected and stored soil-sediment and radiocarbon specimens. Dr. Jones sampled and analyzed palynological specimens utilizing the stratigraphic designations of the geomorphology team (Jones 2006; Schuldenrein et al. 2003). Backhoe Trenches 1 and 3 (BHT-1 and BHT-3) produced significant data with comprehensive interpretive implications for paleoenvironmental reconstruction (Section 2.4) and human ecology (Sections 2.6, 2.7, and 2.8).

Phase III geoarchaeological efforts served dual purposes. Initial fieldwork focused on development of area-specific natural stratigraphies that were integrated with cultural sequences over the course of the fieldwork. The more overarching objective was to formulate a site-wide stratigraphy and develop timelines for structuring linked landscape histories and occupation sequences across the areas and attendant landscape segments (principally the T3 terrace, Casting Basin, and Back Channel). The field and laboratory analyses coupled with the archaeological studies of the primary excavations provided the outlines for the site-wide stratigraphic framework (Section 2.6). In this way, it would be possible to construct interrelated models of archaeological sensitivity, landform evolution, and intrasite relationships that were internally consistent and accounted for the substantial stratigraphic and archaeological variability between areas and supplementary tracts (Schuldenrein et al. 2003).

More specifically, per the Consultants Proposal (Greenhorne & O’Mara 2001:A-1 – A2), the services to be provided by the geomorphology team during data recovery included such tasks as:

• The construction of detailed stratigraphic profiles for all units and block excavations within each area, identifying and describing all appropriate lithostratigraphic and/or pedostratigraphic (soil horizons) units;
• The excavation of strata/soil horizons in 10-cm (3.9-in) arbitrary levels within natural deposits, with efforts made to minimize cross-cutting of levels within deposits through close monitoring of changes in soil or sediment color, texture, and structure;
• The careful description and profile mapping of all strata/soil horizons in the field with notation on the thickness, horizontal extent, Munsell soil color, texture, structure, and any important diagenetic features (e.g., silt skins, mottling, etc.);
• The detailed description in daily geomorphology field notes of weather, artifacts with regard to stratum, occurrence of features, radiocarbon samples, archaeological work progress, changes in stratigraphy, and stratigraphic correlations;
• The association of all geomorphology samples collected for post-field analysis from each area with site datums and hubs; and
• The collection of two sets of geomorphological samples for post-field analysis including those related to:
Natural sedimentation and weathering processes; samples were to be analyzed through granulometry, detrital grain assessments, soil/sediment biogeochemistry, clay mineral analysis, and micromorphology; and

Matrix modification by cultural processes (i.e., features, middens, and occupation surfaces) to be analyzed through phosphate fractionation, geochemistry of occupation fills, and micromorphology (soil thin sections) of cultural sediments.

These tasks were completed through an integrated program of field description, documentation (e.g., mapping, photography, etc.), and sample collection, along with a series of laboratory analyses focusing on the physical and chemical markers of both natural and cultural processes.

**Model of Genetic Stratigraphy**

The foundation for the site-wide and intersite models proposed for Site 36AL480 is rooted in the concept of genetic stratigraphy, a geomorphic model which both structures and bridges site formation histories inductively and across a range of scales. These scales project initially from the site-specific to intersite to drainage-wide, and then expand more broadly to the local and regional (Galloway 1989; Räsänen et al. 2009; Soil Survey Staff 1994, 2004). The following is a brief discussion regarding genetic stratigraphy and its archaeological application.

At the most fundamental level, geomorphologists recognize two types of depositional events: autogenic and allogenic. Autogenic events are localized and apply to a confined area. Allogenic events are extra-local, more widespread, and have regional implications in terms of landform and environmental histories (Busch and Rollins 1984). Genetic units, when identified (e.g., in exposures or cores) are of unknown lateral extent prior to correlation. The scale of allogenicity and autogenicity is relative, dependent upon the scale of observation and lateral exposure. The determination of the geographic extent of a genetic unit is based on its potential to be correlated beyond a single exposure. The primary goal of genetic stratigraphy, whether applied to marine strata or to archaeological deposits within Holocene alluvium, is to develop high-resolution chronostratigraphic frameworks that can be projected across a variety of subsurface contexts.

Alluvial sequences are viewed as representing long intervals of stasis (indicated by buried A horizons), punctuated by brief episodes of deposition or erosion manifested at a site by the emplacement of coarse-grained C horizons or accumulating B horizons (Goldberg and Macphail 2006; Holliday 2004; Waters 1992). Alluvial paleosols account for only a small fraction of the vertical sediment package, but represent up to 95 percent of the involved time interval of accumulation of an alluvial sequence (Kraus 1987; Retallack 1984).

As such, paleosols are ideal genetic units for establishing a chronostratigraphic framework at an archaeological site. Because they reflect temporal stability, paleosols can
represent allogenic genetic units traceable over considerable distances. The degree of
temporal stability—the time interval represented by paleosols—varies widely. Of particular
utility in this regard are cumulic A horizons which reflect conditions of temporal stability in
humid regions. Here, A horizons may form on alluvium in only a few hundred years (e.g.,
Scully and Arnold 1979, 1981). Alternatively, sustained paleosol formation may take tens of
thousands of years (e.g., Kraus and Bown 1986). B horizons, where present, may even be
more diagnostic because of the duration of weathering. Given the prominence of the
weathering signature, paleosols may function as ideal allogenic units. Thus, in structuring
the genetic stratigraphy of alluvial sequences, it is the paleosol proper (A horizons and A-B
sola), and not the basal parent material (C horizons), that must be considered the basic
genetic unit.

Typically on flood plains and terraces, mature distal paleosols should be more easily
traced over wide areas, while cryptic, immature, and proximal paleosols will contain
localized features of autogenic overprinting (e.g., episodic channel migration, avulsion). In
practice, however, both the mature distal, as well as the cryptic, immature, and proximal
paleosols, can serve as “marker” horizons that facilitate designation of particular stratigraphic
sections, forming the foundation for an integrated chronostratigraphic framework. Retallack
(1988) has established criteria for the field recognition of paleosols that enhance the genetic
use of paleosols in alluvial sequences. A strategy based on careful stratinomic (stratum-by-
stratum) description, preferably anchored by paleosols and measurement of individual
alluvial sequences, is therefore essential to building a model of intrasite and intersite genetic
stratigraphy. In this process, recognition of four aspects of any profile is critical: 1)
lithostratigraphic successions (sediment changes); 2) cultural deposits (archaeological
horizons); 3) erosional breaks (unconformities); and 4) weathering profiles (soil horizons).

Once these key components of a section are mapped and described, first individual
profiles, and next, sets of profiles can be compared through the tracking (vertically and
spatially) and matching of genetic units. During the Phase I and II geomorphic investigations
at Site 36AL480, for example, the buried A horizons, developed (cambic, fragic and argillic)
B horizons, and in some cases, even coarse-grained and laterally persistent C horizons, could
be mapped across the T3 terrace (see Section 2.3). The initial study demonstrated the
chronostratigraphic utility of this approach (Schuldenrein et al. 2003; Vento et al. 2001). The
previous work suggested that relative thicknesses of strata played little to no role in linking
the sections, whereas marker horizons were the linchpins of the chronostratigraphic
framework. It is stressed that marker horizons can be established on the basis of other
diagnostic paleoenvironmental criteria, including: 1) faunal or floral (such as distinct pollen
assemblages like the Boreal pine/oak assemblage); 2) cultural (e.g., Susquehanna
Broadspars); or 3) radiometric (14C dated) zones. At Site 36AL480, for example,
diagnostic paleofloral assemblages (i.e., pollen and phytolith; Jones 2006) offset marker
horizons and assisted in correlating stratigraphies between landforms, specifically between
the T3 terrace and Back Channel (see Section 2.6). Taken together, marker horizons permit
first-order adjustment in the floating of the genetic units and their transposition to other
sequences on site. It follows that the utility of genetic sequences is enhanced as criteria for
designating marker horizons increases, thus allowing for higher resolution
chronostratigraphic adjustment of the matched sections.

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The origins of the allogenic A horizons cannot always be isolated. In a classic soil profile, the A horizon overlies the B horizon as continuous soil formation produces a composite weathering profile. However, as the depositional and erosional cycles of flood plain construction proceed, stripping of the A horizon is a common product of an erosional phase in flood plain history. In this case, an A horizon above a B may represent aggradation of episodic flood deposits atop a stripped solum and the genetic utility (of the preserved succession) may be somewhat compromised. More typically, however, the A horizon would be linked to the underlying solum. At Site 36AL480, a typical soil-sediment package (for Areas 2 and 3) would consist of an A horizon above either a cambic B (Bw) or weak to moderately developed argillic/fragic B (Bt or Btx) horizon. In Area 1, thin A horizons and AC horizons were more common soil-sediment packages. The base of the deeper profiles (across all areas of the site) consisted of coarse-grained alluvium (C horizons) of varying thicknesses. These textually variable B and C marker horizons reflect changes in flood intensity and flood plain stability during cool/moist and warm/dry intervals of the Holocene. Such paleoclimatic conditions may have affected vegetation cover and led to increased rates of surface runoff, mass-wasting, and more frequent floods, which in turn would have inhibited A horizon development as vegetation could not take root. Upbuilding of soil profiles, attendant to sustained weathering, resulted in progressive leaching of the A horizon and its incorporation into the B horizon.

Thus the origins of the A horizon cannot always be determined and the unique AC-C soil-sediment packages registered in Area 1—chronologically equivalent to or at least overlapping with the more prevalent soil forming sequences in Areas 2 and 3 South—present a clear exception to the classic depositional and pedogenic succession common for the central and southern portions of the landform.

Given that the model of genetic stratigraphy depends upon the initial assumption of allogenicity, the stratigraphic variability within the T3 terrace sequence necessitates a consideration of the alternative to allogenicity. Operationally, it would be ideal to detect and trace marker A horizons, for instance, among all sections or areas of a site. In practice, of course, individual sections may not contain specific A horizons. The presence or absence of buried soils along a given section of the river, or in this case even within a site, reflects autogenic (local) influence, which, in the case of alluvial sequences, may be a result of five possible situations, including: 1) local erosion (ravinement); 2) tributary order; 3) position within the alluvial landscape; 4) valley morphology and stream dynamics; and lastly, 5) climate change and paleosol occurrence (Vento et al. 2008). These influences can be briefly considered in terms of their impact on the Leetsdale sequence.

First, the local erosion or ravinement along stream channels will impact the preservation of buried solas. Generally, small first-order tributaries are in a phase of active downcutting and headward erosion. Locally, an example of tributary influence in the past would include the impacts of Sewickley Creek and/or the Back Channel which is adjacent to the T3 terrace. A previous period of downcutting (in the higher terrain to the north and east) could have flushed sediment from the upper reaches of the stream system, where the gradient is steepest, to the confluence, where base level is graded. In the past, it is possible that sediment discharging from one of these former drainages may have resulted in deposition of
coarser sediment on a former levee (of the T3 terrace) that would spatially conform to the location of Area 1.

The second significant autogenic influence is the tributary order of the stream. Low-order streams are less likely to laterally migrate and aggrade their valleys than higher-order streams. Thus, these smaller stream confluences are less likely to contain artifact-bearing buried solas. Furthermore, first or second-order tributaries may not have been present during formation of some older paleosols associated with stretches along the trunk stem of the Ohio. At Site 36AL480, these would include the small, consequent streams, Big Sewickley Creek, and/or an older artery or chute linked to the Back Channel that drain into the Ohio River. These influences could be sorted out topographically and chronostratigraphically, such that the capping deposits of Area 1 would be younger and perhaps lower in elevation than the higher surfaces of the T3 landform.

A third impact affecting the preservation of buried soils is the landform position within the alluvial landscape. In the Susquehanna, Ohio, and Delaware drainage basins, allogenic genetic units (paleosols) are most easily traced and preserved along the higher, better-drained levee or bank-edge areas of the flood plains and along reaches of straight channels between rapid accreting point bars (Vento and Rollins 1989). This is especially true along first through third-order streams in the basin. Increased distance landward from the actual channel is accompanied by reduced thickness of the overbank deposits, as well as the accumulation and number of buried soils. However, on a T1 terrace or channel bar, frequent flooding and overbanking may not provide the temporal stability for the formation of an A horizon proximal to the stream channel. At Site 36AL480, the horizontally discontinuous T1 terrace was identified approximately 4 m above the active river channel and was comprised almost entirely of coarse-grained flood deposits or stacked C horizons (Vento et al. 2001).

Fourth, underfit streams with V-shaped cross sections and poorly developed flood plains rarely display multiple paleosols. In first-order streams, this V-shape valley form, combined with steep gradient valley sidewalls and accompanying small flood plains, promote the rapid scouring of previously emplaced overbank deposits by large flood events. In contrast, higher order streams, with straight segments or areas near stream junctions along large rivers, are more likely to display multiple stacked A horizons than are stream segments near meanders, where active lateral channel migration and pronounced avulsion have resulted in scour and soil-sediment stripping. Site 36AL480 was not associated with an arcuate meander loop, although the ancient channel may have been somewhat more sinuous (Vento et al. 2001).

Finally, micro-climatic factors can account for bias in the preservation of soil-sediment stratigraphies for the more limited sequences registered on the banks of lower order drainages. Localized pressure, moisture, and circulation regimes will play an inordinately significant role in affecting run-off and patterns of deposition in confined alluvial landscapes where soft-sediment based landforms are small and subject to extreme erosion. Here only evidence for the highest energy events can be preserved. It can be assumed that since such locations are often removed from loci of sustained alluvial construction, minimal evidence for soil development is retained.
Summarily, the baseline sequences along the Ohio River trunk drainage at Site 36AL480 implicate contributions from both allogenic and autogenic components to account for the composite stratigraphic record. Allogenicity is dominant because of the preponderance of evidence for sustained intervals of soil formation over the course of nearly 10,000 years on the primary Holocene landform, the T3 (and to a lesser degree on the T2 terrace). Thus, the genetic stratigraphy model represents a viable construct. Nevertheless, various autogenic influences, linked to lower order drainage activity, have modified the sequences, and specifically the expression and extent of the pedogenic archive preserved along the peripheries of the primary landform. The recognition of multiple, buried, Holocene genetic sola punctuated by alluvial events (Vento and Rollins 1989) at Site 36AL480 has required sorting at the variety of scales implicit in a model of genetic stratigraphy.

At the core of the model is an understanding of paleoclimatic variability that accounts for the dynamic equilibrium between environmental change (per the alluviation record) and stability or stasis (per the soil formation chronology). A hypothesis that remains to be refined is the temporal equivalence between stable surfaces (B horizons), archaeological occupations, and paleoclimatic cycles. One proposed construct of the model is that Holocene phases of climatic amelioration include the Boreal (Archaic Period), Sub-Boreal (Late Archaic/Terminal Archaic Period), and Scandic and Pacific (Woodland Period) (Vento et al. 2008). For Site 36AL480, the questions of A horizonation, chronology and processes of soil formation, and their collective paleoclimatic implications are discussed in Section 2.8.

As noted above, such a model is contingent upon accurate field description and the use of a stratigraphic framework that accommodates the range of interdisciplinary sequence transitions preserved in the Leetsdale successions.

**Stratigraphic Nomenclature**

The use of appropriate stratigraphic and soil nomenclature (Schoeneberger et al. 2002; Soil Survey Staff 1994, 2004) posed a challenge during Phase III, in part because of the variety of principles used in codifying sequences during earlier phases of investigation, but also because of the difficulties inherent in bridging both archaeological and geological observations under a single overarching stratigraphic system. In the Phase III study, the primary organizing principles for the description of vertical sequences were pedostratigraphic, as soil horizonation was prominent in the earliest phases of the work (Vento et al. 2001). Subsequently, sets of soils were incorporated into a more general lithostratigraphic/geological framework on the site proper (specifically for Areas 1, 2, and 3 South on the T3) and, eventually, expanded across landforms (Back Channel and T2) for the comprehensive allostratigraphic scheme. However, it should be recognized that while pedostratigraphic criteria were generally utilized as the initial organizing principle for building the allostratigraphic scheme, pedostratigraphy is governed by strict taxonomic criteria that were not always appropriate for bridging the often subtle stratigraphic transitions that allowed the geoarchaeologists to develop sequences across the complex of landforms and archaeological horizons preserved within the Leetsdale landscape. Accordingly, some of the rigor inherent in pedological taxonomy may have been (minimally) compromised in the interests of developing an overarching and integrated geoarchaeological model of landscape change and human occupation.
Emergence of the Stratigraphic System for Site 36AL480

Since archaeological work began prior to the release of the geoarchaeology contract, baseline stratigraphic contexts were established by the archaeological team excavating in Area 3 South. They utilized organizing principles based on an area-specific variant of the Harris Matrix (Harris 1989; Harris et al. 1993). That system was designed specifically for archaeological stratigraphy, whose objective was to order stratigraphic units and features according to vertically or laterally based divisions between field-recognized units (see also Goldberg and Macphail 2006). Unit designations could be modified and revised based on laboratory results, as well. A key element of the system was to stress the boundaries between units and whether or not they represented discrete cultural manifestations (e.g., hearths, processing pits) or more extensive occupation or anthropogenic horizons. Interpretive problems could derive from sorting out geological strata from activity areas and especially from the more extensive anthropogenic horizons (e.g., middens), whose imprint on geological horizons may be significant. The GRA-Clarion team initially correlated the Harris Matrix strata for Area 3 South (labeled “F-units”; see Anderson et al. 2010) with the pedo-stratigraphy developed for Area 3 South (Schuldenrein et al. 2003: Table 4.7). Subsequently, Harris Matrix designations were eliminated as the pedostratigraphic nomenclature was subsumed, first within the geological (or lithostratigraphic) sequence and, ultimately, into the allostratigraphic scheme that extended across the entire project area of Site 36AL480.

For the Area 1 and Area 2 excavations, arbitrary stratigraphic systems were first utilized by excavators, but these were readily incorporated into the emerging master stratigraphic scheme, as excavations in both areas occurred concurrent with the geoarchaeological field and early analysis efforts (Miller and Marine 2005; Miller et al. 2010). All examined sections and profiles for both areas were first integrated into the pedostratigraphy (per protocols followed for Area 3 South) and, subsequently, into geological stratigraphies.

The geological stratigraphies were structured by ordering vertical sets of soil sequences that developed on broadly similar parent materials and, specifically, alluvium of consistent texture. This pedostratigraphic framework was followed from the outset, as it was utilized in the initial testing phases at Leetsdale (Schuldenrein et al. 2003; Vento et al. 2001). Because numerous distinguishable and superposed soils were identified, separate generations of soils were registered in Area 1, Area 2, and Area 3 South. Each generation was identified by traditional “A-B-C” horizons or other soil horizons (Table 2.4 below). Across the site, vertically ordered soils were common; in some portions of the site, as many as eight stacked soils were recognized from the top to the base of the stratigraphic column. Not all soils preserved intact sola above alluvium (intact A-B-C horizonation). Horizons, or portions of horizons, were often stripped by erosion over the course of landform construction. By convention, the individual soils were numbered sequentially, from top to bottom (younger to older) for individual profiles. The separation of each soil in the vertical column was based on a change in the parent material. Thus, while the parent material (C horizon) for the upper soil in a column may have been a silt loam, the parent material of the underlying buried soil may have formed on coarser sands (2C horizon).
At a number of exposures, soil horizons were defined by intermediate classifications (e.g., AB, BC, CB, etc.) in situations where the horizon of concern exhibited characteristic features of both a master and subordinate horizon (Holliday 2004: Table 1.1). In such instances, the first letter represents the dominant pedogenic characteristics. For example, an AC designation in Area 1 reflected the prevalence of organic content (root traces, dark Munsell color) within the sandy, massive, and low-consistence parent alluvium. Thus, the in-field designation of the AC highlighted a horizon dominated by the features of brief surface stability, but developed within a matrix of virtually unaltered parent alluvium.

Table 2.4 Selected Horizon Nomenclature for Site 36AL480.

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master</td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>Horizon of organic enrichment; dark colored.</td>
</tr>
<tr>
<td>A</td>
<td>Mineral horizon formed below O horizon with humic enrichment; dark colored.</td>
</tr>
<tr>
<td>E</td>
<td>Pale horizon formed under O or A; characterized by a loss of clay, soluble salts, and/or organic matter.</td>
</tr>
<tr>
<td>B</td>
<td>Mineral horizon formed below O, A, or E; characterized by illuvial accumulation of clay, iron, aluminum, humus, or other mobile soil elements.</td>
</tr>
<tr>
<td>C</td>
<td>Subsurface mineral horizon consisting of unaltered or partly altered parent materials.</td>
</tr>
<tr>
<td>R</td>
<td>Lithified or consolidated bedrock.</td>
</tr>
</tbody>
</table>

Subordinate

<table>
<thead>
<tr>
<th>Subordinate</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>b</td>
<td>Buried genetic horizon.</td>
</tr>
<tr>
<td>g</td>
<td>Gleyed soil horizon; due to anaerobic conditions.</td>
</tr>
<tr>
<td>p</td>
<td>Plow layer or other disturbance.</td>
</tr>
<tr>
<td>t</td>
<td>Indicates significant increase in illuvial silicate clay; typified by firm, subangular to angular blocky peds (soil units).</td>
</tr>
<tr>
<td>w</td>
<td>Modifier of B horizon; weak color or structure; typified by firm to friable, sub-angular to sub-rounded peds (soil units).</td>
</tr>
<tr>
<td>x</td>
<td>Horizon of distinctly hard consistence (fragipan characteristics).</td>
</tr>
</tbody>
</table>

The versatility of site-wide applications of lithostratigraphic (or geological) criteria became apparent as the progressive expansion of excavation areas revealed the vertical and lateral complexities of soil horizonation and the inability to trace subtly expressed sola across the landform. Pedogenesis is uniquely sensitive to even minor variations in topography, drainage, and parent material texture. For this reason, lithostratigraphy, and its focus on
grouping observations on geologically based criteria was useful in grouping stratigraphic observations across the T3 landform.

Given that the project area subsumed additional landscape segments underlain by lithologies somewhat different than the T3 terrace, and that a comprehensive stratigraphy was warranted for incorporating cultural chronologies, it was determined that an allostratigraphic scheme would be most appropriate for the Phase III study. Allostratigraphy accommodates synchronic transition in the Holocene record for the range of paleo- and human ecological data sets represented in the landscape. Allostratigraphy, therefore, provided the organizational framework for grouping observations of systemic landscape and archaeological change and formed the operational core for the genetic stratigraphic model proposed in this study.

Figure 2.22 highlights the key sequence components that contribute to the allostratigraphic construct at Site 36AL480. The central landform is the T3 terrace, whose Late Quaternary history is chronicled both by changes in flood plain deposition (lithostratigraphy) and intervals of surface stability (pedostratigraphy). The latter are typically linked to sustained or shorter-term periods of prehistoric occupation (cultural stratigraphy). While the T3 landform was the locus of settlement, the locale’s diverse mesoenvironment—especially the Back Channel—functioned as a dynamic resource zone for prehistoric subsistence. Thus, off-site landforms, including the Back Channel and related T2 terraces, would also provide diagnostic information on changing vegetation communities. The data sets in support of the individual sequence components are identified in the model (Figure 2.22) and the field and laboratory methodologies utilized to collect and analyze these data are detailed in the balance of this discussion. The allostratigraphy provides a genetic stratigraphy model which is, in turn, compared to the stratigraphic sequences of 12 additional sites on the Ohio, Susquehanna, and Delaware, and minor drainages regionally. Such a comparative analysis serves to highlight the significance of occupations and depositional sequences within the project area.

Finally, it is noted that the allostratigraphic model took shape early in the course of Phase III excavations. The fundamental units had been designated as the field observations and initial laboratory analyses from the Area 3 South excavation block were completed. Thus, the AU-based stratigraphic model had initially been applied, in the interim report, to explain the deep column sequence chronology at Area 3 South (Schuldenrein et al. 2003; summarized for this report in Section 2.3). Subsequently, observations in Areas 1 and 2 allowed for refinement of the AU chronologies, accommodations of facies changes peculiar to each Area (for example, the proliferation of AC couplets in Area 1 and the deep cultural stratigraphy at Area 2), and the splitting of AU-2 into two subunits (AU-2a and AU-2b). These refinements were based both on observations of complex alluvial and erosional patterns in the central portion of the T3 landform (most strikingly in Area 2), and on laboratory analyses, which confirmed that the magnitude and timing of changes in the depositional environments of the T3 terrace warranted designation of sub-units.
Methods and Procedures

Fieldwork Strategy

As with early phase archaeological testing at Site 36AL480 (see Section 2.3), Phase III geoarchaeological fieldwork in the excavation areas was performed under the joint direction of Dr. Vento (CUP) and Dr. Schuldenrein (GRA). Both were responsible for finalizing the stratigraphic framework and soil-sediment sampling strategies. Two GRA field personnel, Ms. Lee Anna Walker (2001) and Dr. Suanna Selby Crowley (2001-2003), were staffed on-site for daily field observations, consultation with excavators, and sample collection. Continuous interaction with and feedback from the archaeological teams, Greenhorne & O’Mara, Inc., Tetra Tech, Inc., Michael J. Baker, Inc. (all Area 3 South), URS Corporation (Area 1), KCI Technologies, Inc. (Area 2), and ASC Group, Inc. (Phase II blocks), was key in the development of the site-wide stratigraphy. Preliminary field observation notes, geomorphological drawings, and sample inventories were submitted to the USACE over the course of the excavations.

In the area-designated excavation tracts, Phase II blocks, Back Channel, and Casting Basin, the geoarchaeological assistant recorded sections in conjunction with field supervisors and excavators. All profiles were mapped using standard geological or lithostratigraphic (NASCN 2005) and/or soil horizon designations (Soil Survey Staff 1994). In general, lithostratigraphic units were preferred for designating primary depositional bodies of sediment. Soil sequences were then used to isolate weathering profiles in these primary units. The initial Site 36AL480 report used both ordering systems, but relied strongly on soil correlations, since lithostratigraphic correlations could not be as readily extrapolated utilizing the transect sampling strategy (Vento et al. 2001). Because of the wider vertical exposures afforded during Phase III, lithostratigraphic units could be extensively mapped on the site-wide level. Unit classifications followed the North American Stratigraphic code (NASCN 2005). Consistent with the earlier investigative phases, soil horizon designations followed the standard U.S. Department of Agriculture Soil Taxonomy (Soil Survey Staff 1994, 2004).

Operationally, a provisional stratigraphic framework was finalized for every vertical meter of excavation since field excavation methods were somewhat confined by OSHA constraints, as well as by the relative richness of an archaeological record that varied both laterally and vertically. Once the base of an excavation block was reached, at a typical depth of 2-4 m (6.5-13 ft), windows of vertical exposure became severely limited. Narrow backhoe exposures and/or core probes into the basal gravels (below the fifth meter) afforded confined views of stratification. At the conclusion of each area-wide excavation, a comprehensive working sequence for the area was established, that accommodated the stratigraphic variability for the various sub-areas.

Soil and sediment sampling, followed by laboratory analyses, were undertaken at all three excavation areas as well as in the Back Channel and Casting Basin. The field sampling strategy and objectives of the soil and sediment testing are discussed below.
**Field Sampling Methods**

Two representative granulometric soil/sediment columns were collected from each area along the most diagnostic and accessible walls of mapped excavation units. However, accessibility in each area was limited by the telescoping nature of the excavation units as archaeological recovery stepped inward with each meter of depth, according to OSHA safety protocols, often making contiguous downward sampling columns unavailable. Therefore, as the excavations proceeded with depth, sampling columns were developed within designated corners of the excavation block (southwest, northeast, etc.) by examining open, preferably neighboring, units within those corners. Samples were collected from natural levels within soil and/or lithostratigraphic horizons at 10-cm intervals. If more detailed microstratigraphic resolution was necessary, samples were taken at appropriately selected intervals from a specified column. Soil and sediment samples were taken in half liter and one liter quantities and sealed in labeled plastic bags for processing through CUP or GRA. All samples were individually numbered and recorded in a Microsoft Excel 2002 (updated to Microsoft Excel 2007) spreadsheet for inventory control. The total number of samples collected during data recovery exceeded 2,000 samples (Table 2.5). Of this total, 589, or 28.9 percent, were submitted for laboratory analysis. Multiple units from each exposed meter were collected in order to provide the greatest range of soil and sediment variability for testing.

As 1-m-deep excavation units were opened and profiles exposed, Drs. Vento and/or Schuldenrein standardized in-field stratigraphies and coordinated sampling strategies with the field geoarchaeologist, who recorded and sampled the identifiable strata. Sampling was conducted after all archaeological recording was complete. Each observed profile was photographed and at least two wall exposures were drawn, labeled, and described. Technical descriptions for soils and sediments followed standardized criteria (Table 2.6; following Garrison 2003; Holliday 2004; Reed et al. 2000; Waters 1992), modified to the exigencies of the site. Descriptive criteria included: 1) field determinations of texture; 2) color according to Munsell soil color chart comparison; 3) structure of soil aggregates; 4) consistence; 5) diagenetic features (e.g., silt skins, mottling, etc.); 6) bulk density (weight per unit volume of soil as measured via hand-held penetrometer); and 7) type and frequency of inclusions, roots, pore space, and cultural materials, if present.

All field assessments of texture were considered provisional pending granulometric analysis, which provided quantitative measure of particle sizes and proportions. Field designations were made by labeling the excavated walls with 2-cm-diameter round, hard cardboard tags (or similar method) to allow for correlation of strata between excavation units, within a given excavation area, or between areas, if the latter could be reliably determined.

Profile mapping was completed by the field geoarchaeologist, frequently in consultation with field archaeology staff (for each area), and all strata were tied to the Site 36AL480 grid system through a local datum or hub. Vertical control issues emerged, however, during the fall of 2002 for both Areas 1 and 2. Provenience problems were related to the previous phases of investigation in which measurements were made with respect to arbitrary grids and extant surface elevations. Grids were not always linked to universal benchmarks, and surface elevations changed because of non-uniform and pre-excavation stripping. For this study, topographic relations are expressed in terms of meters above sea
level (m asl) (relative to the National Geodetic Vertical Datum [of 1929]) when absolute elevations were known, or meters below datum when a fixed datum was utilized for a given locus (i.e., Area 1, Area 2, Area 3 South). Wherever possible, however, absolute elevations were used.

Topographic reliability for Area 1, in particular, was compromised by the available elevation records. Multiple correction factors were issued during and subsequent to the field testing stages in 2002, but no mention of the elevation issue was found in the Area 1 reports by Barse (2003) or Miller et al. (2010). A review and synthesis of the URS data sets converged at an elevation correction from -1.15 to -1.96 m. For purposes of site-wide topo-stratigraphic uniformity, GRA and Clarion University standardized the average correction to -2 m; all interpretations (graphics, tables, etc.) herein are keyed to that estimated correction factor. Further, the geomorphology team deferred to published elevation data for units, blocks, or features where available in Miller et al. (2010). However, the -2 m correction factor should not be considered incontrovertible. A review of the radiocarbon data base for Areas 2 and 3, occupying the highest (T3) landform, places the Area 1 (Barse 2003) feature set .25-.5 m higher than feature elevations of comparable age from the other two areas. Since Area 1 straddles the lower back slope of the T3 terrace and the proximal edge of the T2 terrace to the east (see Figure 2.2), the expectation is that, if anything, the Area 1 elevations should be lower than those for the other investigated areas. While the geomorphology investigations have proceeded with their interpretations based on the correction factor estimate, the lack of an accurate elevation correction must be considered a drawback in structuring the subtleties of landform chronology (of the T3). While this shortcoming may have implications for intrasite and intersite comparisons of radiocarbon, geochemical, and other laboratory results, our findings are generally convergent and facilitate an operational, if not unequivocally comprehensive, geoarchaeological reconstruction.

Profile drawings produced over the course of field work included unit identifiers (unique to each area as established by the archaeological consultants), relevant elevation data as available or subsequently corrected, stratum descriptors, key archaeological features, or diagnostic artifacts, and other pertinent spatial or explanatory information, as necessary.

In addition to exposed profile walls, several deep cores extracted by hand auger were examined and sampled. These were described only with regard to color, texture, consistence, and inclusions, since the twisting motion used to insert and remove the hand auger frequently disturbed the in situ structure and diagenetic features of the soil-sediment complex. Schematic profiles of the core were recorded with relevant elevation and coordinate information. Samples from each auger bucket were also collected, as appropriate, for laboratory analysis.
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Table 2.5 Summary of Phase III Samples Collected and Analyzed by the Geomorphology Team from Site 36AL480 by Area.

<table>
<thead>
<tr>
<th>Area/Locus</th>
<th>Grain Size</th>
<th>Biogeochemistry</th>
<th>Clay Mineral</th>
<th>Feature Geochemistry</th>
<th>Micro-morphology</th>
<th>Phosphate Fractionation</th>
<th>$^{14}$C*</th>
<th>Total Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area 1</td>
<td>229 (166)</td>
<td>229 (50)</td>
<td>177</td>
<td>18 (17)</td>
<td>22 (10)</td>
<td>43 (11)</td>
<td>274 (3)</td>
<td>992 (257)</td>
</tr>
<tr>
<td>Area 2</td>
<td>78 (75)</td>
<td>78 (39)</td>
<td>136</td>
<td>39 (27)</td>
<td>31 (19)</td>
<td>39 (14)</td>
<td>151 (2)</td>
<td>552 (176)</td>
</tr>
<tr>
<td>Area 3 South</td>
<td>115 (63)</td>
<td>23 (22)</td>
<td>56 (14)</td>
<td>n/a</td>
<td>28 (20)</td>
<td>25 (10)</td>
<td>94</td>
<td>341 (129)</td>
</tr>
<tr>
<td>Casting Basin</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>6(6)</td>
<td>6 (6)</td>
</tr>
<tr>
<td>Back Channel</td>
<td>47 (17)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>1(1)</td>
<td>n/a</td>
<td>4(3)</td>
<td>52 (21)</td>
</tr>
<tr>
<td>Block 6 (Phase II)</td>
<td>21</td>
<td>21</td>
<td>19</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>28</td>
<td>89</td>
</tr>
<tr>
<td>Total Samples</td>
<td>490 (321)</td>
<td>351 (111)</td>
<td>388 (14)</td>
<td>57 (44)</td>
<td>82 (50)</td>
<td>107 (35)</td>
<td>559 (14)</td>
<td>2,034 (589)</td>
</tr>
<tr>
<td>Percent Analyzed**</td>
<td>65.5%</td>
<td>31.6%</td>
<td>0.04%</td>
<td>77.2%</td>
<td>60.9%</td>
<td>32.7%</td>
<td>0.03%</td>
<td>28.9%</td>
</tr>
</tbody>
</table>

Key: Collected (Analyzed)
*Samples collected and submitted by GRA only.
** Based in total collected.
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<table>
<thead>
<tr>
<th>Descriptive Category</th>
<th>Physical Indicator</th>
<th>Interpretive Application</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>Hue, value, chroma</td>
<td>Sedimentary sources; pedogenesis; chemical composition</td>
<td>Banning 2000; Schoeneberger et al. 2002</td>
</tr>
<tr>
<td>Texture</td>
<td>Sand, silt, clay particle ratios</td>
<td>Sedimentary sources; mode of transport; depositional environment</td>
<td>Holliday 2004; Rapp &amp; Hill 1998; Stein 1992; Schoeneberger et al. 2002; Waters 1992</td>
</tr>
<tr>
<td>Structure</td>
<td>Soil unit grade, class, and morphology</td>
<td>Degree of pedogenesis; clay fraction</td>
<td>Goldberg &amp; Macphail 2006; Schoeneberger et al. 2002</td>
</tr>
<tr>
<td>Consistence</td>
<td>Chemical and physical bonds; moisture content</td>
<td>Clay fraction</td>
<td>Goldberg &amp; Macphail 2006; Schoeneberger et al. 2002</td>
</tr>
<tr>
<td>Boundary</td>
<td>Distinctness, form of soil horizon/stratum interface</td>
<td>Depositional environment; post-depositional alteration; erosional events; floral/faunalturbation</td>
<td>Rapp &amp; Hill 1998; Schoeneberger et al. 2002</td>
</tr>
<tr>
<td>Floralturbation</td>
<td>Roots and root traces; organic ghosts and mats</td>
<td>Post-depositional alteration; buried surfaces</td>
<td>Rapp &amp; Hill 1998; Waters 1992</td>
</tr>
<tr>
<td>Faunalturbation</td>
<td>Burrowing by animals and insects</td>
<td>Post-depositional alteration</td>
<td>Rapp &amp; Hill 1998; Waters 1992</td>
</tr>
<tr>
<td>Porosity</td>
<td>Void space</td>
<td>Permeability; post-depositional alteration</td>
<td>Rapp &amp; Hill 1998; Schoeneberger et al. 2002; Waters 1992</td>
</tr>
<tr>
<td>Mottles</td>
<td>Gleys and redoximorphic features</td>
<td>Post-depositional alteration (water table fluctuation, etc.)</td>
<td>Schoeneberger et al. 2002; Soil Survey Staff 1994, 2004</td>
</tr>
<tr>
<td>Stoniness</td>
<td>Size, morphology, clast origin</td>
<td>Sedimentary sources; human inputs</td>
<td>Schoeneberger et al. 2002</td>
</tr>
</tbody>
</table>
Laboratory Analysis

The following analyses were conducted to structure the data sets underpinning the allostratigraphic framework (Figure 2.22) and to apply that framework to the model of genetic stratigraphy. The analyses address issues of sediment stratigraphy, soil formation histories, weathering parameters, anthropogenic sedimentation, absolute chronology, landscape evolution, and paleoenvironmental and paleoclimatic reconstruction. Specific analyses were performed under Drs. Vento and Schuldenrein and their respective facilities as designated below.

Two basic types of post-field analysis were required under terms of the Scope of Work (USACE 2001), including treatment of specimens diagnostic of: 1) natural sedimentation and weathering processes; and 2) matrix modification by anthropogenic/cultural processes. Analyses associated with the determination of natural sedimentation and soil formation included: granulometry (grain size analysis) and detrital grain assessments, biogeochemistry of soils and sediments, clay mineral analysis, and micromorphology. Analyses critical for site formation process assessment included: phosphate fractionation, geochemistry of occupation fills (feature geochemistry), and micromorphology. Radiocarbon assays provided the basis for site chronology in both geological and archaeological contexts. Additionally, Dr. Vento conducted raw materials analyses of lithic materials and steatite samples for the purpose of identifying source locations (Appendix C and D). In sum, this array of tests was useful for dating and reconstructing natural patterns of deposition (e.g., flooding), soil formation (e.g., emergence of stable surfaces), and human impacts on the landscape or land use.

Lithic Raw Material Sourcing

During 2001-2003, a set of lithic debitage and tools were collected from Area 1, Area 2, and Area 3 South at Site 36AL480 for the purpose of determining the source location of the cryptocrystalline raw materials (primarily chert) found within the project area. Focus was placed on identifying the major chert sources that were utilized by the groups occupying Site 36AL480 over time, specifically examining whether the raw materials were local (river pebbles and cobbles) or extra-local (from sources or quarries outside the project area). Such raw materials may occur as occur as nodules, lenses, or laterally extensive beds, and are typically are associated with limestone or dolomite sedimentary rock outcrops from locations in central and southern Ohio, West Virginia, Kentucky, and Pennsylvania. Archaeological populations within these regions are known to have procured, transported, and shaped these raw materials for use in the production of lithic tools. Named chert types for this area include the Onondaga, Upper Mercer, Uniontown, Monongahela, Kanawha, and others (Biggs 1957; Dever et al. 1977; Eisert 1974; Herbstritt 1981; Lamborn 1951; Reppert 1978; Wray 1948).

A series of representative lithic raw material samples were selected by Dr. Vento (CUP) based upon hand sample analysis (color, inclusions, microfossils etc.) for further examination in order to illicit information on provenance. The analysis included visual examination of macroscopic features of the raw material (e.g., general texture or inclusions), microscopic examination of prepared thin-sections (petrography), and comparison with the
petrographic character of known samples of named chert. Samples were thin-sectioned by the Von Huene Laboratories, Pasadena, California, and analyzed petrographically using a Lietz polarizing microscope under both plain polarized and cross-polarized light at four degrees of magnification (35X, 60X, 100X, and 250X). Standard point-counting techniques of individual grains within each slide were not followed, due to the homogeneous character of the sample cherts (Ingersoll et al. 1984). Specific mineralogical variability or unique features were, however, noted for relevant samples, and aided in the determination of source locations for the lithic tools and debitage found at Site 36AL480. Results of the analyses are produced in detail in Appendix C.

**Steatite Sourcing**

During 2001-2003, a set of nine samples of steatite or soapstone (a massive rock of metamorphic origin primarily composed of the mineral talc) was obtained from Areas 2 and 3 South at Site 36AL480 and subjected to neutron activation analysis (NAA). These samples were collected from archaeological horizons associated with the Transitional Archaic period (4200-3000 B.P.). The Site 36AL480 steatite dataset was compared to three additional samples from Sites 36FA306, 36SO62, and 36WA359 in Fayette, Somerset, and Washington Counties, respectively. A total of 12 analytical samples was processed in this study for the purpose of identifying the source locations of the raw material and, potentially, providing insight into the trade and exchange networks utilized by inhabitants of the project area, as fewer than a dozen quarry locations are known from Pennsylvania, Maryland, North Carolina, and Virginia (Luckenbach et al. 1975). The NAA results of two reference samples were also obtained from the U.S. Geological Survey for comparative analysis.

The objective of the NAA examination was to identify and quantify the abundance of distinct rare earth elements within the sample set and associate these characteristics with the geochemical properties of recognized quarry locations. These elements differ as the result of the unique metamorphic origins of the source lithology, generating quantifiable variation in elements such as lanthanum (La), neodymium (Nd), samarium (Sm), and others (Allen et al. 1975). The results, thereby, provide a chemical fingerprint of the sample, which can be compared to the geochemical properties of comparative quarry samples.

All samples were submitted to Dr. Theiny Daubenspeck at the Radiation Science and Engineering Center (RSEC; formerly the Neutron Activation Facility) at the Pennsylvania State University, University Park, Pennsylvania. The samples were catalogued and .5 grams (gr) of each was crushed into a fine powder for nuclear testing. The samples was subsequently placed into a sterile, pre-weighed polyvial, which was re-weighed to ascertain exact sample mass. The samples were irradiated for one hour in a neutron flux of \(10^2 n/cm/sec\). After seven days, the samples were analyzed on a gamma spectroscopy system for 10,000 seconds to quantify the amounts of the rare earth elements in parts per million (ppm) values. These results were compared with known reference samples and are summarized in Appendix D.
Granulometry

Grain size analysis for the Leetsdale study was utilized primarily to determine the record of former channel and flooding patterns preserved within the Site 36AL480 landform. The analysis of grain sizes is typically applied as a proxy for the hydrodynamics of the stream transport mechanism, as well as the environment of deposition for those particles (Folk 1974; Holliday 2004; Shackley 1975, 1981; Stein 1987). Generally, a high energy system (fast moving water) has greater capacity to carry all sized particles, whereas a low energy system (slow moving water) transports only finer sands, silts, and clays. Observation of modern drainage networks suggests that zone of high energy is within the main stream channel, and low energy zones are found away from the bankline or within back swamp areas. Gravels and sands are dominant grain sizes in the channel bed, while silts and clays are found along stream margins and low-order tributaries (Folk 1974; Friedman and Sanders 1978). Such modern examples provide analogies for what is observed in the geomorphic record, and permit reconstruction of paleotopography and paleohydrology.

At Site 36AL480, the variability in stream energy through time and across landforms (the terrace complex and Back Channel) is a key to understanding changing stream dynamics (through time) and the climatics behind these dynamics (see Section 2.4 in this report). Additional applications of the grain size study were directed at determining the degree to which alluvium was weathered during soil formation intervals. Accordingly, it is possible to infer whether changing climate influenced rates of weathering, depth of soil formation (detected through increased translocations of clays in a Bt or Btx horizon), and extent of soil formation across the landform.

In practice, grain size analysis was undertaken at select excavation profiles at various localities on the T3 terrace. These would serve as textural fingerprints for the site sediments of various origins or from specific depositional events. Following field collection, wet and dry separation techniques were undertaken at CUP to determine the distribution of grain size fractions (gravel through clay-sized components; Allen 1968; Gee and Bauder 1986). This technique was applied only to the inorganic and non-artifactual components of the soil/sediment matrix.

Sediment samples of 500 gr or more were taken from the cultural and non-cultural stratigraphic levels from designated excavation units in Areas 1, 2, 3 South, and the Back Channel. Samples were then reduced to a single 50 gr (1.7 ounces [oz]) fraction using a random sample splitter.

A standard granulometric sieve analysis was performed on the reserved 50 gr fraction from each of the samples. Wet sieving was used to determine the distributions of grain sizes (by fractions) within each sediment sample. The samples were rinsed through nested mesh sieves until the discharge liquid ran clear, at which point the remaining material in each sieve was dried and weighed. Whole phi (φ) sieve size intervals were used, including: 4 mm (-2 φ), 2 mm (-1 φ), 1 mm (0 φ), .5 mm (1 φ), .250 mm (2 φ), .125 mm (3 φ), and .063 mm (4 φ) size classes (Courty et al. 1989; Shackley 1981). In addition to the wet sieve analyses, subsets of select columns were run for the analysis of the clay and silt-sized fractions utilizing a Coulter Counter apparatus at the Mercyhurst Archaeological Laboratories,
Mercyhurst, Pennsylvania. This method measures fine particle size fractions while in suspension in water (Folk 1974; Holliday 2004; Stein 1987). The silt and clay-sized data were subsequently integrated with the wet sieve results, as appropriate.

In sum, the percentage of each sieve class was determined by comparing the weight of each dried sieve fraction to that of the initial dry sample weight. The percentage for sediments finer than .063 mm (4 φ) is essentially the loss from the initial sample weight after wet sieving (Vento et al. 1980).

The dried and weighed fraction for each size class was saved and stored in a sealed vial for subsequent detrital grain composition analysis. For granulometric analysis, statistical formulas were used to calculate mean, median, standard deviation, skewness, and kurtosis of grain size classes for each sample. These statistical parameters are standard protocols for characterizing depositional environments and were used to examine questions of relative strength of stream flow, the emergence of depositional environments during prehistoric periods, or in connection with transitions in alluvial environments. Specifically, the granulometric data was used to reconstruct changes in the fluvial regime of the Ohio River in the vicinity of the project area, as well as define the boundary between the overlying Holocene age vertical accretionary deposits from the underlying late Pleistocene age lateral accretionary deposits.

The statistical methods used follow those of Friedman and Sanders (1978:78-80) and are correlated with statistical parameters for grain size analysis presented by Folk (1974:38-61).

Using the method of moments (Folk 1974), the first moment determines the mean (m) and is written as follows:

\[
first moment = \frac{3f_{m} - \chi}{100} = \frac{3f_{m} - \phi}{100}
\]

This formula indicates that f is the frequency for each class size and mode is the midpoint of each phi class. The mean indicates the general size of the constituent particles ("coarse-grained" vs. "fine-grained") and is a measure of the competence of the transport medium (fast water vs. slow water).

The second moment is a measure of dispersion about the first moment (x), and is expressed mathematically as follows:

\[
second moment = \frac{3f_{(m_0-x)^2}}{100}
\]

This second moment is the numerical value of the standard deviation squared. In order to obtain the numerical value of the standard deviation (σ), the square root of the second moment is obtained as follows:
The standard deviation gives information on the extent to which sediment particle sizes are clustered about the mean, thereby providing an index of sorting. Poorly sorted deposits display a range of particle sizes, while well-sorted samples reflect little variation in size class. This information helps to identify the transport medium (well-sorted fluvial deposits vs. poorly sorted glacial deposits) and the potential influence of post-depositional infiltration of particles.

The third moment of the distribution is a measure of the symmetry of the frequency curve about the mean and is written as follows:

\[ \text{third moment} = \frac{3 \cdot f(m \omega - x)^3}{100} \]

This moment is known as the “100 cubed deviation” and a rating of the symmetry of the curves is the measure of its normality. Since \((m \omega - x)\) is positive to the right of the mean and negative to the left of the distribution is 0. A positively skewed distribution indicates an excess of fine particles to the left of the mean and generally points to a fluvial origin.

The skewness of the curve is commonly derived by dividing the mean by the cube of the standard deviation. This is expressed as follows:

\[ \text{skewness} (\sigma^3) = \frac{1 \cdot f(m \omega - x)^3}{1000 \sigma^3} \]

Skewness reflects deviation from symmetry of the curve and is sensitive to the presence or absence of the fine or coarse fraction in a sample.

The fourth moment of the distribution is expressed as:

\[ \text{fourth moment} = \frac{3 \cdot f(m \omega - x)^4}{100} \]

The fourth moment is used to calculate the peakedness (e.g., leptokurtic, mesokurtic or platykurtic), or kurtosis, of the distribution. Kurtosis is calculated by dividing the fourth moment by the standard deviation raised to the fourth power, thus:

\[ \text{kurtosis} (\sigma^4) = \frac{1 \cdot f(m \omega - x)^4}{1000 \sigma^4} \]
Grain size analysis in concert with the detrital grain composition study has allowed for determining the various origins of the site’s sediment suite. Grain size analysis has proven highly successful for this purpose, not only at closed sites such as Meadowcroft Rockshelter in Pennsylvania and at the Bay Springs Rockshelter in Mississippi, but also at open sites along the Little Platte River in Missouri and the Illinois River in central and southern Illinois (Adovasio et al. 1977; Adovasio et al. 1985; Vento 1980).

Results of the distributions were transferred into a Microsoft Excel spreadsheet for tracking and development of a distribution curve, together with identifications of classic grain size parameters (per Folk 1974), including mean grain size, sorting, skewness, and kurtosis as described above. Appendix E presents these data.

Overall, the textural analysis assisted in determining and characterizing: 1) depositional emplacement; 2) the degree of diagenesis (to a more limited extent); and 3) stream competence accounting for alluviation at examined localities. The granulometric evidence was then used to reconstruct systemic changes in the fluvial regime of the Ohio River, beginning with the segregation of Middle to Late Holocene overbank alluvium from the underlying late Pleistocene/Early Holocene lateral accretion deposits. The interpretive potential of the analysis is provided in the discussion of the excavation areas in Section 2.6.

**Detrital Grain Analysis**

Detrital grain analysis was used to provide information on the source area for alluvial deposits based on the examination of the sand-sized fraction and, specifically, its mineral composition (Folk 1974; Garrison 2003). This method was specified in the Consultant’s Proposal of 2001 and the SOW modification of 2001 (Appendices N and O). The goal was to complement the granulometric (textural) analyses and to determine the bulk mineralogy (composition) of the terraces and flood plain deposits. These data, coupled with the grain size analysis, aided in characterizing the age, depositional history, degree of diagenesis, and origin of the sediments at the site.

Initially for Area 3 South and later for Areas 1, 2, and the Back Channel locations, portions of the sand-sized particle class from each granulometric sieve sample was set aside to visually scan for both microfaunal elements and to determine the detrital grain composition of the Site 36AL480 sediment suite (Ingersoll et al. 1984). This analysis was completed by visual scan under up to four degrees of magnification (35X, 60X, 100X, and 250X) via a Lietz polarizing microscope attached to a television monitor at the CUP geology laboratory.

Over 95 percent of the sample constituents from the excavation areas were identified as quartz; no feldspars or other silicate minerals appeared in significant quantities. Further, due to the low pH (high relative acidity) of Site 36AL480 soils, there were no identifiable microfaunal (gastropod) remains in the samples reviewed under magnification. Although samples from all areas were examined, the lack of identifiable microfaunal remains, coupled with a relatively homogeneous detrital grain suite, indicated that the potential for identifying changing source areas or important paleoenvironmental data was minimal. However, the analysis did provide useful general information about the constituent mineralogy of the
sediment suites and depositional history at Site 36AL480. Results are integrated into the discussion of the allostratigraphic packages in Section 2.6, as appropriate.

**Biogeochemistry and Feature Geochemistry**

Biogeochemical analyses, including: 1) the determination of pH; 2) the presence and proportion of soluble salts; 3) quantification of organic matter ratios; and 4) measurement of trace metals and elements, provided a chemical fingerprint of a soil or sediment. Such fingerprinting was considered the product of either soil weathering or anthropogenic inputs into the soil matrix, generally related to past human activity.

More specifically, batteries of biogeochemical tests reflected the variable influences of soil formation, including: 1) patterns of weathering and degradation of humic mats (locally prehistoric surfaces); 2) transformations to the soil or sediment matrix because of human activity, and, to a lesser degree; and 3) parent material (Eidt 1977; Kolb et al. 1990; Moody and Dort 1990; Schuldenrein 1995; Schulte et al. 1987). Further, these tests provided information for determining soil horizonation, degree of subsoil development, and may have acted as a relative chronometer for age of deposits (Goldberg and Macphail 2006; Goldberg et al. 2001; Holliday 2004). All chemical abbreviations are provided in the Glossary (Appendix K).

The elements, or ions, tested to identify weathering and anthropogenic additions to the profiles included calcium (Ca), magnesium (Mg), potassium (K), and phosphorus (P), along with organic matter (OM) and pH. The most common cultural residues isolated by these ion tests were bone, wood ash, excreta, animal meat, and tubers (Anderson and Schuldenrein 1985; Cook and Heizer 1965; Kolb et al. 1990; Schuldenrein 1995; Schuldenrein et al. 2003).

When taken together, simultaneously high values of phosphorus, calcium, potassium, and organic carbon were often optimal indicators of cultural additions to a site’s sediments, principally by human waste and the decomposition of foodstuffs. Further, varying contributions of organic and chemical elements might often be associated with formerly stable surfaces that may have sustained prehistoric occupation, thus providing a geochemical imprint of human activity within the archaeological profile (Holliday 2004).

Soil and sediment specimens were taken from select excavation units in all areas as well as from identified cultural features. Samples of approximately 50 gr (1.7 oz) size were split from the granulometric bags. These were prepared at CUP and processed by the Penn State Agricultural Analytical Services Laboratory of University Park, Pennsylvania, per the specifications of Dr. Vento. Results of the biogeochemical analyses are integrated with the summary of results from the areas (Section 2.6). Biogeochemical methods used in the analysis of Site 36AL480 samples are summarized in Table 2.7 (see also Appendix F).

Geochemical sampling was also undertaken to identify the composition and function of individual features. The approach has potential to inform on the origins of activity areas internally or site function generally (Goldberg and Macphail 2006). Thus, for example, co-varying trends in pH, in conjunction with elevated values of organic matter, P, K, Ca, and
Mg, might be indicators of prehistoric activity. High concentrations of iron (Fe), copper (Cu), zinc (Zn), and manganese (Mn) are typically linked to household sites. The presence of these chemical complexes at Site 36AL480 could provide indices of specific site use. The tests were undertaken to isolate the specific function of various identified features, including hearths, pits, and artifact scatters (Goldberg and Macphail 2006; Goldberg et al. 2001; Holliday 2004). Samples of approximately 50 gr (1.7 oz) size were collected from features in Areas 1 and 2 and were processed through the Texas Agricultural Extension Service at Texas A&M University under the specifications of Dr. Schuldenrein. Table 2.8 below summarizes the procedures and the results of these analyses are provided in Section 2.6.

Table 2.7 Biogeochemical Laboratory Methods Used in the Analysis of Soil/Sediment Samples from Site 36AL480.

<table>
<thead>
<tr>
<th>Biogeochemical Method</th>
<th>Interpretive Application</th>
<th>Method</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen Ion Concentration (pH)</td>
<td>Increased pH may signal presence of bone, ash, shell, teeth.</td>
<td>1:2 soil to water extract:</td>
<td>Schulte et al. 1987</td>
</tr>
<tr>
<td>Organic Matter</td>
<td>Buried A identification; humic enrichments; grasses, cooking residues, human and animal wastes.</td>
<td>Loss-on-ignition:</td>
<td>Dean 1974; Schulte 1995</td>
</tr>
</tbody>
</table>
Table 2.8 Geochemical Laboratory Methods Used in the Analysis of Feature Samples from Site 36AL480.

<table>
<thead>
<tr>
<th>Geochemical Method</th>
<th>Interpretive Application</th>
<th>Method</th>
<th>Citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen Ion Concentration (pH)</td>
<td>Increased pH may signal presence of bone, ash, shell, teeth.</td>
<td>1:2 soil to water extract</td>
<td>Schulte et al. 1987</td>
</tr>
<tr>
<td>Available P, K, Ca, Mg</td>
<td>Minerals associated with decay/decomposition of human and animal bone, soft tissue, wood ash, excreta, and food residues; typically used to detect prehistoric sites</td>
<td>Mehlich 3 (ICP)</td>
<td>Mehlich 1978, 1984; Wolf &amp; Beegle 1995</td>
</tr>
<tr>
<td>Organic Matter</td>
<td>Organic enrichments; grasses, cooking residues, human and animal wastes.</td>
<td>Loss-on-ignition</td>
<td>Dean 1974; Schulte 1995; Schulte &amp; Hopkins 1996</td>
</tr>
<tr>
<td>Cu, Fe, Mn, and Zn</td>
<td>Sediment classification; human inputs often associated with household sites</td>
<td>DTPA extraction method</td>
<td>Lindsay &amp; Norvell 1978</td>
</tr>
</tbody>
</table>

Clay Mineral Analysis

Clay mineral analysis is used to determine the extent and patterns of mineral weathering in a soil column through X-ray diffraction (XRD) (Herz and Garrison 1998). In alluvial soils, especially those where parent material is dominantly sandy (as in many of the Leetsdale lithostrata), weathering is generally limited and clay mineral studies can only isolate trends, if the magnitude of weathering is sufficiently pronounced as a result of mineralogical transformation through time.

Chemical transformation of sediment load (laid down by streams) is potentially detectable in weathering suites. The dominant clastic component is quartz, which is generally very stable and not easily degraded, although it may dissolve under moderate temperatures and pressure (Folk 1974; Pettijohn 1975). More susceptible to breakdowns are feldspars, which weather to kaolinite with the removal of potassium (K). With the abundant K in solution during intervals of soil formation, when climates were relatively moist and warm, the development of an illite-rich profile is promoted (Folk 1974: 94; Friedman and Sanders 1978: Table 5-2). Alternatively, or in conjunction with the prevalent weathering suite, illite formation may be attributable to the presence of mica in bedload levels. Clay
mineral profiles can show clear weathering trends favoring dissolution of K and strong presence of illite in weathered horizons. However, the soil should generally be well developed (i.e., pronounced Bt horizon) for clay mineral analysis to be a useful barometer of both the extent of soil formation due to climatic influence, and its relative antiquity (since sustained pedogenesis is also a function of time). Bw horizons are generally less suitable for clay mineral analysis. However, at 36!L480 the relatively degree of soil weathering was difficult to detect in the field and clay mineral analysis was utilized to help determine the degree of illuviation and general mineral breakdown associated with matrix degradation.

The technique of X-ray diffraction analysis involves the introduction of X-ray energy to a powdered sample of soil or sediment for the purposes of measuring the reflection wavelengths of the constituent minerals (Goldberg et al. 2001; Herz and Garrison 1998). Different minerals have different reflective qualities based on their regular internal crystalline structure. These structures are known and provide a fingerprint for a range of clay mineral types found in soils, sediments, and even in cultural sediment matrices. The structure of the mineral is determined by these measurements, and therefore identification of different clay minerals is possible (Herz and Garrison 1998:219-220).

A select population of 14 weathered sediment specimens was taken from Area 3 South in 2001 for XRD analysis at the Milwaukee Soil Laboratory of Milwaukee, Wisconsin (Table 2.9). All were taken from Area 3 South, for a variety of logistical concerns including scheduling and accessibility. As excavations expanded to Areas 1 and 2, it was decided that Area 3-South contained the most varied and representative soil profiles preserved on site and there was no need to extend sampling to other areas. Original sampling was undertaken from A and C horizons to determine if parent materials contained exotic mineral components that might interfere with assessments of the weathering suite. It was also thought that elements of the mineral weathering suite might be registered in bracketing (i.e., A or C) horizons.

A key application of clay mineral analysis for this study was to assess the degree of surface stability and age implicated by changing depth (and extent of weathering) within the B horizon. The extent of mineral displacement would be expected to increase by age and depth in a given column. The presence and proportion of silicate clays within a sample would indicate a relative age (i.e., an older soil which has accumulated clay over time) and better structural development or deeper weathering. The presence of an older soil provides evidence of a past stable surface, suitable for extended human occupation or preservation of cultural remains. Results of the X-Ray Diffraction analysis are found in Appendix H.
Table 2.9 X-Ray Diffraction Samples for Area 3 South from Site 36AL480.

<table>
<thead>
<tr>
<th>Meter</th>
<th>Sample Number</th>
<th>Location</th>
<th>Field Designation</th>
<th>Elevation m asl</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>23</td>
<td>N70 E225</td>
<td>Ap</td>
<td>215.14</td>
</tr>
<tr>
<td></td>
<td>25</td>
<td>N70 E225</td>
<td>C</td>
<td>214.81</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>N70 E225</td>
<td>4Bw</td>
<td>214.25</td>
</tr>
<tr>
<td></td>
<td>32</td>
<td>N70 E234</td>
<td>Ap</td>
<td>214.74</td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>N70 E234</td>
<td>C</td>
<td>214.52</td>
</tr>
<tr>
<td></td>
<td>37</td>
<td>N70 E234</td>
<td>3AC1</td>
<td>214.03</td>
</tr>
<tr>
<td>Second</td>
<td>112</td>
<td>N66-68 E238</td>
<td>3Bw</td>
<td>213.92</td>
</tr>
<tr>
<td></td>
<td>121</td>
<td>N66-68 E238</td>
<td>5Bw</td>
<td>213.02</td>
</tr>
<tr>
<td></td>
<td>166</td>
<td>N71-73 E226</td>
<td>3AC</td>
<td>214.07</td>
</tr>
<tr>
<td></td>
<td>176</td>
<td>N71-73 E226</td>
<td>5Bw</td>
<td>213.09</td>
</tr>
<tr>
<td>Third</td>
<td>196</td>
<td>N62 E233</td>
<td>5Bw</td>
<td>212.91</td>
</tr>
<tr>
<td></td>
<td>221</td>
<td>N65 E235</td>
<td>5Bw</td>
<td>213.05</td>
</tr>
<tr>
<td></td>
<td>231</td>
<td>N65 E235</td>
<td>6AC</td>
<td>212.05</td>
</tr>
<tr>
<td>Fourth</td>
<td>201</td>
<td>N65 E231</td>
<td>7CB</td>
<td>212.20</td>
</tr>
</tbody>
</table>

**Phosphate Fractionation Analysis**

The unique properties of phosphates and related compounds have been variously applied to archaeological situations (Schuldenrein 1995; Holliday 2004). The compound’s most diagnostic property for reconstructing past human activity is that, in its inorganic form, phosphate is not easily translocated chemically from its source of deposition; it potentially remains a measure of the activities that produced it. Phosphates remain largely bound to their original site of deposition, depending on the pH of the surrounding matrix, displaying only minor migration tendencies and additions over the course of archaeological time (Eidt 1977, 1984). These additions are made either by rock, animals, or plants, or by human activity. If soil phosphate levels are not locally high, anthropogenic phosphates can be isolated or estimated by comparing results of suspected activity areas with control samples from surrounding localities.

The initial measure of cultural residues in a given feature or cultural locus is the abundance of total P. Relative concentrations of P are a baseline index of anthropogenic enrichment. Using a bank of land use patterns, Eidt (1977) calculated the following concentration ranges (in mg/kg) to classify and rank cultural activity levels: 10-300 mg/kg for hack farming (i.e., slash-and-burn agriculture) and ranching; 300-2000 mg/kg for dwelling, gardening, manufacturing, and garbage dumping; and >2000 mg/kg for burials,
refuse pits, slaughter areas, and urban locales. These values may be viewed as broad barometers of the relative intensity of land use. For example, the lower P concentrations (10-300 mg/kg) are measures of limited clearance/low impact cultural activities across a local landscape, while the higher concentrations (>2000 mg/kg) measure more direct human modifications to a specific locus.

When the magnitude of human impact on the landscape can be demonstrated on the strength of the total P concentration, it may also be possible to differentiate specific activity sets. These are typically isolated by a fractionation method that involves chemical separation of inorganic settlement phosphate into three components (fractions) by means of non-overlapping extractions (see Eidt 1984:40-44). Fraction I corresponds to the easily extractable, loosely bound aluminum and iron phosphates; Fraction II to tightly-bound or occluded forms of these same phosphates; and Fraction III to calcium phosphates (also known as HCl 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.

Calculations of the relative loadings of phosphate levels on each fraction provide a refined index, or "print," of land use type. Phosphate "prints" are a strategy for distinguishing patterns of land use based relative proportions of Fraction I, II, and III in the phosphate extraction process. Graphic, tri-axial mapping of the "print" isolates variability through time and space of a constellation of land use types or activity areas. Such a representation underscores patterned site use signatures for a broad range of use types (see Schuldenrein 1995). If a site supported discrete activities—for example animal processing, burning, trash discard—each of which left discrete phosphate concentrations, individual activities could be sorted out by measuring variability in the relative loadings on each of the phosphate fractions. By combining the total P values with the fractionation data, the general magnitude, types, and ranges of activities performed within and across Areas 1, 2, and 3 South can be explored in greater detail. The mapping of phosphate "prints" for a variety of feature types here could, potentially, help segregate different land use types. Phosphate fractionation is also an inductive tool for differentiating feature types where establishment of a feature taxonomy on purely archaeological grounds is not possible. Thus the cultural vs. natural origins of a subsurface anomaly preserving no other visible cultural materials may be determined through phosphate and geochemical techniques. This would be extremely helpful for deeply buried deposits on site at Leetsdale, where diagnostic archaeological indicators are absent.

For this study control samples were collected at locations approximately 1-2 meters outside the feature at the same approximate elevation, where accessible. Control sampling was not optimal, as many specimens were collected post-facto; the phosphate study’s utility and potential was recognized after feature collection and not in conjunction with it. It is noted that feature and non-feature sampling are standard procedures and are valid even under less than optimal conditions, given that primary segregation of feature fill and non-feature sediment is performed under controlled conditions.
Sediment samples from select feature contexts, as well as control samples, were analyzed for phosphate fractionation by Mary Jo Schabel of the Milwaukee Soil Laboratory, LLC, Milwaukee, Wisconsin. A total of 50 feature, soil/sediment, and control samples were processed, representing the dense concentration of features in first 3 m of excavation in Areas 1, 2, and 3 South (Appendix I). Procedures for extraction (based on Chang and Jackson 1957; Eidt 1977; Kuo 1996; and Olsen and Sommers 1982) consisted of a sequential extraction of inorganic phosphates into three fractions, equivalent to the three fractions devised by Eidt (1984). Fraction Ia is phosphate removed by a sodium hydroxide/sodium chloride solution (P adsorbed by colloidal particles containing Al and Fe) while Fraction Ib is phosphate removed by a sodium citrate/sodium bicarbonate solution (P absorbed by carbonates). Combined, Fraction Ia and Ib are equivalent to Fraction I. For purposes of this study there is no need to segregate Fractions Ia and Ib for interpretive purposes since the former simply represents an earlier phase and the latter a more advanced phase of the same process of absorption (see Hutson et. al, 2009). Fraction II is P removed by a sodium citrate/sodium bicarbonate/sodium dithionite solution (P occluded with Al and Fe oxides and hydroxides). Fraction III is P is the acid (HCl) removable form (P occluded with calcium and apatite). Section 2.6 presents ternary plots of the distributions of the three fractions, examines the significance of variability in these distributions, and interprets the results of the analysis in detail.

Micromorphology

Micromorphology is a strategy used to identify particles, configurations of particles and void spaces of natural and human origin through microscopic examination (Goldberg and Macphail 2006). Micromorphological analysis provides a means of examining soils and sediments in great detail (Goldberg and Macphail 2006; Goldberg et al. 2001; Holliday 2004). For this project, micromorphism is instructive in determining the nature and magnitude of soil development, thereby informing on periods of environmental stability. Additionally, micromorphology is one of the few techniques that allows for identifications of anthropogenic inputs to sediments and soils. Micro-particulates (such as coprolitic residue or burnt grains from otherwise indeterminate origins) can be identified and linked to patterns of human activity, both independently and in conjunction with more standard testing for the introduction of humanly altered soil or sediment matrix (i.e., through geochemistry) (Courty et al. 1989; Goldberg and Macphail 2006). For this study, a key objective of the micromorphology study was to determine the degree of soil development on site and within areas. Initial observations during Phase I and Phase II suggested that discrete areas of the site featured relatively thick cambic (“Bw”) horizons whose distributions and lateral correlates were more substantially weathered and could be classified argillic and fragic (ie., “Bt” or “Btx” horizons in both Areas 2 and 3-South). Micromorphology is a technique that may resolve questions of relative soil development by disclosing the extent, depth, and prominence of illuviation structures in the suspected Bt and Btx horizons. Micromorphology was also deemed critical in assessing the composition of the organic matrix contained in the AC-C couplets of Area 1. Sampling for micromorphological purposes is undertaken in the field by removal of fixed and oriented soil or sediment blocks; this allows for intact preservation of the vertical structures of soil constituents. After transport to the lab, soil or sediment blocks are
impregnated with liquid polymers, allowed to solidify, ground into thin-sections, and then mounted onto slides for viewing. The impregnation process preserves the spatial relationships among the constituents of the sample matrix. Such preservation of vertical and horizontal relationships permits in situ examination of microscopic features of sample and, by extension, the characteristics of the cultural or natural deposit. When viewed under different light sources, particles are illuminated and identified, spatial relationships are assessed, and degrees of chemical and physical weathering processes may be distinguished. A digital camera mounted on the microscope is used to photograph key features.

At Site 36AL480, 57 micromorphology samples were collected and, of these, 50 were processed into thin-sections by Spectrum Laboratory of Vancouver, Washington, and the Mineral Optics Laboratory of Wilder, Vermont (Table 2.10). Micromorphological and petrographic analyses was conducted by Dr. Vento at CUP (Area 1 samples) and by Dr. Paul Goldberg of Boston University (Areas 2, 3 South, and Back Channel).

The two labs were used because each addressed separate issues. The Area 1 study (Vento-CUP) targeted the question of AC couplets and short-term depositional events. The emphasis here was on sedimentation and patterns of alluviation, as well as in differentiating humic enrichments to the parent matrix. The Area 3 South and Area 2 studies examined weathering contexts where, as discussed, the relative degree of pedogenesis was in question (Bw vs. Bt characteristics). In the case of the latter, field examination suggested that properties of either type of B horizon may have been in evidence and the micromorphological study would determine the extent of soil development. As discussed in the text unequivocal determinations of “B horizon” types were difficult to measure even with the application of micromorphological techniques and graded degrees of soil formation were largely registered across the T3 landform.

As noted, samples were selected from within excavation units which exhibited significant soil development in the field. The goal was to assess the microscopic fabric and textural pedofeatures of soils from Site 36AL480. Results of the analyses are summarized in Section 2.6 below.

Table 2.10 Summary of Micromorphology Samples from Site 36AL480.

<table>
<thead>
<tr>
<th>Area/Location</th>
<th>Meter</th>
<th>Sample Number</th>
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<th>Field Designation</th>
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<td>144</td>
<td>N258 E150 TU4</td>
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</table>
Table 2.10 Summary of Micromorphology Samples from Site 36AL480.

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</tr>
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<td>231</td>
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<td>232</td>
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Table 2.10 Summary of Micromorphology Samples from Site 36AL480.

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<th>Area/Location</th>
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<td>N71-73 E226</td>
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<td>213.39</td>
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<tr>
<td><strong>Back Channel</strong></td>
<td>Third</td>
<td>Area 1 #389</td>
<td>BHT-1</td>
<td>Bw</td>
<td>207.30</td>
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</table>
Radiocarbon Analyses

In this section, we initially discuss the methodology for radiometric sample collection and processing for specimens collected during Phase III by the GRA-CUP team. We follow this with a discussion of the total population of radiometric samples utilized for developing a site-wide absolute chronology for Site 36AL480. Our study integrated the entire pool of dates for the Leetsdale study, covering all phases of the work and merging the radiocarbon records of all contractors since the initial phases of work on site.

Phase III Radiocarbon Date Collection. Radiocarbon specimens were collected by the GRA-CUP team from a variety of contexts across all site excavation areas and from the Back Channel and Casting Basin. Wherever possible, charcoal samples were collected and prioritized for dating. However, the vast majority of dated samples were submitted as bulk sediment matrices and included soils (buried A horizons for paleosols) and organically enriched sediment matrices (i.e., AC-C sediment complexes on the T3, and organic silts and peaty horizons within the Back Channel and Casting Basin). For soils, the dating of intact A horizons (Ab) was preferred but AB and even Bw or Bt horizons were sampled and submitted for determination, if the geomorphic context was critical for interpretive purposes. All radiometric specimens were submitted to Beta Analytic Laboratories, Coral Gables, Florida, for processing. Where quantities of dating material were small, processing by Accelerator Mass Spectrometry (AMS) was undertaken.

There are several considerations that must be taken into account concerning the dating of the bulk sediment population. Within the soil or sediment matrices, dating is performed on fractions of soil organic matter (SOM). The fractions that are dated include the NaOH-soluble (humic acid), NaOH-insoluble (humin or residue) fractions or the total (“bulk”) organic carbon subsequent to acid treatments (Martin and Johnson 1995). It is stressed that whenever bulk sediments are dated, the fraction on which the processing is performed is a measure of a mixture of young and old carbon, derived from mobilized inputs into the soil or sediment’s matrix. Thus, what is being dated is an approximation known as the “apparent mean residence time” or AMRT (Scharpenseel 1971; Matthews 1985). For soils, these determinations are generally younger than the time that pedogenesis was initiated (see Holliday 2004). However, for sediments and in cases where there may be some upward migration of carbon (i.e., by groundwater in an alluvial situation), older dates are also possible. Accordingly, a large proportion of the geomorphic radiometric dates represent AMRT determinations.

The pretreatments followed for processing the SOM are those specified by Beta Analytic Labs (2010) and typically followed an “acid/alkali/acid” pretreatment. Additional acid washes were warranted for some of the more organic and peaty sediments.

The Leetsdale Radiocarbon Data Base. A total of 104 radiocarbon dates was obtained from the Site 36AL480 (Appendix B). The following contractors provided dated radiocarbon results: ASC Group (2 dates), CDC (9 dates), GRA (13 dates), Gray & Pape (33 dates), KCI (24 dates), Tetra Tech (6 dates), and URS (14 dates). Supporting documentation suggests that, with very minor exceptions, the dates were derived from cultural features. Conventional radiocarbon dates for the site range from <47,200 B.P. to 1760 ±60 B.P.
Dates that were presented by contractors in preliminary reports were verified over the course of this study by referencing Beta sample data sheets to confirm the accuracy of reported dates and to obtain the standard deviations and 13C/12C ratio (o/oo) per the Society for American Archaeology reporting standards.

The collection of these data was greatly complicated by the number of contractors and changes in personnel since the time of the original reports, but data were confirmed and collected for 83 of the samples. Original Beta sheets could not be obtained for samples from two contractors: Gray & Pape (Beta #s - 141361, 141363, 141364, 141365, 141367, 141369, 141370, 141371, 141373, 141379, 141380, and 141381) and CDC (Beta #s - 138051, 138052, 138053, 138054, 138055, 141376, 141394, 141396, and 141397). For these samples the final report is reliant upon earlier reports that do not list the 13C/12C ratio (o/oo). Since all dates were processed by Beta Analytic and are reported in conventional 14C format, where possible, the reported determinations are corrected for isotopic fractionization. Calibrations of the conventional radiocarbon dates were done using the Calib 6.0 program (Stuiver and Reimer 1993) and the Intcal09 dataset (Reimer et al. 2009). No laboratory offset was used in the calibrations. The graphs and table provided in this report reflect 2-sigma values (95.4 percent accuracy) for calibrated dates in order to provide the most conservative and inclusive ranges. Interpretations of the radiocarbon data set and its implications for site chronology are presented in Sections 2.6 and 2.8.

**Intrasite and Intersite Analysis Approach**

Geomorphological studies at Site 36AL480 used genetic stratigraphy (described above) to correlate strata between areas (e.g., Areas 1 and 3), and to previously excavated sites in alluvial settings within the Appalachian Plateaus Physiographic Province. On the site-specific level, site areas were joined by lithostratigraphies and soil sequences. On the broader, intersite scale, emphasis was placed on identifying sedimentation rates, development, and persistence of well-developed soil and paleosol markers (i.e., Bt horizons) across drainage nets, and synchronic deposition-soil formation-erosion cycles. Cultural stratigraphies were key for developing comprehensive time lines for these trends across the major drainages and physiographic areas.

The approach taken for intersite and regional comparisons was two-fold. First, we examined the Site 36AL480 geoarchaeological sequences with their correlates at single and multi-component stratified sites across the state of Pennsylvania to determine if the genetic stratigraphy model is synchronous with paleoenvironmental trends over the past 11,500 years (since the Pleistocene/Holocene transition). These included four of the sites specified in the original contract proposal and modification (Greenhorne & O’Mara 2000, 2002), along with three additional localities identified between Leetsdale and Pittsburgh. The assumption is that such macro-trends would be preserved in the trunk stream alluvial and occupation histories at these sites. Second, we attempted to integrate the Leetsdale successions with three downstream correlates along the Ohio River. Essentially, we tested whether or not the site/landform relations and attendant paleo-geographic changes in the upper portion of the Ohio drainage could be tracked along a downstream gradient. Three additional sites were selected for that portion of the comparative study.
Of the seven sites examined in Pennsylvania, three (3) served as comparisons for the Upper Ohio River, including: 1) the Leetsdale Sewerage Treatment Plant, Leetsdale; 2) the North Shore Connector, Pittsburgh; and 3) Point State Park, Pittsburgh. Four (4) regional sites were compared with the results of the study at Leetsdale. The sites chosen included the: 1) Sandts Eddy site on the Delaware River; 2) City Island on the Susquehanna River, near Harrisburg; 3) Memorial Park site along the central Susquehanna River; and 4) Mayview Site on the upper Ohio River.

The aforementioned sites were selected because of their deep stratigraphies and long-term archaeological records. Further, all of the sites were excavated under controlled and well-documented conditions. They occupy geomorphic settings analogous to those of Site 36AL480. Dr. Vento and/or Dr. Schuldenrein have served as geomorphological consultants for each of the seven sites listed above. The sites were studied with regard to soil genetic stratigraphy and the effects of climate change on the developing landform. Chronologies and processes of site formation were incorporated into the research design of each of these studies. Thus, the comparative framework for the proposed work at Site 36AL480 is consistent across the sample to be examined.

Localized comparisons provide an initial comparative context. Part of the complexity of the Site 36AL480 sequence was the identification of episodic depositions that may have been a product of unique events associated with the localized geography of the site setting. The initial geomorphic study (Vento et al. 2001) recognized multiple types of strata (i.e., polytypic facies units corresponding to autogenetic episodes) as single or at least short-term events (Rollins et al. 1989). For example, polytypic facies (channel deposits, splay deposits, and weak AC paleosols) were noted that crossed two landforms (i.e., the T1 and T2 terraces). This type of observation was critical for alluvial sequences like Leetsdale, where the preserved stratigraphic record may account for only five percent of the included time interval (Kraus and Bown 1986). Geomorphological investigations at Site 36AL480 have correlated polytypic (one-time event) strata across excavation areas. When incorporated into a genetic stratigraphy model, nested autogenic events and more major allogenic sequences can be expanded from Site 36AL480 to other sites in the Appalachian Physiographic province. It became possible, therefore, to consider that a distinct flood event or buried A horizon on the T3 terrace at Leetsdale may be temporally and spatially matched with the same flood event at another site on the Ohio River or Susquehanna River, allowing for a more detailed genetic stratigraphy model as well as intersite stratigraphic correlation.

Drainage wide comparisons provide a second, more expansive—or regional-frame of reference—that facilitates recognition of causal agencies on a grander scale. We have selected to test the model of genetic stratigraphy by applying principles of fluvial systematics along the drainage basin, here the Ohio River, to gauge spatio-temporal change in the stratigraphic record. We choose to examine systematic change in alluvial histories the length of a single drainage system, assuming that allogenic impacts will register the length of the drainage. Upstream sequence stratigraphies should be equated to their downstream counterparts if the dynamics of alluvial sedimentation are controlled for. In this regard, Schumm (1977) has proposed a widely accepted model that suggests that ideally a drainage basin will erode its upstream segment and transport sediment downstream. Schumm (1977) divides the basin into three zones: the watershed or sediment source area (Zone 1), a transfer
zone (Zone 2), and a sediment sink or area of deposition (Zone 3). Schuldenrein (1994) abstracted the principals of this basic geomorphic construct to develop a stratigraphically based archaeological preservation model for the Delaware Valley. In this model, upstream archaeological sites on higher terraces and in steep terrain, especially in glaciated terrain, tend to be deeply stratified and older and located on landforms that provide source sediment in the downstream direction (Zone 1). Stratigraphic sequences will tend to overthicken in a downstream direction along the axis of transport as gradients diminish, floodbelts broaden, and younger sites are more deeply buried (Zone 2). The flatter terrain also comprises a more diverse alluvial landscape with greater possibilities for archaeological burial (and preservation) in landforms that are zonally configured. Thus, a variety of archaeological components of different ages may occupy discrete landforms spanning a broader, laterally zoned alluvial terrain. This sedimentary trend, accompanied by terrain diversity, continues to the mouth of the drainage where the stream debouches into the higher order trunk stream and discharges the greatest quantity of both sediment and archaeological material (Zone 3).

The Ohio system is analogous to that of the Delaware, insofar as the upstream source of the river is in glaciated terrain and gradients flatten and broaden in the downstream direction. It follows that the oldest sequences will be housed in the upstream landform and progressively more complex vertical and lateral stratigraphic and geoarchaeological relationships will be expressed in a downstream direction. Since the T3 terrace at Site 36AL480 preserved the most complete record of geological and cultural stratification for the Upper Ohio Valley known to date, its relationship to the better known downstream Ohio chronostratigraphies is worthy of comparison.

The comparative data base for the Ohio Valley included four deeply buried sites associated with the trunk drainage:

- The Pleistocene/Holocene T3 and Late Holocene T2 terraces at Site 36AL480 (this report);
- The T1 terrace and ridge complex at Gallipolis, WV (Mandel 1988);
- An older Pleistocene (T2) and Holocene (T1) landform sequence in Boone County, KY (Schuldenrein 2006);
- The Early Holocene T1 terrace and ridge complex at Caesars, IN (Stafford 2004)

These sites occupy discrete segments of the Ohio basin and represent loci where the stream regime is somewhat different than at Leetsdale. The flood plain-terrace complexes are somewhat more complex since the gradients are less pronounced and sedimentary environments are more depositional along downstream reaches than they are in the more erosional upstream terrain. Nevertheless, these intersite comparisons will assess the degree to which geomorphic systematics account for temporal parallels in landscape history, the evolution of stable surfaces, and the propensity for prehistoric occupants to select certain tracts under changing environmental conditions for protracted or short term settlement. Here
again, the broad human ecological and paleoenvironmental trends can be linked to the genetic stratigraphy model as described in Section 2.7.

**SUMMARY OF GEOMORPHOLOGICAL OBSERVATIONS AND LABORATORY TESTING RESULTS BY AREA**

*Overview of Phase III Geomorphological Observations*

The following discussion summarizes the excavation of each area at Site 36AL480 and describes the geomorphological interpretation of observed stratigraphies. These interpretations correlate the reported results of the analyses performed by the respective archaeological consultants. Further, it considers the available radiocarbon and other environmental data in providing a comprehensive approach to the Leetsdale record. Areas are presented in numeric order, while the discussion of the Casting Basin, Back Channel, and Phase II blocks proceeds as they were examined by the geomorphological team between 2001 and 2003. Several illustrations and schematic profiles highlight the major geomorphological features of each investigation area, and numerous tables synthesize the observations in concise form.

Within the presentation of results by area, this report provides detailed analysis of the identified allostratigraphic units, incorporating field description, grain size, and clay mineral analyses as appropriate. Discussions of the biogeochemistry, feature geochemistry, phosphate fractionation, and micromorphology are included at the close of the chapter. This discussion is previewed by presentation of the composite genetic stratigraphy model for Site 36AL480 in order to facilitate presentation of the myriad of data collected, analyzed, and interpreted during the course of geomorphological investigations.

*Revised Site 36AL480 Genetic Stratigraphy Model*

As described in Section 2.3, the Site 36AL480 genetic stratigraphy model and its constituent allostratigraphic units were introduced in 2003 (Schuldenrein et al. 2003), following Phase I and II investigations (1999-2000) and Phase III data recovery in Area 3 South in (2001; Anderson et al. 2010; Davis 2000; Fenicle 2003; Hardlines 2000; Vento et al. 2001). The original model, based on four allostratigraphic components, is refined and finalized in this report, and reflects a more nuanced understanding of the Site 36AL480 stratigraphic suite, based on the corpus of completed field and laboratory analyses detailed below.

In the early genetic stratigraphy model, the allostratigraphic units (AU-1 through AU-4) reflected the same basic scheme described in 2003, including: the AU-1, consisting of basal coarse sands capped by thin AC-C semi-stable surface couplets and dated to 11,700 B.P. to 6500 B.P.; the AU-2, comprised of overlying cambic (Bw), argillic (Bt), and fragic (Btx) subsoils deeply weathered in place and containing stacked prehistoric features dating between 6500 B.P to 3000 B.P.; the AU-3, thin flood deposits and short term Inceptisols of late Holocene age, 3000 B.P. to 500 B.P.; and finally, AU-4, historic and modern fills (500 B.P. to recent), which were stripped prior to archaeological excavation.
In the finalized genetic stratigraphy model, the sequence is refined to reflect localized depositional events. Figure 2.23 is a plan view that shows the placement of the two representative transects that formed the basis of the final allostratigraphic succession and reconstructed landscape chronology. These transects were designed to capture the primary variation in the sequences spanning the major landforms and occupational loci. Figures 2.24, and 2.25 are composite profiles of the Site 36AL480 allostratigraphy. These figures demonstrate the final interpretation of the soil-sedimentary packages identified during all phases of geomorphological investigation. Further, these figures summarize the complete model, including the separation of AU-2a and AU-2b, to reflect change in deposition after 4500 B.P. and continuing to 3000 B.P., when more frequent overbanking and incision of the T3 landform occurred on both the western and eastern margins of the highest terrace. Evidence for this occurrence is found in the stacked AC-C couplets noted from the eastern site of Area 1 (Block 3 first meter and below) and the southwestern corner of Area 2.

At the base of the sequence, the AU-1 basal deposits are found. These included the top of the channel lag, coarse sands and gravels, gleyed sands, and stacked incipient AC-C couplets found consistently below 210 m asl across the site. These were the deposits of the early Holocene and reflected the braided, multi-channel aspect of the post-glacial Ohio River alluvial system, and later indicated the transition to a stabilized, meandering channel form. Radiocarbon assays reached into the Pleistocene for sediments recovered from the Casting Basin and Back Channel, but most available bulk sediment or deep cultural fills (features such as Feature 507 in Area 2 at 6790 ± 50 B.P. [Beta-179856] below 209.50 m asl) placed this allounit in the 11,500 B.P. to 6500 B.P. range. While the AU-1 was observed, in a limited way, through test trenching and hand augers across the Site 36AL480 landform, its most prominent exposure was visible with the gleyed sands and clays with interspersed peat deposits in the Casting Basin.

Allostratigraphic Unit 2 (AU-2) encompassed the corpus of deeply weathered (cambic, argillic, and fragic) soils, as well as the sandy, infilling sediments that occupy the eastern margin of the T3 in the vicinity of the Back Channel, as well as the southwestern corner of Area 2 on the western edge of the terrace. This AU-2 unit was recognized in Area 3 South through the identification of the 3Bw-4Bw-5Bw subsoil in the center of the excavation block. Formally subdivided into AU-2a and AU-2b after completion of the Phase III data recovery, this refinement of the allostratigraphic model was applied in Areas 1 and 2, where characteristic soil-sediment suites were identified abutting each other within the excavation blocks. The older component, AU-2a dates to the 6500-4500 B.P. period, when minimal accretion of sediments from overbanking events was occurring. Rather, the T3 surface was stable, weathering deeply in place. This occurrence was evidenced by the stacked, or arguably “overlapping” and “welded” horizons (per Holliday 2004: 78), cambic, argillic, and localized fragic B horizons observed through the spine of the uppermost terrace (see Figure 2.24; see Figure 2.7 for Bt and Btx horizons). Such horizons were located in the southwestern corner of Area 1 (Block 2 first meter) and Area 2 northeast corner.

On either side of this T3 landform, localized scouring and infilling of the terrace margins produced the AU-2b soil-sediment package that consisted of stacked incipient AC-C horizons. These units, based on associated feature dates from Areas 1 and 2, suggested a period of renewed overbanking and terrace incision that created multiple generations of
meta-stable surfaces along the flanks of the T3. Both the Back Channel and the main stem of the Ohio contributed to this allostratigraphic unit, dated to the period 4500-3000 B.P., although it is likely the Back Channel was abandoned around 4500 B.P.

The AU-3 deposits were comprised of a suite of incipient soils formed on top of a series of thin flood deposits. Soil sequences generally included Ap-Bw/BC-C horizons of up to two meters in thickness. These were found across the T3 landform, although they were generally absent from the identified sola in the Phase II Block 6 exposures. These soils dated to 3000 B.P through 500 B.P., which fell within the Early to Middle Woodland periods, based on numerous radiocarbon-aged features and diagnostic artifacts recovered from Areas 1, 2, and 3 South.

Finally, the AU-4 capped the Leetsdale terrace system and included the historic through modern period fills, structures (e.g., Harmony Brick Works), and landform modifications of less than 500 years of age. These deposits were the lead-contaminated sediments, which were stripped and isolated prior to archaeological assessment.

By both summarizing and coalescing the geomorphological observations at Site 36AL480, these new cross-sections establish the utility of the allostratigraphic model for the site, as they integrate the myriad of field and laboratory data. These data are presented below.

**Area 1 Allostratigraphy and Pedostratigraphy**

Archaeological investigations in Area 1 were undertaken and completed by URS Corporation, under the direction of Dr. William P. Barse during the 2002 field season. The archaeological studies followed a series of specific seven tasks, which began with the mechanical stripping of historic sediments and lead-contaminated fill material across the 35-x-48-m area. Task 2 involved the establishment of a 5-m grid across the stripped section and subsequent to that, Task 3 required the excavation of 60 1-x-1-m test units to a depth of 1 m below the surface of the stripped block. Task 4 called for the excavation of additional 1-x-1-m test units in a block configuration. During this stage of excavation, 200 m3 of soils were excavated to a nominal depth of 1 m below the top of the stripped surface, or approximately 1.6 m below surface, from five separate blocks (Figure 2.26).

Following completion of the block excavations, the remaining portion of the 35-x-48-m tract was stripped to an accordant depth of the test units excavated during Tasks 3 and 4, leaving the entire excavation area at the same approximate depth below ground surface. Task 6 required that URS Corporation establish a 10-m grid across the newly stripped surface and emplace twelve contiguous 1-x-1-m test units beneath the foot print of previously excavated Block 3 to sample the second meter of soil. Additionally, one 1-x-1-m unit and seven discontinuous 1-x-2-m units were also excavated as part of this final excavation task. Geomorphological observations and sampling was conducted during all tasks where open excavation units were accessible, and included subsurface testing by hand augers to examine stratigraphy at depths over seven meters below ground surface.
During the course of the archaeological and geomorphological studies completed in Area 1, more than 70 cultural features were encountered. Nearly all of these features occurred between 214.8 and 213.6 m asl. Of the 62 prehistoric features mapped and subsequently excavated, 18 features were submitted for 14C assay. The dates for these features ranged from 8550 ± 40 B.P. to 2450 ± 40 B.P., and documented sporadic occupation of Area 1 for short intervals of time, particularly during Late Archaic and Transitional Archaic times (see Figure 2.27 for representative distributions). Area 1 exhibited more variability in the depositional sediment packages, and generally featured more immature or younger soils, particularly along the eastern flank of the excavation area closest to the Back Channel zone. Fourteen soil profiles were sampled and analyzed for grain size distributions (Table 2.11 field results and Appendix E for granulometry results).

Along the western edge of the excavation area toward the center of the T3, in the southwestern corner of Area 1 Block 2 especially, soils with better structural development and higher clay and silt ratios were observed. In that sense, Area 1 contained the most anomalous stratigraphy at the site. As discussed subsequently, part of Area 1 occupied a different landform than Areas 2 and 3 South. Within Area 1, four distinct allostratigraphic units (AU) and subunits can be identified.

**AU-1**

The basal deposits extended from a depth of 2.5-6 m (8-19.5 ft) below ground surface (see Figure 2.27). They consisted of poorly sorted, medium to coarse sands that could not be readily differentiated from underlying late Wisconsin lateral accretion deposits that underlie the T3 terrace. Separation between the late Pleistocene and early Holocene channel or channel margin fills was not possible, since only a single core extended to a maximum (6 m) depth in the southeast corner of Area 1. The Pleistocene deposit was recognized everywhere across the site as AU-1. Given the absence of an extensive profile, it was not possible to identify either a fining upward sequence. In general, however, it was possible to characterize the terminal Pleistocene alluvium for the Upper Ohio as a set of coarse, sandy matrices with a minor component of gravel clasts (see Appendix E Area 1 N275 E167 below the third meter). Test augering at N275 E167 in the southeastern corner of Area 1 indicated that lateral accretion deposits (AU-2 generally), made up of fine to medium sands, and silts displaced the basal coarse sands (AU-1) above 211.00 m asl (Figure 2.27).

The Coulter Counter analysis of the sample size fractions also supported the observation that there was a general fining-upward sequence within the samples from N275 E167, through the middle Holocene, which supports the model of slow aggradation of the stream terraces since this period (Figure 2.28). The uppermost samples, associated with late Holocene deposits, indicated a brief transition to a greater proportion of coarse-grained particles (medium to very coarse sands and fine gravel). This observation may have been related to an intensification of aboriginal impacts on the landscape (regional deforestation), or to the late Holocene cooling trend of the Scandic climatic episode, which helped to generate more high-energy storms and, thus, more frequent terrace flooding events. AU-2a and AU-2b
AU-2 was expressed in two separate stratigraphic contexts in Area 1. First, the AU-2a was found in the extreme southwest corner of the excavation area and contained a denser structural matrix (higher silt content). These deposits were weathered into a Bw (cambic) horizon with a better-developed subangular blocky structure. Second, the AU-2b, localized within the northern and eastern portions of the block, was notably sandier and reflected the overbanking contributions of an active Back Channel zone (see Figures 2.26 and 2.29; see Appendix E N258 E150).

The AU-2a (Bw1-Bw2-Bw3 as represented by N258 E150; Figure 2.30), in this southwestern flank of Area 1, spanned approximately 20 percent of the excavation area. It was consistent with those horizons preserved within the margins of the T3 landform, and was the dominant allostratigraphic unit in Area 3 South, as well as Area 2 (northeastern corner). The silt-rich Bw had a moderately firm, weak subangular blocky structure with a diffuse pore network. Figure 2.30 shows the grain size trends in the profile from N258 E150, which was situated in the southwest corner of Area 1, and documents the consistently silty nature of the successive Bw1-Bw2-Bw3 horizons. Within the second meter of depth, however, these silty horizons transitioned to deeper AC-C couplets (see Appendix E for unit N262 E156), with significant silt and sand ratios observed.

In contrast, the AU-2b (Appendix E; see first meter units including: N261 E158; N275 E170; N280 E165; and N283 E167), reflected a sandier, coarsening-downward trend based on the granulometric results (excluding the poorly-sorted fill caps). Looking at these results from the southwestern edge toward the opposite corner of the Area 1 excavation, there was an observable rise in the proportion of medium sands in the BC horizons, as the units transitioned to the northeast. Silt ratios also declined in the BC levels of these same units as the horizons moved away from the fine-grained Bw horizons of the southwest corner. Figure 2.30 illustrates this transition. In this southward view, the AU-2a cambic package graded into a series of less-developed, sandy BC horizons (BC1-BC2-BC3) and, into the eastern half of Area 1, where a thick series of stacked AC-C couplets resided (Figure 2.31; see Appendix E for unit N275 E170 within the first meter and deeper units, including: N268 E169; N268 E167-168; N275 E167).

Figure 2.32 documents the granulometric character of a deep test from N273 E163, along the eastern margin of Area 1. Here, the fill horizon was again distinguished by its coarse texture and poorly-sorted character, while underlying horizons tended toward being moderately well-sorted. The AC-C couplets had measurable medium and fine sand components, with C horizons demonstrating consistently higher ratios of 2φ- or 3φ-sized particles than their overlying AC counterparts (Appendix E; see also second meter units, including: N271 E149; N272 E166; and N278.5 E142.5). These AU-2b couplets appeared associated with a rather lengthy episode of periodic high to moderate overbank discharges along the proximal or levee margin from the Back Channel zone during flood episodes (Appendix E; see also second meter units, including: N268 E167-168; N271 E149; and N298 E152). This subunit was a slightly younger component of AU-2, dated to 4500 B.P.-3000 B.P., and was the product of episodic fluvial discharges and natural levee deposition.
<table>
<thead>
<tr>
<th>Block/Corner</th>
<th>Allostratigraphic Unit</th>
<th>Horizon</th>
<th>Elevation m asl</th>
<th>Color</th>
<th>Field Texture</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block 2/</td>
<td>AU-4</td>
<td>Fill</td>
<td>215.22-214.61</td>
<td>n/a</td>
<td>n/a</td>
<td>Lead-contaminated historic and modern fills. Stripped and segregated 0.61 m from surface during Task 1.</td>
</tr>
<tr>
<td>Southwest</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AU-3</td>
<td>AB</td>
<td>214.50-214.31</td>
<td>10YR4/4</td>
<td>Silt loam</td>
<td>Weak very fine subangular blocky structure, &lt;10% gravels, very friable, clear smooth lower boundary.</td>
</tr>
<tr>
<td></td>
<td>AU-2a</td>
<td>Bw1-BC1</td>
<td>214.31-214.05</td>
<td>10YR4/4</td>
<td>Silt loam to sandy loam</td>
<td>Grades west to east: increase in sand fraction, ped structure grades from weak fine to medium subangular blocky to very fine granular/weak subangular blocky, clear smooth lower boundary.</td>
</tr>
<tr>
<td></td>
<td>AU-2a</td>
<td>Bw2-BC2</td>
<td>214.05-213.79</td>
<td>10YR4/4</td>
<td>Silt loam to sandy loam</td>
<td>Grades west to east: increase in sand fraction, ped structure grades from weak fine to medium subangular blocky with faint clay films on ped faces to very fine granular/weak subangular blocky structure, clear smooth lower boundary.</td>
</tr>
<tr>
<td></td>
<td>AU-2a</td>
<td>Bw3-BC3</td>
<td>213.79-213.68</td>
<td>10YR4/4</td>
<td>Loam/clay loam to sandy loam</td>
<td>Grades west to east: friable medium subangular blocky structure with distinct clay films on ped faces to a loose very weak very fine granular structure.</td>
</tr>
<tr>
<td>Block 3/</td>
<td>AU-4</td>
<td>Fill</td>
<td>215.53-215.13</td>
<td>n/a</td>
<td>n/a</td>
<td>Lead-contaminated historic and modern fills. Stripped and segregated 0.61 m from surface during Task 1.</td>
</tr>
<tr>
<td>Southeast</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2.11 Summary of Area 1 Stratigraphy as Observed in the Field.

<table>
<thead>
<tr>
<th>Block/Corner</th>
<th>Allostratigraphic Unit</th>
<th>Horizon</th>
<th>Elevation m asl</th>
<th>Color</th>
<th>Field Texture</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>AU-3</td>
<td>BC</td>
<td>214.99-214.85</td>
<td>10YR4/4, 10YR4/6</td>
<td>Loamy sand</td>
<td>Weak fine subangular blocky structure, very friable, abrupt to clear smooth lower boundary.</td>
<td></td>
</tr>
<tr>
<td>AU-3</td>
<td>C</td>
<td>214.85-214.70</td>
<td>7.5YR4/4</td>
<td>Loamy sand</td>
<td>Massive structure, &lt;10% gravels, loose to very friable, abrupt smooth to wavy lower boundary.</td>
<td></td>
</tr>
<tr>
<td>Block 3/</td>
<td>AU-2b</td>
<td>2AC</td>
<td>214.70-214.66</td>
<td>10YR4/6</td>
<td>Very fine sandy loam</td>
<td>Weak very fine subangular blocky structure, very friable, abrupt smooth lower boundary.</td>
</tr>
<tr>
<td>Southeast</td>
<td>AU-2b</td>
<td>2C</td>
<td>214.66-214.61</td>
<td>7.5YR4/6</td>
<td>Sand to loamy sand</td>
<td>Weak very fine subangular blocky to granular, loose to very friable, abrupt smooth to wavy lower boundary.</td>
</tr>
<tr>
<td></td>
<td>AU-2b</td>
<td>3AC</td>
<td>214.61-214.51</td>
<td>10YR4/6</td>
<td>Sandy loam</td>
<td>Very fine subangular blocky slightly sticky, slightly plastic very friable, abrupt smooth lower boundary.</td>
</tr>
<tr>
<td></td>
<td>AU-2b</td>
<td>3C</td>
<td>214.51-214.49</td>
<td>7.5YR4/6</td>
<td>Sand to loamy sand</td>
<td>Very fine subangular blocky to granular, very friable, abrupt smooth lower boundary.</td>
</tr>
<tr>
<td></td>
<td>AU-2b</td>
<td>4C</td>
<td>214.47-214.42</td>
<td>7.5YR4/6</td>
<td>Sand to loamy sand</td>
<td>Very fine subangular blocky to granular structure, loose, abrupt smooth lower boundary, lens-like morphology.</td>
</tr>
<tr>
<td></td>
<td>AU-2b</td>
<td>5AC</td>
<td>214.42-214.28</td>
<td>10YR4/6</td>
<td>Sandy loam</td>
<td>Very fine to fine subangular blocky, slightly sticky slightly plastic, loose to very friable, abrupt smooth lower boundary. Root traces?</td>
</tr>
<tr>
<td></td>
<td>AU-2b</td>
<td>5C</td>
<td>214.28-214.24</td>
<td>7.5YR4/6</td>
<td>Sand to loamy sand</td>
<td>Very fine subangular blocky to granular structure, loose, abrupt smooth lower boundary.</td>
</tr>
<tr>
<td></td>
<td>AU-2b</td>
<td>6C</td>
<td>214.20-214.16</td>
<td>7.5YR4/6</td>
<td>Sand to</td>
<td>Very fine subangular blocky to granular</td>
</tr>
</tbody>
</table>

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Table 2.11 Summary of Area 1 Stratigraphy as Observed in the Field.

<table>
<thead>
<tr>
<th>Block/Corner</th>
<th>Allostratigraphic Unit</th>
<th>Horizon</th>
<th>Elevation m asl</th>
<th>Color</th>
<th>Field Texture</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>AU-2b</td>
<td>7AC</td>
<td>214.16-214.14</td>
<td>10YR4/6</td>
<td>Sandy loam</td>
<td>loamy sand</td>
<td>structure, very friable, abrupt smooth lower boundary</td>
</tr>
<tr>
<td>AU-1</td>
<td>7C-8AC-8C-9AC-9C</td>
<td>214.14-213.52</td>
<td>7.5YR4/6 (AC), 10YR4/4 (C)</td>
<td>Loamy sand to coarse sand</td>
<td>Fine lamellae of sandy loam (8AC-9AC) interbedded in fining upward sequence, massive structure, loose, abundant dispersed charcoal, abrupt smooth lower boundary.</td>
<td></td>
</tr>
<tr>
<td>Block 3/ Southeast AU-1</td>
<td>10AC</td>
<td>213.52-213.32</td>
<td>10YR5/4</td>
<td>Sandy loam</td>
<td>Weak subangular structure, slightly sticky and slightly plastic, abundant organics including large flecks of charcoal, abrupt smooth lower boundary.</td>
<td></td>
</tr>
<tr>
<td>AU-1</td>
<td>10C</td>
<td>213.52-213.02</td>
<td>10YR4/4</td>
<td>Medium to coarse sand</td>
<td>Some silt, massive structure, abrupt smooth lower boundary.</td>
<td></td>
</tr>
<tr>
<td>AU-1</td>
<td>11AC</td>
<td>213.02-212.42</td>
<td>10YR5/4, 10YR5/3</td>
<td>Sandy loam</td>
<td>Weak subangular structure, slightly sticky, slightly plastic, abrupt boundary. Root traces?</td>
<td></td>
</tr>
<tr>
<td>AU-1</td>
<td>11C</td>
<td>212.42-212.22</td>
<td>10YR5/6, 10YR5/8</td>
<td>Very coarse sand</td>
<td>Massive structure, loose, some silts, ferromanganese mottles.</td>
<td></td>
</tr>
<tr>
<td>AU-1</td>
<td>12AC</td>
<td>212.22-211.82</td>
<td>10YR5/4, 10YR5/3</td>
<td>Sandy loam</td>
<td>Weak to moderate fine to medium subangular structure, slightly sticky and slightly plastic.</td>
<td></td>
</tr>
<tr>
<td>AU-1</td>
<td>12C</td>
<td>211.82-210.32</td>
<td>10YR4/4, 10YR4/6</td>
<td>Medium to coarse sand</td>
<td>Massive structure, loose, fines upward.</td>
<td></td>
</tr>
<tr>
<td>AU-1</td>
<td>13AC</td>
<td>210.32-210.22</td>
<td>10YR5/4</td>
<td>Sandy loam</td>
<td>Weak subangular structure, slightly sticky, slightly plastic, increased charcoal.</td>
<td></td>
</tr>
<tr>
<td>AU-1</td>
<td>13C</td>
<td>210.22-209.92</td>
<td>10YR4/4</td>
<td>Gravelly medium to coarse sand</td>
<td>Coal gravels, top of channel lag deposits.</td>
<td></td>
</tr>
</tbody>
</table>
Table 2.11 Summary of Area 1 Stratigraphy as Observed in the Field.

<table>
<thead>
<tr>
<th>Block/Corner</th>
<th>Allostratigraphic Unit</th>
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<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>AU-1</td>
<td>14AC</td>
<td>209.92-209.82</td>
<td>10YR4/4</td>
<td>Loamy sand to sandy loam</td>
<td>Mixed horizon with abundant free carbon, massive structure with possible pockets of weak subangular structure.</td>
<td></td>
</tr>
<tr>
<td>AU-1</td>
<td>14C</td>
<td>209.82-209.62</td>
<td>10YR5/4, 10YR4/6</td>
<td>Fine to medium sands</td>
<td>Massive structure, loose.</td>
<td></td>
</tr>
<tr>
<td>AU-1</td>
<td>15AC</td>
<td>209.62-209.29</td>
<td>10YR4/4, 7.5YR4/6</td>
<td>Fine sandy loam</td>
<td>Granular to weak fine subrounded structure, reddened matrix, increase free carbon with flecks of charcoal.</td>
<td></td>
</tr>
</tbody>
</table>
The fluvial couplets from AU-2b extended across the distal end of the landform. Each couplet documented a single, autogenic event with a clear fining upward package. The AC component of the couplet represented a relatively short-lived episode of in situ weathering. Such weathering was identified by slightly reddish hues in the matrix, although there was local variation in the intensity of reddening (Figure 2.33; see Table 2.11). More generally, during a brief episode of subaerial exposure, the AC horizon was enriched in organics (as evidenced by root traces described in the field) with some oxidation of the iron bearing minerals. Biogeochemical results, discussed and integrated below, documented the increased organics measured from these AC horizons (generally measured above .5 percent), whereas the C horizons exhibited less organic material (typically below .5 percent). All of the features encountered in the AU-2b originated either within or on the surface of the AC horizon. The short-lived nature of the couplets, and rather short temporal span for the AC-C couplet package in general, was supported by the suite of radiocarbon dates from features in AU-2b (all ranging from ca. 3500 B.P.), as well as from diagnostic stone tools (Barse 2003; Miller et al. 2010).

**AU-3 and AU-4**

Allostratigraphic Unit 3 was a fine-grained package of vertical accretion deposits of probable late Holocene age, which conformably rested on both AU-2a and AU-2b. In most areas of the site, this unit consisted of a truncated strong, granular, sandy loam BC horizon overlain by historic fill material and historic flood deposits (see Figure 2.34). In Block 2 in the southeast corner of Area 1, however, the BC graded into a more organic-rich AB horizon, which was overlain by historic fill. The Ap horizon, which should be associated with the BC-AB horizons, was discontinuous and largely absent, having been removed by recent and past historic disturbance to the terrace. In all likelihood, any Woodland or Contact period artifacts or remains would have been present in these upper sola in Area 1. AU-4 was entirely comprised of historic fill material, which variously and disconformably caps either Block 2 or Block 3 across the excavated portion of Area 1. Granulometric analysis of these uppermost horizons was limited, and documented a generally weakly developed and friable, fine, sandy silt with frequent to occasional gravels (Appendix E; see N283 E167).

**Area 2 Allostratigraphy and Pedostratigraphy**

The data recovery block in Area 2 covered an area of 13-x-15-m (195 m²; Figure 2.35). Excavations were conducted in accordance with an excavation plan, certified by a professional engineer that prescribed the use of 1.5 m (horizontal; 4.9 ft) to 1.0 m (vertical; 3.3 ft) safety benches for excavation below a depth of 1.2 m (3.9 ft). The excavation proceeded in stages, with each stage involving the excavation of a package of soils one meter (3.3 ft) in depth. Each of the three upper meter packages encompassed 200 m³, including selected expansions of the 13-x-15-m block to encompass 5 m³ in each meter (Figure 2.36). The fourth and fifth meters of excavation were reduced in area to create safety benches (Miller and Marine 2005).

Previous archaeological work in Area 2 included a Phase 1 backhoe trench with a 1-x-1-m test unit on the margin (T-8/U-9), excavated near the center of Area 2 (Davis 2000; Schuldenrein et al. 2003), and fell along the northern wall of the data recovery excavation.
block of this area. Two cultural features (Features 2 and 4) were identified. Feature 4 was observed in the trench between 1.4 and 1.7 m (5-5.6 ft) below the surface. Feature 2 was found at the base of the plow zone, and was radiocarbon dated to 2670 ± 60 B.P.

A 1-x-2-m test unit (at N149.89 E131.05) was excavated in Area 2 in September 2001, to provide information for scoping of the data recovery (Schuldenrein et al. 2003). The unit was outside and to the east of the data recovery excavation block. It was excavated to approximately a meter and a half below the surface. The soil profile revealed fill overlying a plow zone (Miller and Marine 2005). A 2AB horizon was found below the plow zone and overlying a 2Bw horizon that was approximately .60 m (1.9 ft) thick. Below were found a 3AC horizon and a 4Bw horizon extending to the base of the excavation. Artifact densities ranged from one to 95 per level and were highest in the 2Bw horizon. Only three ceramic artifacts were found in the unit; they were identified near the top of the 2Bw horizon. A stemmed point was found in the 2Bw horizon and a Brewerton side-notched point was found near the base of the excavation (Miller and Marine 2005).

Two geomorphology trenches were excavated in the Area 2 vicinity as part of the 2000 geomorphological investigations at the site (Schuldenrein et al. 2003; Vento et al. 2001). Trench 4-3 was to the north and Trench 3-2 was to the south of the Area 2 excavation block. Trench 3-2 revealed a series of Bw horizons overlying stacked lamellar bands (AC-C horizons), encountered at an elevation of 212.28 m asl in the east and 211.47 m asl in the west (Miller and Marine 2005; Vento et al. 2001: Figures A6 and A7). Four archaeological features were identified in the lamellar bands of the trench, but it was noted that in the geomorphological studies overall, only six features were found in the lamellar sediments at Site 36AL480. Two features in lamellar deposits in Trench 3-2 were radiocarbon dated to 6620 ± 40 B.P. (Beta-141364) and 6740 ± 40 B.P. (Beta-141365). Based on this evidence, it was concluded that the upper lamellae deposits dated to the early Middle Archaic period (Miller and Marine 2005). Trench 4-3 encountered lamellae bands at approximately 210.44 m asl. The trench revealed a profile generally similar to that of Trench 3-2, but with Bw and Btx horizons overlying stacked lamellae bands (Vento et al. 2001: Figure A8). Two radiocarbon dates were secured from bulk soil samples, but these were older than 10,000 B.P. and considered unreliable (Vento et al. 2001).

Geomorphological investigations on the T3 terrace since 2000 have identified multiple soil horizons within four distinct depositional cycles or soil generations (Table 2.12; Figure 2.37). At the base of the section, coarse-grained, relict, lateral accretion deposits of 11,000-10,000 B.P. (Younger Dryas) age were overlain by a thick package of lamellar sands (AC-C horizons). These AC-C couplets were emplaced by repeated, frequent, cyclic deposition with short intervals of stability dating between 10,000 B.P. and 6500 B.P. (Pre-Boreal, Boreal, and early to mid Atlantic), creating the build-up of a natural levee. At this time, the terrace was in a lower topographic position relative to the active river channel, thus receiving sediments deposited under higher more competent discharges along the proximal, or levee, margin of the terrace. Stabilization of the T3 terrace was represented by fragic Btx horizons, as identified during 2000 trench examinations (Vento et al. 2001: Figures A6 and A8), and moderate to well-developed cambic B horizons in the central and eastern portions of Area 2, dated from 6500-3000 B.P. (mid Atlantic to Sub-Boreal). The fragic soils documented a rather lengthy episode of in situ weathering during a period of terrace
aggradation associated with low magnitude floods. As the river laterally migrated to the east and the terrace aggraded higher above the thalweg, sediment deposition of finer grained overbank alluvium (silt loams, fine sandy loams) took place across the T3 surface.

Archaeological unit exposures and geomorphic testing disclosed considerable lateral variability in the depositional regime and chronology of Area 2 (see Appendix E Area 2 granulometry results). It was expressed most prominently in the central two meters (between E111-E113) of the sedimentary sequence (Figure 2.37). The riverward (western) segment of the block preserved a series of lamellar and non-lamellar sands post-dating 4000 B.P. The landward (eastern) portion of the block at the same elevation was distinguished by well-developed argillic and fragic soils with features dated older than 5000 B.P. This observation also spurred a refinement of the allostratigraphic system for Area 2, requiring a subdivision of the AU-2 designation into AU-2a and AU-2b components. Thus, within Area 2 there were two discrete soil-sediment complexes and archaeological occupations, separated by two millennia (Figure 2.38). As discussed subsequently, the older eastern portion of the Area 2 block was continuous geochronologically with Area 3 South (AU-2a), while the later succession represents a renewed aggradation phase subsequent to a sustained period of erosion and likely represents an inset of the younger T2 terrace (now identified as AU-2b) into the proximal margin of the higher T2 terrace. Morpho-stratigraphically, the boundary between the T2 and the T3 terrace landforms retreated to the north and east with increasing elevation. Erosion, grading, and filling from industrial activities, occurring during the last 150 years, had resulted in significant disturbance to the upper sola with the emplacement of a variably thick, historic fill deposit.

Radiocarbon dates suggested deposition rates averaging 1 m (3.3 ft) per hundred years between 4500-3000 B.P. (Transitional Archaic and Early Woodland period) in the southern and western portion of the block. Deposition on the older landform between 5200 and 5000 B.P. was much more rapid, at approximately .45 m (1.48 ft) per hundred years. The depositional rate between 6500 B.P. and 4500 B.P. (Middle Archaic and early Late Archaic periods on the older landform was approximately .22 m (.72 ft) per hundred years. The higher rates for the period 6500-4500 B.P. might be explained by the ablation of the late Wisconsinan ice sheets, which allowed for a shift from zonal to more meridional atmospheric circulation, and the penetration of large cyclonic storms from the south affecting the Ohio River (Knox 1983).

**AU-1**

Deep AC-C horizons soils were present in the southwestern part of the block (third through fifth meters; Figure 2.39). These sediment-soil successions were continuous across the site. The Middle Archaic component was present in lamellae deposits on the northern landform, which was also preserved in Trench 3-2 from 2000 (Schuldenrein et al. 2003; Vento et al. 2001). The trench revealed two features with radiocarbon dates roughly contemporaneous with the Middle Archaic component in the data recovery excavation block. With the exception of Feature 495/497 and a few scattered artifacts, the swale or erosional inset was devoid of cultural material until the ca. 3760 B.P. occupations were encountered (Miller and Marine 2005).
Table 2.12 Summary of Site 36AL480 Area 2 Stratigraphy.

<table>
<thead>
<tr>
<th>Block/Corner</th>
<th>Allostratigraphic Unit</th>
<th>Horizon</th>
<th>Elevation m asl</th>
<th>Color</th>
<th>Field Texture</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northeast Corner (N155 E121)</td>
<td>AU-4</td>
<td>Fill</td>
<td>214.25-214.09</td>
<td>2.5Y3/2</td>
<td>Sandy loam to silt loam</td>
<td>Weak fine subangular blocky structure, &lt;10% gravels, friable, historic debris, clear smooth lower boundary.</td>
</tr>
<tr>
<td></td>
<td>AU-3</td>
<td>Ap</td>
<td>214.09-214.00</td>
<td>2.5Y3/2</td>
<td>Sandy loam to loam</td>
<td>Weak fine to medium subangular blocky structure, slightly sticky, slightly plastic, friable, abrupt smooth lower boundary.</td>
</tr>
<tr>
<td></td>
<td>AU-2a</td>
<td>Bw, 2Bw</td>
<td>214.00-212.80</td>
<td>10YR3/4, 10YR3/6</td>
<td>Silt loam</td>
<td>Moderate to strong medium subangular blocky structure, &lt;10% gravels, faint clay films.</td>
</tr>
<tr>
<td></td>
<td>AU-2b</td>
<td>BC/CB, 2BC, 3BC</td>
<td>212.80-211.50</td>
<td>10YR4/3, 10YR4/4</td>
<td>Sandy loam</td>
<td>Weak to moderate fine subangular structure, possibly sequence of weathered/degraded former AC-C lamellae, observed discontinuous and very localized cambic and argillic soil development.</td>
</tr>
<tr>
<td></td>
<td>AU-1</td>
<td>AC-C</td>
<td>211.50-209.25</td>
<td>7.5YR3/4, 7.5YR4/3 (AC lamellae); 10YR4/4 to 7.5YR4/4 (C interlamellae)</td>
<td>Sandy loam (AC lamellae); Loamy sand (C interlamellae)</td>
<td>Approximately six (6) interbedded sequences of well developed lamellae/inter-lamellae couplets dipping to the southwest.</td>
</tr>
<tr>
<td>Southwest Corner</td>
<td>AU-4</td>
<td>Fill</td>
<td>213.79-213.71</td>
<td>2.5Y3/2 with 10YR3/4, 10YR4/6 mottles</td>
<td>Loam to silt loam</td>
<td>Weak fine subangular blocky to platy, slightly sticky, slightly plastic, very friable, historic debris/fill, &lt;10% gravels, abrupt smooth lower boundary.</td>
</tr>
<tr>
<td></td>
<td>AU-3</td>
<td>Ap</td>
<td>213.71-213.50</td>
<td>2.5Y3/2 with 10YR3/4 mottles</td>
<td>Loam to silt loam</td>
<td>Weak fine subangular blocky to vertical platy, &lt;10% gravel, very friable, few faint mottles, abrupt smooth to wavy lower boundary.</td>
</tr>
<tr>
<td>Block/Corner</td>
<td>Allostratigraphic Unit</td>
<td>Horizon</td>
<td>Elevation m asl</td>
<td>Color</td>
<td>Field Texture</td>
<td>Notes</td>
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</tr>
<tr>
<td>Southwest Corner</td>
<td>Au-2a</td>
<td>Bw1</td>
<td>213.50-212.40</td>
<td>10YR3/2, 10YR3/3</td>
<td>Silt loam</td>
<td>Moderate subangular blocky, &lt;10% gravels, organic enriched (possible adsorbed AB), roots and root casts abundant, slightly sticky, slightly plastic, friable, distinct clay films on ped faces, clear smooth lower boundary.</td>
</tr>
<tr>
<td>AU-2a</td>
<td>Bw2</td>
<td>212.40-211.40</td>
<td>10YR3/4, 10YR3/6</td>
<td>Silt loam</td>
<td>Moderate subangular to angular blocky structure, &lt;10% gravels, slightly sticky friable, locally distinct clay films on ped faces.</td>
<td></td>
</tr>
<tr>
<td>AU-2b</td>
<td>BC</td>
<td>211.40-210.70⁰</td>
<td>10YR4/4</td>
<td>Loamy sand</td>
<td>Very weak moderate subangular blocky structure that weakens with depth as sand fraction increases, gradual smooth lower boundary.</td>
<td></td>
</tr>
<tr>
<td>AU-1</td>
<td>AC-C</td>
<td>210.70⁰-209.25</td>
<td>7.5YR3/4, 7.5YR4/3 (AC lamellae); 10YR4/4 to 7.5YR4/4 (C inter-lamellae)</td>
<td>Sandy loam (AC lamellae); Loamy sand (C inter-lamellae)</td>
<td>Partially degraded sequences, lamellae are thicker than inter-lamellae which are very loose sands; lamellae have a very weak subangular blocky structure.</td>
<td></td>
</tr>
</tbody>
</table>
**AU-2a and AU-2b**

As noted earlier, AU-1 was overlain by one of two soil-sediment packages. In the central and eastern portion of Area 2, a thick, moderately to well-developed B horizon was represented by Allostratigraphic Unit 2 (AU-2a) (Figure 2.40). The B horizon soils were classified as Bw (cambic B horizons) throughout, rather than Bw overlying Bt horizon as recorded in Area 3 South, although the soils had high clay content and moderate to strong, subangular, blocky structure. Coulter Counter analysis of the horizons from units in the northeast corner confirms that a significant proportion of these samples was composed of very fine silt and clays (phi sizes greater than 7; see Appendix E Area 2 Northeast Corner). The earliest date for the Bw horizon in AU-2a in Area 2, recovered from near its basal levels in the northern part of the block excavation, was 5600 ± 50 B.P. (Beta-176131) for Feature 488 at 212.05 m asl, supporting the modeled period of stability during the middle Atlantic climatic phase. Two radiocarbon assays at 5080 B.P. (Beta-188213 for Feature 470 at 213.04 m asl) and 5210 B.P. (Beta-190556 for Feature 478 at 212.18 m asl), separated by 80 cm of sediment within the BC horizon, argued for low magnitude, but frequent, overbanking events for the T3 terrace at this time.

The second facies, AU-2b, was approximately 1,500 years younger. It consisted of a series of AC-C couplets, sedimentologically analogous to those identified along the relict levee margin of the Back Channel in Area 1. The younger facies registered a separate and later landform with cyclic infilling characterized by repeated deposition of AC-C horizons, hence the appearance of younger radiocarbon determinations at nearly the same elevations as older dates (see Figure 2.38). The precise contact between the stacked AC-C horizons present in the southwest corner of the Area 2 excavation block was difficult to distinguish horizontally from the northeastern sandy and silty BC-Bw horizons of the AU-2a, although unit-specific textural and structural differences between horizons were clearly recognized as early as the base of the first meter. A radiocarbon date of 3450 ± 40 B.P. (Beta-188212 from Feature 465 at 212.92 m asl) was secured from this AU-2b stratum at approximately the same elevation as the 4940 ± 40 B.P. (Beta-176129) date on Feature 467 at 213.08 m asl present in the northern part of the block in a well-developed Bw horizon (AU-2a). The two landforms in the block extended to at least the top of the second meter of excavation, where the occupation, dating to ca. 3400 B.P. in the south and west, were at the same elevation as occupations dating to ca. 4900 B.P. in the north. The older landform was likely present in the first meter of excavation, where there was a distinct break in artifact distribution between the northeast corner and the remainder of the block (Miller and Marine 2005).

The AC-C lamellae that occurred immediately below the 3760 B.P. occupation on the southern landform (i.e., below 212.40 m asl) were not present in Trench 3-1 (Vento et al. 2001). Rather, soils here were designated as a Btx horizon, documenting prolonged stability of this portion of the terrace. Trench 3-1 was located approximately 33 m (104 ft) to the southwest of Area 2. The absence of the lamellae in this portion of the profile suggested that the swale or insetting of the terrace did not extend as far to the southwest as Trench 3-1 (Miller and Marine 2005; Schuelenrein et al. 2003; Vento et al. 2001).

Geomorphological observations in Area 2 indicated that a new incision of the oldest terrace initially undermined the T3 and initiated formation of the T2 on the western margin.
of the Site 36AL480 landform. Subsequent phases of vertical accretion (AU-2b and AU-3) and historic recontouring (AU-4) obscured the proximal edge of this newly recognized T2 margin, concealing it from topographic detection. The period of this geomorphic threshold—erosion of the T3 and the subsequent rapid and episodic aggradation—was approximately 4500-3000 B.P. As noted above, the casual mechanism for these events was a period of active lateral channel migration and/or channel avulsion during the warm and dry Sub Boreal climatic interval. This process allowed for erosion of the proximal edge of the T3 terrace, and the subsequent infilling of the erosional inset by a series of rapidly emplaced lamellae horizons. The T3 terrace riser was obscured during historic times, in response to grading and flood deposition.

**AU-3 and AU-4**

The AU-2 unit was overlain by a discontinuous, truncated plow zone horizon (Ap) designated AU-3. The Ap horizon yielded both historic and prehistoric artifacts. As elsewhere across the Leetsdale site, the surface package (AU-4) was comprised entirely of historic fill material. These historic fill deposits, in places, disconformably rested on a now-truncated A/Ap horizon, or in areas of deeper disturbance, a Bw horizon with some localized Bt development, as described in the field.

**Area 3 South Allostratigraphy and Pedostratigraphy**

As in Area 1, the initial task for excavation in Area 3 south entailed the removal of vegetation as well as the upper .61-.81 m (2-2.66 ft) of fill/soil that may have been contaminated with lead. The stripped and mechanically removed fill/soil was confined on site and sealed in place with a .2 mm plastic liner. Following removal of the contaminated soil, hand excavation in 1-x-1-m units was undertaken in a 200 m2 block. After the 200 m2 block was excavated to a depth of 1 m (3.3 ft), selected 1-x-1-m test units on the 5-m grid were excavated to an additional depth of 1 m (3.3 ft; Figures 2.41 and 2.42).

During the course of the archaeological investigations in Area 3 South, a total of 37,156 artifacts were recovered along with 84 prehistoric features. The features ranged in age from terminal Middle Archaic to Early Woodland as identified by archaeologists from Tetra Tech, Inc. and Michael Baker, Inc. (Anderson et al. 2005, 2010). Of the 84 features identified, 40 are of Early Woodland age, 14 are of Transitional Archaic age, 17 are of Late Archaic age, 11 are of early Late Archaic age, and two are of later Middle Archaic age (Anderson et al. 2005:xxii). The majority of the dated features were consistent with the observed stratigraphy.

Furthermore, eight generations of soil development grouped into four allostratigraphic units were recognized in the excavation and analysis of the subsurface strata (Table 2.13). Figure 2.43 illustrates an east-west view of the Area 3 South horizons as observed. Figures 2.44 and 2.45 depict the granulometry analyses for the column samples in Area 3 South (see also Appendix E).
Table 2.13 Summary of Area 3 South Stratigraphy.

<table>
<thead>
<tr>
<th>Block/Corner</th>
<th>Allostratigraphic Unit</th>
<th>Horizon</th>
<th>Elevation m asl</th>
<th>Color</th>
<th>Texture</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center</td>
<td>AU-4</td>
<td>Fill</td>
<td>216.00</td>
<td>n/a</td>
<td>n/a</td>
<td>Lead-contaminated historic and modern fills. Stripped and segregated 0.61 m from surface during Task 1.</td>
</tr>
<tr>
<td>AU-3</td>
<td>Ap</td>
<td>215.25-215.14</td>
<td>7.5YR3/4 to 7.5YR3/2</td>
<td>Silt loam to loam</td>
<td>Massive structure; frequent dispersed charcoal; Late Woodland.</td>
<td></td>
</tr>
<tr>
<td>AU-3</td>
<td>AB</td>
<td>215.14-214.83</td>
<td>7.5YR4/3-4/4 to 7.5YR3/4</td>
<td>Silt loam</td>
<td>F14 on the west, F9 on the east</td>
<td></td>
</tr>
<tr>
<td>AU-3</td>
<td>C</td>
<td>214.83-214.74</td>
<td>7.5YR4/4</td>
<td>Sandy loam</td>
<td>Massive structure; thickest on the west; possible flood event.</td>
<td></td>
</tr>
<tr>
<td>AU-3</td>
<td>3Ab1</td>
<td>214.60-214.45</td>
<td>7.5YR3/3</td>
<td>Sandy loam</td>
<td>Probably Late Archaic midden; discontinuous across Area 3.</td>
<td></td>
</tr>
<tr>
<td>AU-3</td>
<td>3Ab2</td>
<td>214.55-214.30</td>
<td>7.5YR3/3-7.5YR3/4 to 7.5YR4/4</td>
<td>Silt loam to sandy loam</td>
<td>Weak soil development.</td>
<td></td>
</tr>
<tr>
<td>AU-2</td>
<td>3Bw</td>
<td>214.30-213.60</td>
<td>10YR4/4</td>
<td>Silt loam</td>
<td>Moderate soil development; secondary clays visible; possible terminal Middle Archaic or early Late Archaic.</td>
<td></td>
</tr>
<tr>
<td>AU-2</td>
<td>4Bw</td>
<td>213.60-213.35</td>
<td>10YR4/4</td>
<td>Silt loam</td>
<td>Strong soil development; prevalent secondary clays.</td>
<td></td>
</tr>
<tr>
<td>AU-2</td>
<td>5Bw</td>
<td>213.35-212.45</td>
<td>10YR4/4</td>
<td>Silt loam to fine sandy loam</td>
<td>Weakened soil development in SE corner; thickened profile to N and E.</td>
<td></td>
</tr>
<tr>
<td>Block/ Corner</td>
<td>Allostratigraphic Unit</td>
<td>Horizon</td>
<td>Elevation m asl</td>
<td>Color</td>
<td>Texture</td>
<td>Notes</td>
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</tr>
<tr>
<td>AU-2</td>
<td>5BC</td>
<td>212.45- 212.25</td>
<td>10YR4/4 to 10YR5/4-5/6</td>
<td>Fine sandy loam to loamy sand</td>
<td>Weakly developed.</td>
<td></td>
</tr>
<tr>
<td>AU-1</td>
<td>6AC</td>
<td>212.25 - 211.85</td>
<td>7.5YR3/4 to 10YR3/4 (AC lamellae); 10YR4/6 (C inter-lamellae)</td>
<td>Fine to medium sandy loam</td>
<td>Stacked incipient A and C horizons sloping and thickening to the east.</td>
<td></td>
</tr>
<tr>
<td>AU-1</td>
<td>6BC</td>
<td>211.85- 211.75</td>
<td>10YR4/4, 10YR4/6</td>
<td>Loamy fine to medium sand</td>
<td>Thin to the west, thickened between N233-234, pinching to the east; possible single flood event.</td>
<td></td>
</tr>
<tr>
<td>AU-1</td>
<td>7AC</td>
<td>211.80- 211.50</td>
<td>7.5YR3/4 to 10YR3/4 (AC lamellae); 10YR4/6 (C lamellae)</td>
<td>Loamy sand</td>
<td>Stacked incipient A and C horizons sloping and thickening to the east.</td>
<td></td>
</tr>
<tr>
<td>AU-1</td>
<td>7CB</td>
<td>210.70*</td>
<td>10YR3/6</td>
<td>Silt loam</td>
<td>Variable structure; numerous silt and sand lenses.</td>
<td></td>
</tr>
<tr>
<td>AU-1</td>
<td>8AC</td>
<td>207.25*</td>
<td>7.5YR3/4 to 10YR3/4</td>
<td>Loamy sands</td>
<td>Stacked incipient A and C horizons to basal gravels at 8.0 m below datum.</td>
<td></td>
</tr>
</tbody>
</table>
Four allostratigraphic packages were identified in Area 3 South. AU-1 was variously observed to depths of greater than 4 m. It was dominated by two sets of deposits: 1) couplets of coarse and medium sands capped by a discrete iron and organically mineralized horizon; and 2) deep, 0.3 m (0.98 ft) thick stratified sands with diffuse organics. The stratigraphy was described as featuring weakly developed incipient A horizons with associated BC and CB horizons (e.g., 6AC-6BC; 7AC-7CB). Channel lag deposits, of probable late Wisconsin age, were contained in the lowest exposed meter (8AC, 8C). An isolated flake was identified at the approximate level of horizon 8AC (Anderson et al. 2010:8-59). The 8C horizon may have corresponded with the Younger Dryas (11,000 B.P.-10,000 B.P.).

In all likelihood, most of the upper part of AU-1 (6AC-6BC; 7AC-7CB) was emplaced during the Pre-Boreal/Boreal climate intervals (10,000 B.P.-8000 B.P.). As noted above, the weakly developed sola, present in the upper part of AU-1, essentially consisted of incipient weathered A/AC horizons, overlain by variably thick C horizons that fine upward. The A/AC horizons, associated with each of these now deeply buried sola, document episodes of short-lived subaerial weathering interrupted by moderate to large magnitude flood events and emplacement of the C horizon sands. During deposition of these sands, the aggrading surface of the T3 terrace was probably only two to three meters above the thalweg of river during the early Holocene. While no cultural features and only a single flake were found in association with AU-1 (from the 8AC horizon recovered during mechanical excavation in the center of the block [Anderson 2010:8-56]), its stratigraphic position relative to other dated horizons (including the exposed soils at the base of the Casting Basin excavation), and mapped soils in adjacent areas of the terrace, an age of 11,500 B.P. (base of unit) to 6500 B.P. was inferred. This estimate was based upon the AU-1 stratigraphic position above the dated late Wisconsinan age sands and gravels and the occurrence of a late Middle Archaic Chesser Notched projectile point from the overlying 4Bw horizon (Anderson et al. 2010).

The lower two meters (6.6 ft) of the excavation block consisted of finer lamellar bands indicative of suspended load deposition. These cover redoximorphic silts, sands, clays, and organic peats that unconformably rested on relict channel and lag gravels of probable late Wisconsin age (ca. 40,000-14,000 B.P.). At a depth of approximately 209.75 m asl, a basal buried A horizon was encountered and designated 8AC. The 8AC horizon documented a short episode of terrace stability during the early Holocene. The occurrence of root rhizomes and a strong pollen sequence were indicative of Boreal climatic conditions during the early Holocene (9200 B.P. to 8000 B.P.; Jones 2006).

The deepest four meters, exposed by mechanical excavation, represented the channel and near channel environment of the early to late middle Holocene period. Numerous radiocarbon determinations (Vento et al. 2001:38) bracketed this interval to ca. 11,000-6500 B.P. for the duration of AU-1, which was coeval with the emergence of the early Holocene channel. While a single lithic flake was identified in the deeper AU-1 deposits, more prominent evidence for cultural activity was recognized in the upper meter of AU-1 in Trench 3-2 during the initial geomorphological work (Vento et al. 2001). Features 6, 7, and 9 were classified at that time, and overlying deposits were dated to the interval 6740-6620
B.P. This suggested Middle, and probably Early Archaic, occupations on the relict levee/point bars that were forming during the early stages of Ohio River floodplain development, when the channel form shifted from a braided to meandering habit. Such coarse basal deposits were indicative of a stream with a braiding aspect that eventually gave way to a meandering regime, as stream velocities slowed and point bars began to characterize the architecture of a progressively stabilizing floodplain. The point bars developed during the early Holocene (perhaps slightly earlier), as the loci of deposition became the convex side of a critical curve in the newly emerging channel environment of the Ohio River at what was Site 36AL480 (see discussion and figure in Section 2.8).

**AU-2**

The allostratigraphic unit identified in Area 3 South was associated with the older AU-2 component. AU-2 consisted of a package of three distinct soil generations 3Bw-4Bw-5Bw, although the geomorphology team noted argillic (Bt) development in places across the second meter of excavation in Area 3 South. A distinct increase in finer fraction particles was noted from the Area 3 South samples (Figures 2.44 and Figure 2.45). Culturally, these stacked sola ranged in age from Late Archaic to late Middle Archaic. Each of these soil generations documented periods of relative terrace stability and subsequent A and B horizon development, interrupted then by periods of increased rates of sediment deposition, in most cases by low-magnitude overbank deposition. The cumulic A horizons (e.g., 3Ab1 and 3Ab2) corresponded with warmer and moist intervals of the Atlantic climatic phase.

Only a single, untyped, expanding stem projectile point, 29 pieces of debitage, and six groundstone artifacts were recovered from the deeper 4Bw soil. In addition, two cultural features were defined in the 4Bw horizon, but were not submitted for 14C assays by the archaeologists. The basal generation unit was the 5Bw-5BC, but no artifacts or prehistoric cultural features were recorded for these horizons, perhaps due to the limited number of units excavated at this depth (per safety requirements within the block). The fine-grained texture, evidence of greater stability, and deeper weathering of the soils was in marked contrast to the lamellar sands deposited as the upper part of AU-1. This occurrence suggested a change from higher flow velocities and more rapid vertical accretion associated with AU-1, to lower rates of vertical accretion and in situ soil pedogenesis for AU-2.

The boundary between AU-2 and lower AU-3 was problematic, largely because it remained difficult to separate the B horizons for soil generations 3, 4, and 5. One interpretation favored separation of three cambic subsoils (3Bw-4Bw-5Bw). A second interpretation recognized 3Bw as the base of the succession of Inceptisols, thereby marking the unconformable surface of the underlying vertical accretion of deposits and soils that built up the T3 terrace. Assuming that horizon 3Bw formed the base of AU-3, the total thickness of AU-2 is 1.6 m (5.25 ft).

Archaeologically, AU-2 was dominated by an artifact-rich stratum (designated F13; Anderson et al. 2005) in Area 3 South, which extended through horizon 5Bw. The underlying 5BC horizon (corresponding to F167; Anderson et al. 2005) was devoid of cultural materials. Excavations of the 4Bw-5Bw retrieved a Brewerton point, suggestive of a lower Late Archaic or terminal Middle Archaic occupation, ca. 5000 B.P. This timeframe
was consistent with the Area 3 South bulk radiocarbon date of 5340 ± 40 B.P. (Beta-15914) taken from the Bw complex.

The depth of sediment, its age, and the well-developed character of the soils formed on the parent materials (as many as three distinct types), were indicative of long, sustained aggradation of the T3 landform. No distinct flooding evidence was observed in AU-2a soils, verifying the slow, continuous vertical accretion depositional regime, as well as sustained soil formation. The soil horizons all exhibited a developmental structure with depth, proceeding from strong subangular to prismatic structure, with continuous to discontinuous silt skins on ped surfaces. The horizons had high bulk densities, as determined by field penetrometer readings, and were classified as a silt loam based on field observation of texture.

Although laboratory analyses on grain size and biogeochemistry was performed on these horizons (see below for further detail, along with Appendices E and F), questions remained as to whether or not several generations of cambic (Bw) soils or a deeper more prominent argillic (Bt) soil was characteristic. In the former case, the A horizon which should be associated with the 4Bw and 5Bw horizons would have been leached and weathered with minerals illuviated into the developing profile. To support the latter case, a weak 4AB horizon was identified in portions of the site, overlying the Bw/Bt horizon. Locally within Area 3 South, the Bt candidate also had, in places, a brittle consistence and weak, bleached cracks in profile, indicating an incipient fragic (Btx) horizon; this was seen elsewhere on site (Schuldenrein et al. 2003; Vento et al. 2001). In any case, there was strong evidence of extended weathering and stabilized surfaces. The 5Bw horizon was underlain by a variably thick silt loam to fine, sandy loam BC horizon, which thickened toward the east. The soils were formed on fine sandy to dominantly silty alluvium and the sequence was dated to 6500-3000 B.P.

AU-3

Regarding the AU-3 package, reference is made here to the uppermost 1.9 m (6.2 ft) of soils and sediment beneath the fill. Identified archaeological horizons were preserved in stratigraphic order. These spanned the timeframes of the Early Woodland, Transitional Archaic, and later Late Archaic prehistoric periods. In general, these archaeological horizons were preserved in a series of short-term Inceptisols or Entisols that began accumulating above the eroded 3Bw horizon. The soils formed on fine-grained alluvium that accumulated between ca. 3000 B.P. and 500 B.P. The thickness and pervasiveness of the AC-C couplets across Area 1, together with the depth of the late Holocene overbank silts along the convexity of the T3 landform, accounted for the differentiation of AU-3 as an allostratigraphic unit of site wide proportions.

The AB horizon was the highest near-continuous soil horizon present across the site. It was a silt loam to fine sandy loam and attains a nominal thickness of 25 cm. The horizon contained an Early Woodland component that was perhaps intrusive into Transitional Archaic period deposits. The AB occurred in similar sedimentary matrices, and may be laterally separable archaeologically. A total of 23 projectile points, 39 bifaces, 3,542 pieces of debitage, 568 ceramics, and 40 prehistoric features were identified in the AB horizon from
across the excavation block. The top of the horizon was dated by Feature 243 at 1760 ± 60 B.P. (Beta-182458), while the bottom of the horizon is was dated from Feature 166 at 2890 ± 40 B.P. (Beta-159894).

The AB horizon was conformably underlain by a variable package of loamy sand to sand C horizon. The C horizon varied from five to 30 cm in thickness, increasing in thickness to the northeast, or in the direction of the active river channel. It was probable that the C horizon represented an episodic (autogenic) flood event that deposited overbank sediment from the Ohio River during a regionally based cyclonic flood event. Finer grained sediment to the west suggested lower flow velocities away from the levee (along the Back Channel) and active river channel. There was no archaeological material associated with C horizon, and the AB-C horizons corresponded with the Sub-Atlantic climatic phase (ca. 3000 B.P.-2000 B.P.) – a brief period of relative stability on the terrace during a phase of warm and moist climatic conditions.

Transitional Archaic period remains were contained within a weak sandy loam (2BC horizon) approximately 25 cm thick. The 2BC horizon exhibited a strong weak subangular blocky structure. Transitional Archaic period artifacts were principally concentrated in the upper and lower 2BC horizon. Climatic conditions during accumulation of the parent sediment would have been warm and dry with less effective precipitation. The warm and dry conditions would have favored more frequent flooding, due to a decreased vegetative cover. During this time, and slightly before (ca. 4500 B.P.), the basin was significantly affected by meridional circulation and the penetration of large storms from the Gulf of Mexico. This 2BC horizon corresponded with the Sub-Boreal climatic phase (ca. 4500-3000 B.P.).

Late Archaic period features were preserved in the solum of the 3Ab1-3Ab2-3Bw succession. The organic-rich incipient A horizons and underlying Bw were the earliest of the Inceptisols and followed a period of protracted soil development. More sustained flooding was implicated by the warm and moist conditions of the Atlantic climatic phase that dated to ca. 4500 B.P., but may have begun a millennium earlier. The 3Ab1 and 3Ab2 horizons yielded a low number of prehistoric artifacts. For example, only 216 pieces of debitage and two diagnostic projectile points were recovered during excavation of the horizons across the area. While the artifact inventory was low, a surprisingly high number (n=16) of prehistoric cultural features was identified, including three features from the 3Ab1 horizon and 13 features from the 3Ab2 horizons.

Five radiocarbon assays from these horizons were very similar and suggested a nominal age for the 3Ab soil horizon at 3780 ± 40 B.P. (Beta-182454). Unlike the 3Ab horizon soils, the underlying subsoil horizon (3Bw) yielded 3,526 pieces of debitage, 12 bifaces, five projectile points, and 10 prehistoric cultural features. One prehistoric feature from the 3Bw horizon gave a date of 4730 ± 40 B.P. (Beta-176121). This date correlated with the recovered Bottleneck and Brewerton side-notched projectile points, which are associated with the early Late Archaic period Laurentian Tradition. The 3Bw horizon reflected an episode of long-term surface stability with slow, but continuous, vertical accretion of the terrace. The 3Bw horizon was consistently underlain by a 4Bw soil package that marked the top of AU-2.
The uppermost meter of sediment in Area 3 South consisted of a now-truncated Ap plow zone horizon and historic fill (AU-4). The sediment included prehistoric artifacts from formerly intact Middle and Late Woodland (ca. 500 B.C. - A.D. 1600) contexts and historic fill. The fill was removed by grading prior to formal excavation, and was the most dominant sediment across the site. In some locations, historic fills were interdigitated with a series of short-term flood deposits, which may represent up to 500 years of irregular deposition and generally episodic, high-energy, discharge events. Lack of sustained sedimentation was a function of the high elevation of the T3 terrace, which was rarely overtopped by flooding activity.

Evidence for pockets of Middle to Late Woodland occupation on higher T3 surfaces was demonstrated during Phase I excavations that identified a Middle Woodland component in the vicinity of BHE-1 (see Figure 2.3). Similar loci may have been preserved on lower elevations, or distal locations, on the T3 terrace. This 1,000-year interval was characterized by the cool and wet period of the Scandic climatic phase (ca. 2000 B.P.-1500 B.P.). Vertical accretion of the T3 would have been somewhat rapid. In places, there was evidence for a thicker cumulic A horizon, attesting to meta-stable conditions during the Neo-Atlantic climatic phase (ca. 750 B.P.-200 B.P.). In some lower-lying areas, the A horizon might have been buried by a package of weak B and C horizons that may correspond with the cool and wet periods of the Pacific climatic phase (ca. 1000 B.P.-750 B.P.). Where lower boundaries of non-fill sediments were preserved, they were conformably underlain by the early Woodland AB horizon. The upper 1 m of sediment on the T2 terrace was probably laid down during the last 1,000 years, as well.

**Block 6 (Phase II)**

Geomorphologically, the soil stratigraphy encountered in Blocks 1-5 was consistent with the deep profiles encountered in Area 1. For the deep exposure of Block 6, the closest correlation occurred with the southwestern part of Area 2 (Table 2.14). Of the soil horizons observed in the blocks, the upper truncated Bw horizon present in Block 2 and Block 6 was of probable late Holocene age (younger than 3000 B.P.), likely emplaced during the cool and moist conditions of the Scandic climatic phase (2000 B.P.-1500 B.P.). Such a cambic horizon documented deep in situ weathering with fine-grained, slow continuous aggradation of the T3 terrace by generally low magnitude flood events from the Ohio River. Unfortunately, the overlying younger soils were absent in this area due to historic grading and filling activities, thus limiting our reconstruction for sediment deposition on the eastern margin of the T3 terrace during late Holocene times.
Table 2.14 Summary of Site 36AL480 Phase II Block 6 Stratigraphy.

<table>
<thead>
<tr>
<th>Soil Horizon</th>
<th>Elevation (m asl)</th>
<th>Color</th>
<th>Texture</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bw</td>
<td>AU-2 214.62-213.50</td>
<td>10YR4/4, 10YR4/6</td>
<td>Loam to silt loam</td>
<td>Coarse subangular blocky structure, sticky, plastic, firm, some clay films on ped faces and pores, abrupt wavy to irregular lower boundary.</td>
</tr>
<tr>
<td>AC-bifurcates below C horizon</td>
<td>AU-1 213.50-213.20</td>
<td>7.5YR4/4, 7.5YR4/6</td>
<td>Sandy loam to silt loam</td>
<td>Weak, fine subangular blocky structure, slightly sticky to slightly plastic, friable, faint infrequent clay skins, abrupt wavy lower boundary.</td>
</tr>
<tr>
<td>C</td>
<td>AU-1 213.30-213.00</td>
<td>10YR5/4, 10YR5/6</td>
<td>Sand</td>
<td>Massive, abundant heavy minerals, abrupt wavy to irregular lower boundary.</td>
</tr>
<tr>
<td>AC-C</td>
<td>AU-1 213.00-212.20</td>
<td>7.5YR4/4, 10YR4/6 with 10YR5/4, 10YR5/6</td>
<td>Sand to silt loam</td>
<td>Bifurcating AC lamellae which are slightly plastic, slightly sticky, between very friable sandy inter-lamellae, abrupt wavy boundaries between lamellae.</td>
</tr>
<tr>
<td>C</td>
<td>AU-1 212.20-211.70</td>
<td>10YR5/4</td>
<td>Fine to medium sand</td>
<td>Massive, abundant heavy minerals, abrupt wavy to irregular lower boundary.</td>
</tr>
<tr>
<td>AC-C</td>
<td>AU-1 211.70-210.37</td>
<td>10YR4/4 (AC lamellae); 10YR4/6 (C inter-lamellae)</td>
<td>Sand to sandy loam to silt loam</td>
<td>Eight (8) couplets, each appx. 5 cm thick, lamellae are slightly sticky, slightly plastic, abrupt wavy lower boundaries.</td>
</tr>
<tr>
<td>AC-Cg</td>
<td>AU-1 210.37-209.36</td>
<td>10YR3/4, 10YR5/8 (sands) and gley 4 4/1 and 2.5 5BG</td>
<td>Sandy loam to sand overlying gleyed sandy clay</td>
<td>Three (3) sequences of oxidized sands above gleyed and mottled sandy clay; massive gleyed and mottled, sticky, plastic, firm, abrupt wavy lower boundary.</td>
</tr>
<tr>
<td>AC-Cg</td>
<td>AU-1 209.36-207.40</td>
<td>10YR3/4, 10YR5/8 (sands) and gley 4 4/1 and 2.5 5BG</td>
<td>Sandy loam to sand overlying gleyed sandy clay</td>
<td>Similar sequence as above, but limited observation because of hand auger excavation.</td>
</tr>
<tr>
<td>C</td>
<td>AU-1 207.40-207.36</td>
<td>n/a</td>
<td>Gravels</td>
<td>Gravels at base of bucket auger.</td>
</tr>
</tbody>
</table>
The Bw horizon, when present, would then be underlain by a thick package of lamellar sands. These lamellar zones contained incipient A horizons being overlain and underlain by variably thick C horizon sands. Such C horizons documented single autogenic flood events. Subsequent weathering (redox of iron) and organic matter additions to the uppermost part of these C horizon flood sands effectively formed the incipient A horizon. The lamellar sands typically dated to the Transitional Archaic (4200-3000 B.P.) and documented rapid sediment accumulation during the warm and dry Sub-Boreal climatic phase on the eastern margin of the terrace adjacent to the relict Back Channel. In all likelihood, these lamellar sands, which slope to the east, in most cases reflected overbank deposition to the terrace from the relict Back Channel (levee building), rather than the main stem of the Ohio River. In Blocks 1-5, excavation was generally terminated within or immediately below these lamellar sands in the weakly developed BC horizon of probable late middle Holocene age.

In Block 6, the lamellar sands extended to a depth of five to six meters below ground surface (Figure 2.46 and Figure 2.47). It appeared that, through the late middle Holocene (until 4500 B.P.), the eastern margin of the T3 terrace was receiving relatively frequent, moderate to high magnitude flood events. This occurrence may be due in part to its proximal position adjacent to the Back Channel.

**Casting Basin**

The archaeological and geomorphological examination of the Casting Basin was undertaken by archaeological personnel from Tetra Tech, Inc. and Michael Baker Engineers, and Dr. Frank J. Vento of Clarion University. The objective of the Casting Basin study was to gain stratigraphic data and assess the cultural potential of soils lying directly above the coarse-grained lateral accretion deposits which are of late Wisconsin age (Figure 2.48; Table 2.15).

The field work entailed the excavation of a 2-x-6-m block trench. The top of the trench was situated at 210.06 m asl, with the base of the trench occurring at 208.03 m asl. The trench excavation was terminated at the top of relict late Wisconsin age channel lag. A second 1-x-2-m deep test unit was subsequently excavated at grid units N186.42 E82.64 to N185.12 E81.10. The deep test unit was also excavated to the top of relict channel lag deposits. In both the 2-x-6-m block trench and the 1-x-2-m deep test unit, relict channel lag deposits were encountered at a nominal elevation of 207 m asl.

The channel lag deposits were then overlain by a two-meter-thick package of alternating incipient loam sand to sandy loam A horizons interbedded with fine to medium, loamy sand to sandy C horizons. Within this two-meter package, no less than 11 distinct AC-C couplets were identified. These couplets were likely emplaced along an aggrading point bar lying less than one to two meters above the active river channel. In all cases, the horizons exhibited a gentle dip to the west. Radiocarbon dates from the Casting Basin proper, as well as from earlier backhoe trench excavations, place the age of the basal channel lag deposits at 13,000-11,000 B.P., and essentially fall within the Bølling-Allerød (warm period) and the cold and dry phase of the following Younger Dryas (11,000 B.P.-10,000
The overlying AC-C couplets document initial stabilization of the Ohio River channel from a braided to meandering channel habit with the onset of the Holocene at 10,000 B.P. No artifacts were recovered from the Casting Basin excavations; however, the organic rich gleyed horizons and associated radiocarbon dates provide important palynological information with regard to late Wisconsin and early Holocene paleoenvironments.

Table 2.15 Summary of Stratigraphy from Site 36AL480 Casting Basin (all AU-1).

<table>
<thead>
<tr>
<th>Soil Horizon</th>
<th>Field Unit</th>
<th>Elevation (m asl)</th>
<th>Color</th>
<th>Texture</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>20C-27A</td>
<td>I</td>
<td>209.84-209.80</td>
<td>10YR4/4 or 7.5YR4/3</td>
<td>A: sandy silt</td>
<td>Stacked incipient A and C horizons; lamellar sands.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>C: massive medium to coarse sand</td>
<td></td>
</tr>
<tr>
<td>27C</td>
<td>II</td>
<td>209.22-208.76</td>
<td>10YR4/6</td>
<td>Massive sand</td>
<td>Manganese stained.</td>
</tr>
<tr>
<td>28A</td>
<td>III</td>
<td>208.86-208.68</td>
<td>n/a</td>
<td>Silty clay</td>
<td></td>
</tr>
<tr>
<td>28C</td>
<td>IV</td>
<td>208.62</td>
<td>n/a</td>
<td>Massive sand</td>
<td></td>
</tr>
<tr>
<td>29A-31A</td>
<td>V</td>
<td>208.40-208.32</td>
<td>n/a</td>
<td>Clay-silt</td>
<td></td>
</tr>
<tr>
<td>31Cg</td>
<td>VI</td>
<td>208.22-208.06</td>
<td>&quot;olive brown&quot;</td>
<td>Medium to coarse sands</td>
<td>Thin interbedded lenses of peat.</td>
</tr>
<tr>
<td>Below 31Cg</td>
<td>VII</td>
<td>208.02-207.92</td>
<td>&quot;grey&quot;</td>
<td>Gleyed silt and clay</td>
<td>Fine sands present; two horizons of peat resting above channel lag.</td>
</tr>
</tbody>
</table>

Three samples from the Casting Basin were examined for pollen (Figure 2.49). The lowermost sample collected came from 207.87 m asl, while the remaining two samples were collected at 208.03 and 208.30 m asl. The samples were gathered from organic-rich sands, likely emplaced in a sand bar-back slough environment adjacent to the active river channel. Each of the samples contained an abundance of nearly perfectly preserved pollen grains. Significant quantities of Pennsylvanian age palynomorphs (see Jones 2006) were also present, and suggested that the organic fraction was potentially contaminated with old carbon. Phytolith sampling was unproductive at this location.

The sample at 207.87 m yielded a date of 36,270 B.P. (Beta-176078), while the samples at 208.03 m and 208.30 m yielded dates of 7080 B.P. (Beta-171920) and 5870 B.P. (Beta-176077) respectively. While the date of 36,270 B.P. likely represented organics reworked from older deposits and subsequently redeposited, the material above 208 m asl contained a pollen assemblage dominated by grass, ragweed, birch, hickory, oak, and beech. Interestingly, pine, spruce, and eastern hemlock were wholly lacking in this specimen. This older and deeper sample (at 207.87 m as); also contained a unique and unexpected assemblage with high concentrations of heath, possibly blueberry, or mountain laurel, and
basswood. There was more birch and grass pollen in this deep sample than within the 208 m asl samples (Jones 2006).

Pollen from the two remaining and younger samples was remarkably similar to the local environment with high counts of oak, elm, hemlock, beech, and hickory. The occurrence of ragweed (likely indicating clearing and cultivation) and sedges was suggestive of a riverine, rather than a marshy, setting, and likely indicates deposition along an open, swaled, point bar adjacent to the active river channel.

The pollen record from the base of the Casting Basin profile was consistent with Boreal vegetation assemblages dated to 9000 B.P. or later, although the presence of heath vegetation was unique. The earliest reliable determinations from the site occurred at an elevation of 208.20 m asl and produced a date of 11,380 ± 90 B.P. (Beta-138053) from the lower lamellar sands within AU-1 (Vento et al. 2001:38). This provenience and the determination were consistent with observations that the vegetation recorded within the Casting Basin dates to the Pleistocene/Holocene interface. However, the absence of pine, fir, and spruce pollen throughout the sampled area underscored the need for recovering a detailed biostratigraphic record from this region (Jones 2006).

**Back Channel**

The Back Channel zone, which lies north and east of Area 1 and Phase II Blocks 1-5, was initially investigated because it was situated within the proposed alignment of the Site 36AL480 roadway corridor (see Figures 1.3, 2.2, and 2.5). During the field studies, it was obvious that the Back Channel was a hydric soil, situated only 4-5 m (13.5-16.5 ft) above the Ohio River. There was historic evidence from early maps (ca. 1795) that showed a stream flowing in this relict Back Channel. Given the size of the valley in relation to the size of the small tributary, it was obvious that the stream is misfit and had inherited the Back Channel zone.

During the study by Christine Davis, Inc. (Davis 2000), four deep backhoe trench soundings (designated Transect 7) and several auger probes were excavated along the “footprint” of the narrow roadway corridor. All of the trenches exhibited rather weakly developed profiles (Inceptisols) with strong hydric soil characteristics. Trench 7-1 was emplaced in the Back Channel to determine the approximate time when it was abandoned by the Ohio River, and subsequently inherited by the unnamed tributary (Schuldenrein et al. 2003). Trench 7-1 was located about 46 m (150 ft) due east of Trench 5-3 at a nominal elevation of 210 m (690 ft) above mean sea level.

The soil stratigraphy encountered in Trench 7-1 consisted of a 30-cm-thick, dark brownish black, silt loam A horizon, which was in turn underlain by a 25-cm-thick silt loam to clay loam Bg horizon, which exhibited a strong gray color and abundant mottles in its lower part. The Bg horizon was then underlain by a 60-cm-thick organic rich gray clay 2A horizon. A 14C sample from the 2A horizon yielded a date of 3570 ± 70 B.P. (Beta-141381), which fell close to the AU-2/AU-3 interface. The 2A horizon was then underlain by coarse-grained (cobbly sands) relict lateral accretion deposits. The 2A horizon documented that the Back Channel was abandoned prior to 3,600 B.P., and accompanied by subsequent infilling.
of the channel by the unnamed tributary, as well as back flooding from the Ohio River. After its abandonment, the Back Channel continued to serve as a pathway or outlet for flood waters throughout the late middle to late Holocene, and as a resource-rich wetland ecotone that would have been attractive to the prehistoric occupants of the site. The well-developed lamellar sands, which were encountered in Phase II Blocks 1-5 as well as in Area 1 (AU-2b) on a relict levee, were probably emplaced by overbanking events associated with the Back Channel than by the Ohio River. The absence of these lamellar sands in Area 2 (eastern margin) and Area 3 South situated to the south and west of Area 1 further supported emplacement of these sands by the Back Channel during high magnitude flood events.

As discussed above, the second geomorphologic study of the Back Channel in 2002 sampled four deep backhoe trench soundings (BHT-1, BHT-2, BHT-3, and BHT-4) situated south of Trench 7-1 (see Figure 2.3). The soil stratigraphy encountered in each of these was consistent with the stratigraphic profiles described above for Trench 7-1 (Table 2.16). Phytolith, pollen, and 14C samples were collected from each of the trench units.

BHT-3 yielded radiocarbon dates from 170 cm, 205 cm, and 230 cm below ground surface. All samples were gathered from dispersed charcoal/carbon and organics in the thick, gray brown to gray 2Bw horizon (Figure 2.50, 2.51, and 2.52). The dates ranged from 6570 ± 40 (Beta-176074) to 4580 ± 40 B.P. (Beta-176076). The date of 6570 B.P. was problematic given that it occurred 55 cm above the 4580 B.P. date and, hence, could not be considered a reliable determination.

The results of the pollen and phytolith studies (Jones 2006) underscored dominance of an oak, hickory and beech forest zone for the back channel over 5,000 years (Figure 2.53 and Appendix T). The rise in grass pollen may signify desiccation consistent with warm and dry conditions of the Sub-Boreal climatic phase (4500-3000 B.P.).

**Anthropogenic Components**

In addition to the interpretation of soil development and depositional histories at Site 36AL480, anthropogenic inputs to the soils and sediments of Site 36AL480 were observed through the analysis of four complementary data sets, including: integrated biogeochemical comparison; feature geochemistry examination; phosphate fractionation results; and micromorphological interpretations. As specified in the Contractor Proposal (Greenhorne & O’Mara 2000:A-2), this integrated analytical program contributes new understanding to the general site formation processes active at Site 36AL480 and the unique geochemistry of occupation fills and features. These results and relevant data tables or figures are discussed below.
<table>
<thead>
<tr>
<th>Trench</th>
<th>Soil Horizon</th>
<th>Depth below surface (m)</th>
<th>Color</th>
<th>Texture</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>0-0.30</td>
<td>10YR4/3</td>
<td>Silt Loam</td>
<td>Weak, very fine, subangular blocky</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>0.30-0.47</td>
<td>10YR4/3</td>
<td>Sand to sandy loam</td>
<td>Massive, with laminar banding</td>
</tr>
<tr>
<td></td>
<td>2Ab</td>
<td>0.47-0.67</td>
<td>7.5YR4/6</td>
<td>Silt loam</td>
<td>Weak, fine subangular blocky; end of root zone; 4/N mottles (~20%)</td>
</tr>
<tr>
<td></td>
<td>2BC</td>
<td>0.67-1.00</td>
<td>7.5YR4/4</td>
<td>Loamy sand to silt loam</td>
<td>Weak, fine, subangular blocky; redox and Mn staining</td>
</tr>
<tr>
<td></td>
<td>2C1</td>
<td>1.00-1.40</td>
<td>7.5YR4/4, 7.5YR 4/6</td>
<td>Sandy loam</td>
<td>Massive; laminar bedding with redox staining on ped faces</td>
</tr>
<tr>
<td></td>
<td>2C2</td>
<td>1.40-2.20</td>
<td>7.5YR4/4, 7.5YR 4/6</td>
<td>Loamy sand</td>
<td>Massive, laminar bedding; sandier with depth</td>
</tr>
<tr>
<td></td>
<td>3Cg</td>
<td>2.20-3.00</td>
<td>5/N to 4/N</td>
<td>Sand to loamy sand</td>
<td>Water table encountered at ~290 below surface</td>
</tr>
<tr>
<td>3</td>
<td>A</td>
<td>0-0.30</td>
<td>10YR3/3</td>
<td>Sandy loam</td>
<td>Massive, soft, very friable</td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>0.25-0.27</td>
<td>10YR4/6</td>
<td>Sand to loamy sand</td>
<td>Distinct redox band</td>
</tr>
<tr>
<td></td>
<td>2Bw</td>
<td>0.27-1.65</td>
<td>7.5YR4/3, 7.5YR4/4</td>
<td>Silt loam</td>
<td>Strong subangular blocky to weakly prismatic; mottled with 10YR4/6 silt skins</td>
</tr>
<tr>
<td></td>
<td>3Cg</td>
<td>1.65-2.65</td>
<td>5/N to 4/N</td>
<td>Silt loam to clay loam</td>
<td>Massively bedded</td>
</tr>
<tr>
<td></td>
<td>4C</td>
<td>2.65+</td>
<td>4/N</td>
<td>Sand</td>
<td>Sandy gravel (channel lag), massively bedded</td>
</tr>
<tr>
<td>4</td>
<td>Ag</td>
<td>~0-0.35</td>
<td>10YR4/1</td>
<td>Silt and clay</td>
<td>Coarse, medium subangular blocky; organic rich</td>
</tr>
<tr>
<td></td>
<td>Bw</td>
<td>~0.35-1.00</td>
<td>7.5YR4/4 (mottles)</td>
<td>Sandy clay</td>
<td>50-60% redox mottles with gleys</td>
</tr>
<tr>
<td></td>
<td>Bw/Cg</td>
<td>~1.00-3.25</td>
<td>4/N</td>
<td>Sandy clay</td>
<td>Bands of sands and clay alternating; water table at ~3.25 m below surface</td>
</tr>
<tr>
<td></td>
<td>Cg</td>
<td>~3.25-3.50</td>
<td>4/N</td>
<td>Sandy clay</td>
<td>Sands abundant; water logged and inaccessible</td>
</tr>
</tbody>
</table>

Notes: Trench 2 opened, but inaccessible due to safety concerns. Trench 4 also inaccessible, but probed with shovel to collect samples for hand examination.
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Integrated Biogeochemical Analysis and Interpretation

**Area 1 Results**

**Area 1 Acidity.** The pH values for all samples examined from Area 1 showed relatively consistent and moderately acidic pH values ranging from 4.8 to 6.0 (see Figure 2.54; Appendix F). Levels above 5.5 were generally noted in the upper three meters (above 211.00 m asl and particularly AU-3 and AU-4) at the site. These levels reflected either the contribution of carbonate ions from the historic fill material, which once capped the truncated soil profile in Area 1, or the more alkaline levels from prehistoric food stuffs introduced by the aboriginal inhabitants of the site. Given the low numbers of bone and shell artifacts recovered from the upper horizons in Area 1, the latter premise was not strongly supported.

It is interesting to note that noticeably higher pH values (5.2 to 5.7) corresponded with those excavated levels (in AU-2b) associated with high numbers of flaked stone artifacts and associated fire features. The slightly more acidic values for the lower stratigraphic levels in Area 1 (AU-1) were not unexpected, given the coarse texture of the sediments (loam sand to sands) and the removal of carbonate ions by fluctuating ground waters.

**Area 1 Elemental Geochemistry.** Phosphorous values for the columns analyzed in Area 1 once again exhibited three high points occurring at: 213.67 m to 213.00 m asl; 212.68 m to 212.00 m asl; and 210.88 m to 210.58 m asl (see Figure 2.54; see Appendix F). Given the resistance of phosphorous to translocation by leaching, the high phosphorous values were an excellent indicator of human occupation, and the high values (when compared to the stratigraphic position of fire features) showed a correlation with both fire features and flaked stone artifact highs (William Barse, personal communication 2010).

Calcium values for Area 1 show three distinct modal peaks occurring at: 213.77 m asl; 212.08 m asl; and 210.78 m asl in AU-2b (see Figure 2.54). These three modal peaks, when compared to the frequency of flaked stone artifacts and the mapped occurrence of fire features, show a high correlation. In Block 2 for example, nine of the 12 identified features were encountered between 212.20 m and 212.00 m asl. In Block 3, 44 cultural features were encountered at elevations ranging from 213.70 m to 211.70 m asl, with 30 of the features occurring in a tight stratigraphic package (213.70 m to 213.20 m asl), which consistently displayed high calcium, potassium, and phosphate values. The varying magnesium values for Area 1 essentially mirror the highs and lows seen in association with the calcium values at the site.

Potassium (K) values in Area 1 also showed three distinct peaks for the analyzed samples occurring at 213.77 m to 213.27 m asl; 212.28 m to 211.98 m asl in AU-2a and AU-2b; and high values for the upper levels for AU-1 occurring at 210.88 m to 210.58 m asl (see Figure 2.54). These modal peaks corresponded with somewhat high organic matter and generally higher values for phosphate and calcium. Once again, these higher values reflected the introduction of such ions into the soils from the decomposition of food wastes, the burning of hardwood trees and from the seasonal intervals of prehistoric site utilization, primarily during the Transitional and Late Archaic periods.
Area 1 Total Organic Matter. The total organic matter values for Area 1 ranged from .1 percent (at 209.48 m asl) to as much as three percent (at 210.28 m asl) in the upper levels of AU-1 (see Figure 2.54). Levels were more generally at 2.1 percent for Area 1 samples, however, and it was likely that the extreme of three percent reflects the inclusion of wood or other large organic fragment. In examining the organic matter values with the mapped occurrence of in situ prehistoric cultural features and flaked stone artifacts (Miller et al. 2010), there was an indication that the organic matter content was likely due to the decomposition of food stuffs and on-site burning of trees by aboriginal occupants. This statement was further supported by the micromorphological and detrital grain composition analyses from Area 1 (see above), both of which documented increased field observation of free carbon (dispersed charcoal fragments) in the second and third meter soils, particularly as observed in profiles occurring between 213.00 m to 211.00 m asl.

Area 2 Results

Area 2 Acidity. The pH levels for Area 2 were markedly higher (more alkaline) than those encountered in Area 1 (compare Figures 2.54 and 2.55). There were three distinct modal peaks for the analyzed samples from Area 2, which occurred in the AU-2a and AU-2b soil package at 214.40 m to 214.00 m asl (AU-3 and AU-4); 213.33 m to 213.03 m asl (AU-2a); and 212.36 m to 212.06 m asl (AU-2b). Aside from the uppermost peak (214.40 to 213.90 m asl), which may reflect soil buffering by historic activity, the other pH peaks corresponded to horizons that yielded the highest numbers of flaked stone artifacts and, in turn, associated cultural features. These more alkaline, or less acidic, levels likely reflected buffering by carbonate ions released by the decomposition of food wastes (bone, shell, etc.) into the developing profile.

Area 2 Elemental Geochemistry. Phosphorus and potassium values for all samples from Area 2 were generally low (see Figure 2.55). The highest phosphorus values were from the uppermost strata (215.40 m to 214.20 m asl) and likely reflect the introduction of phosphate rich materials historically. Aside from this peak, the highest phosphate values were from 212.26 m to 211.86 m asl (e.g., basal levels of AU-2b and transition to the underlying AU-1). In examining the relationship of the soil geochemistry with the artifact inventory, there did not appear to be a strong correlation with those levels that yielded slightly higher phosphate values and those levels that contained higher numbers of flaked stone artifacts and/or cultural features.

Secondary potassium peaks corresponded with levels that yielded higher numbers of flaked stone artifacts and cultural features. Most notably, was relatively uniform and elevated levels of potassium at 213.33 m to 213.03 m asl (AU-2b), which corresponded with Late Archaic cultural materials.

As for calcium and magnesium values for the analyzed samples from Area 2, there was a thick package of soil that exhibited higher magnesium values extending from 212.36 m to 212.06 m asl in the AU-2b (see Figure 2.55). These higher magnesium values were mirrored, for the most part, by higher calcium values. There was a second calcium peak occurring stratigraphically at 214.40 m to 214.10 m asl, and likely reflected carbonate ions contributed by historic land usage. The high calcium and magnesium values within the thick
AU-2a cambic/argillic soil sequence in Area 2 corresponded closely with those stratigraphic intervals (213.33 m to 213.03 m asl) that yielded high numbers of flaked stone artifacts and cultural features associated with the late Transitional Archaic and Late Archaic occupations in the northwest corner of the site.

**Area 2 Total Organic Matter.** Total organic matter for all analyzed samples ranged from .3 percent to 2.2 percent (see Figure 2.55). The lowest levels occurred at 211.20 m to 210.90 m asl in the AU-2 to AU-1 transition. The highest organic matter values, not unexpectedly, were encountered in the uppermost horizons (214.40 m asl to 214.10 m asl) and were likely contributed by rooting trees and rodents associated with the late Holocene and recent sediments of the AU-3 and AU-4. However, a series of three organic matter peaks (above .9 percent) were identified from 213.23 m to 211.53 m asl within the AU-2a/AU-2b soil package (see Appendix F data table for values).

For the unit of the northwest corner, according to Miller (personal communication, 2010), these peaks corresponded, in part, with cultural features and higher artifact counts from the northern excavation units in Area 2, where the archaeological stratigraphy was described by a “stratum” and “level” designation system (Miller and Marine 2005). Such high counts occurred in Stratum III Levels 9-11 at 212.8 m asl and Stratum III Levels 17 to 24 at 211.50 m asl, levels that dated firmly to the Late Archaic (5600 B.P. to 4975 B.P.), and were associated with AU-2a horizons.

Similarly, the southern excavation units showed a peak in artifact counts and cultural features from Stratum III Levels 3 to 7 at 212.80 m asl (late Transitional Archaic to Early Woodland) and from Stratum III Levels 9 to 11 at 212.40 m asl (early Transitional Archaic). A weak organic matter high at 210.77 m to 210.47 m asl likely corresponded with a documented Middle Archaic occupation, which extended from 210.55 m to 209.40 m asl.

**Area 3 South Results**

**Area 3 South Acidity.** Determination of pH (soil acidity) on the samples from Area 3 South was performed in order to vertically profile changes in acidity levels from the excavation surface to the limit of deep testing. Figure 2.56 showed a trend toward decreasing levels of acidity through the profile. The upper allostratigraphic units, AU-4 and AU-3 showed slightly alkaline soils. At the break between AU-3 and the sola of AU-2, there was a marked increase in soil acidity levels, with pH values measuring below 5.6 consistently (see Appendix F).

The 3Ab1/3Ab2 to 3Bw transition showed a steep drop in pH level from 214.27 m asl, where acidity was measured at 7.4 (a neutral to very slightly alkaline value), to 214.07 m asl where acidity was 5.4 (a strongly acidic value). This rise in acidity below the AU-3/AU-2 interface was the result of differential soil formation processes, including the movement of water through the solum and the influence of silt- and clay-enriched parent materials. In the case of the AU-2, field identification (see Table 2.13) and granulometric analyses (Figure 2.44 and 2.45 and Appendix E) confirmed the increase in fines (silts and clays) starting at or about 213.89 m asl with the appearance of the stacked 3Bw-4Bw-5Bw soil sequence.
**Area 3 South Elemental Geochemistry.** The measurement of several chemical elements in the sample columns provided additional detail regarding human activity. Figure 2.56 showed the measurement of total phosphorus, potassium, and magnesium in parts per million (ppm) concentrations. In the case of total phosphorus, the curve measured below 30 ppm throughout the profile and the overall pattern is rather flat with depth. However, slight increases in total phosphorus were found between 214.47 m and 214.27 m asl, at 213.79 m asl, and again below 212.23 m asl. These increases corresponded to the elevations of the 3Ab1/3Ab2, the 3Bw-4Bw transition, and below the 6AC. In the case of the 3Ab horizons, these increases attested to higher levels of human activity at the time of the Late Archaic. At the 3Bw-4Bw, the rise likely signified the presence of adsorbed surface A horizons, no longer extant in field observation. For the 6AC horizons, proveniences were suspect, since P values may have been increased as a result of coarser materials being redeposited during high energy flood events.

The available concentration of potassium generally paralleled the pattern of organic matter content. The K levels were high for the first-meter A horizons, dropped markedly within the first meter C or BC units, and rose again for the second meter stacked Bw sequence. The curve stayed below 35 ppm from the top of the third meter to the base of excavation. Magnesium levels reflected a similar, although more distinct, curve between 75 to 300 ppm for the Area 3 South profile. The observed change in magnesium levels within the profile likely reflected magnesium contribution from organic matter, which decreased with depth, as well as magnesium being precipitated by fluctuating groundwater within the soil profile.

Finally, calcium concentrations followed the overall pattern set by the organic matter and soil nutrient measurement (see Figure 2.56). Calcium levels, however, showed a notable spike (>5000 ppm) for the A horizons of the first meter, reflecting the presence of the least degraded (best preserved) bone remains (or, potentially industrial contamination) according to the most recent archaeological analysis (Anderson et al. 2010).

**Area 3 South Total Organic Matter.** The percentage of organic matter in the sample columns was shown in Figure 2.56. Measurement of organic matter aided the identification of activity areas and site boundaries. Figure 2.56 showed fluctuating levels of organic matter within the soil profile of Area 3 South. Generally, A horizons indicated the highest accumulation of organic matter (>1 percent), while C horizons showed the lowest concentration. Interestingly, the faint signature of adsorbed A horizons within the 3Bw-4Bw-5Bw sequence seemed to appear in the profile between 213.89 and 213.09 m asl (see Figure 2.56).

As expected, Figure 2.56 featured a high organic content at 215.27 m asl, which coincides with the first A horizons identified under fill. These horizons included the Ap and the AB strata. A significant drop was noted between 214.97 and 214.47 m asl, where the C and 2BC horizons occurred. There was a slight increase of organic matter again between 214.07 and 213.99 m asl, where the 3Ab1/3Ab2 units were identified. Below 213.99 m asl, there was a sharp rise above 1 percent organic matter content, which remained elevated until reaching roughly 213.09 m asl. This zone of high organic content corresponded to the stacked 3Bw-4Bw-5Bw horizons. Each of these was likely to have had an A horizon at one
time, which has since become adsorbed into the overlying Bw. The slow accumulation of fine-grained sediments, in situ weathering, and translocation of organic rich minerals and clays through the solum permitted this distinctive pattern in the second meter soil profile.

The percentage of organic matter dropped sharply again at 212.83 m asl, an elevation which corresponded to the 5Bw-5BC transition. Below the 212.83 m asl elevation, Figure 2.56 presented low (<1 percent) pulsed increases of organic matter to the base of excavation. This rhythmic pattern occurred in the fourth meter and below of the excavation, where a series of short term A horizons formed on massive lateral accretion sands. Commonly identified as the “lamellae” during excavation, the AC horizons were metastable surfaces with modest concentrations of organic matter.

Taken together, the results presented above illustrated the utility of such laboratory analyses for the identification of geochemical signatures of human occupation on the landscape. Such data, when compared to the vertical distribution of artifacts and features from the various excavation areas, both augmented the interpretation of the overall settlement patterning at Site 36AL480 (Anderson et al. 2010; Miller and Marine 2005; Miller et al. 2010), and complemented the landscape development model discussed herein.

**Feature Geochemistry Results**

Cultural features are repositories of geochemical change because of the activities that have occurred in them and the post-depositional transformations to which they are subjected subsequent to site abandonment. The degrees to which these changes reflect anthropogenic inputs and decomposition vs. natural processes of chemical degradation are often difficult to gauge. At Site 36AL480, representative features and attendant offsite control specimens were sampled for elemental tests by a variety of methods (Section 2.5). The offsite control specimens served to differentiate the weathered soils and parent sediments of the substrate from suspected loci of human activity. More specifically, the objective was to identify those elements and/or compounds that were most directly diagnostic of anthropogenic activity.

Two sets of tests were performed:

- Geochemical assays of features vs. control samples
- Geochemical assays to distinguish between known feature types

In the field, the archaeological teams had established feature typologies based on morphology, depth, composition and structure that would allow for feature groupings. In practice, the set of features sent out for geochemical assays were based on a typology that was designed by the Principal Investigator for Area 1. A separate typology was developed by the Principal Investigator for Area 2. While these typologies differed somewhat, they shared sufficient commonalities to render productive comparisons and interpretations. Raw data for the geochemical feature analysis is presented in Appendix G. Each set of tests is discussed separately for Areas 1 and 2.
General Feature Geochemistry

Figures 2.57 and 2.58 highlight the differences in geochemical concentrations for features and controls for Area 1 and Area 2, respectively. In this analysis, mean values for each parameter (element or compound) are calculated for the population of feature and controls. The difference in the means represents either a positive value for features, specifically chemical enrichment, or a negative value that represents depletions. For example, positive readings on the horizontal axis of the graphic indicate that the population of features was enhanced when compared to the controls. On the other hand, negative readings on that axis show that elemental concentrations for features were diminished, or depleted, when compared to those of the controls.

Comparisons between results of the Area 1 and Area 2 analysis yield the following observations:

- Feature concentrations for both areas are somewhat to significantly enriched for pH, K, Ca, Mg, Fe, Zn, Cu, percent organic carbon (OC), and percent organic matter (OM);
- Feature concentrations for both areas are somewhat to significantly lower (i.e., depleted) for ECE and S;
- Area 1 features are enriched while Area 2 features are depleted for the following: NO3, P;
- Area 2 features are enriched while Area 1 features are depleted for Mn;
- Area 1 features have especially high concentrations of OC, OM, and Zn (>100 percent) when compared to controls; and
- Area 1 enrichments are on the order of 30-100 percent higher than those of controls while Area 2 feature enrichments are on the order of 5-30 percent over controls.

Elevated concentrations of K, Ca, Mg, percent OC, and percent OM are widely cited as evidence for burning and intensive utilization of stabilized surfaces at prehistoric sites (Holliday 2004; Schuldenrein 1995). High OC and OM concentrations reinforce the presence of a former A-horizon that is evidence of a stabilized landform during occupation. K, Ca, and Mg are among the classic indicators of firing and food processing at hearths and related features. Cu and Zn have been linked to household sites at more complex sites, but their origins in these contexts are not widely established (Holliday 2004). In general, the high concentrations of these elements at prehistoric activity loci in Areas 1 and 2 is fully consistent with anthropogenic activity linked to prehistoric occupation. The prominent depletion of S is anomalous, since that element is also often taken as an indicator at prehistoric sites.

More striking, however, is the depletion of P at Area 2, and its low presence in Area 1. P is perhaps the most diagnostic indicator of anthropogenic activity at prehistoric sites.
However, in this case, its negative loading (on control samples) may be related to unique patterns of decomposition and degradation on site. Appendix G shows that at both Areas 1 and 2, P concentrations are so low that the intra-site comparisons of feature vs. control distributions may be inconclusive. Along similar lines, the minimal P concentrations, especially for Area 2 where there is a rich feature population, remain difficult to reconcile.

Several other significant trends include the fact that pH readings are higher in the feature set than in the controls for Area 2; thus, the features are slightly less acidic even though humification levels may have been more sustained in loci of human activity. A possible explanation for this anomaly would be the nature of feature use and the probability that calcareous feature fills would have presented a more basic geochemical signature, while more acidic readings in both feature and non-feature fills would be related to specific feature use and sustained humification (with time) manifest across the surface horizons.

The higher magnitude of anthropogenic enrichment in Area 1 vs. Area 2, as measured by the parameters discussed above, is paradoxically consistent with the rich vertical archive of continuous occupations at the latter portion of the site. In Area 2, the stratified sediment matrices were already enhanced in certain anthropogenic elements both laterally and vertically within the substrate. This was the most densely occupied portion of the landform such that anthropogenic inputs were effectively “recycled” within the confines of Area 2 creating a more homogeneous chemically enriched and finer grained substrate. Area 1 was less intensively occupied on a more porous (sandy) substrate so that discrete features were uniquely enriched in finer textured, more cohesive and mineralized components that resulted in more pronounced contrasts between the natural matrix of the substrate and the mineralized components of the feature matrices.

**Geochemistry by Feature Type**

In general, the same trends in feature enrichment for the general feature populations were replicated in the more detailed breakdown of feature types (Figures 2.59 and 2.60). Thus, for both Areas 1 and 2, pronounced peaks in K, Ca, Fe, Zn, Cu, OC and OM concentrations were obtained for the range of feature types. Notably, for Area 2, organic matter enrichments were uniquely prominent for pit features and to a lesser degree FCR clusters, while they were depleted for hearths and all other feature types. It is possible that this phenomenon is related to weathering, as smaller pits were overprinted by B horizon formation as accretion levels slowed on the terrace and the pedogenesis dominated over sedimentation. Under this scenario, only deeper features would be likely to retain an organic presence, as they were less subject to mineralization at the weathering front.

**Phosphate Fractionation Results**

Specific land use practices at Site 36AL480 are potentially sorted out by feature type on field and geochemical criteria. As noted earlier in the methodology discussion, the mapping of phosphate "prints" for known feature types here could verify independently recognized land use types, and, in the absence of any inference of land use in the early stages of site analysis, the phosphate feature prints offer some indications of land use and intensity of occupation. Results are initially compared to a bank of prints from other archaeological...
sites where land use is known from both the phosphate and material culture record (Hutson et al., 2009; Schuldenrein 1995).

In the field, the archaeological teams had established feature typologies based on morphology, depth, composition, and structure that would allow for feature groupings. In practice, the set of features sent out for phosphate fractionation analysis were based on a typology that was designed by the Principal Investigator for Area 1. This is the typology that is utilized for the present study. It should be noted, however, that the typology has changed somewhat since the initial development of the taxonomy and the completion of the analysis reported in this study. However, the results reported herein should be an informative measure of the utility of the phosphate fractionation methodology. Feature type identifications and raw data for the fractionation analysis are presented in Appendix I.

To review the background to the analysis briefly, it is noted that the anthropogenic component of phosphorous in the soil is measured by the amount of total inorganic P (or Pti) (see Eidt 1977; Holliday 2004). Elevated levels of Pti are present in archaeological soils and sediments when compared to local soils. Sequential extractions of various forms of Pti furnish an index for total inorganic P and this index reveals information on human activity based on a prospective correlation between land use and Pti. As discussed in Section 2.5, this fractionation sequencing method involves extraction of two sub-fractions solution P and loosely bound Al and Fe phosphates (Fraction 1a and 1b in Appendix I, combined as Fraction I here because this is largely an absorption process for three vs. two chemical components [see Hutson et al., 2007: 265]); tightly bound or occluded Fe and Al oxides and hydrous oxides (Fraction II); and occluded Ca phosphates (Fraction III). The results (Appendix I) are plotted on a ternary plot to compare signatures of the suspected anthropogenic soil with that of controls to contrast sources of cultural from naturally occurring inputs. Ultimately, these plots can also inform on anthropogenic activities when matched against known signatures from data banks that have identified specific land use categories of cultural origin.

Initially, we compare the results of fractionation analyses from feature contexts with those of the controls. The controls were taken from sediments immediately adjacent to feature loci, such as a sample from the same stratigraphic horizon but outside of the feature and/or from adjacent off-site loci. In general, control samples were taken approximately 1-2 meters outside the feature at the same approximate elevation, where accessible. Control sampling was not always optimal as many specimens were collected post-facto. This is because the phosphate study’s utility and potential was recognized after feature collection and not necessarily in conjunction with it. Feature and non-feature sampling are standard procedures and are valid even under less than optimal conditions, given that primary segregation of feature fill and non-feature sediment are controlled for. The sampling procedure was followed for each of Areas 1, 2, and Area 3 South. Figure 2.61 is a set of ternary plots for the feature vs. the control loadings by Area.

For Area 1, the control samples tend to converge in a limited range of 40-50 percent of Fraction III, with loadings of 55-60 percent on Fraction II and 38-42 percent on Fraction I. The feature specimens have a broader distribution range, on the order of 15 percent for Fractions I and II. In Area 2, the range is even greater for both the feature and control contexts. Control samples load on a band from 50-65 percent on Fraction II, and 30-48
percent on Fraction I. For features, the corresponding ranges are 50-80 percent on Fraction II and 15-45 percent on Fraction I, underscoring a trend toward greater occlusion of iron and aluminum in the feature population. Finally, Area 3 South is the only location in which both feature and control samples mirror broadly similar loadings; these are on the order of 55-68 percent on Fraction II and 28-38 percent for Fraction I. In this case, there are several outliers (Figure 2.61). It is also emphasized that while sample sizes for Areas 1 and 2 were small, the broader distribution ranges for features on Fractions I and II appear to be indicative of degrees of transformation of ferric and aluminum components in the overall data set. Broader distribution ranges for fractions across the general population of features at Site 36AL480 may be a product of variable inputs to the sediment matrix by human agency. Thus, preliminary indications are that a potentially significant anthropogenic signature is present in Areas 1 and 2, while it is more subdued generally for Area 3 South.

Perhaps a more important component of the fractionation distributions is inherent in the Fraction I to II ratios. Eidt (1977; see also discussion in Holliday 2004: 311) noted that at millennial time scales, acid extractable P is depleted with time, thus enhancing total P. Weakly bound P is depleted through time such that the ratio between Fraction II and Fraction I may be broadly considered a measure of time (see also Hutson et al., 2009, Schuldenrein 1995). Increased ratios reflect greater antiquity. A comparison of the Fraction II to Fraction I ratios shows that the highest differences are manifest in the Area 2 distribution where Fraction II loadings at 80 percent and corresponding Fraction I loadings at 20 percent account for a 4:1 ratio (see Figure 2.61; feature readings on lower right portion of distribution, see Appendix I). Area 2 included the oldest features on site, as well as some of the youngest, a trend that is also underscored by the broad variability in Fraction I and Fraction II loadings for the Area 2 feature sample (see Figure 2.61). By contrast, the more tightly grouped feature distributions in Areas 1 and 3 South (see Figures 2.61) attest to generally younger, more restricted, time frames of occupations in those portions of the site.

Next, we consider the broader significance of the Site 36AL480 feature signatures by comparing the features themselves to an existing data bank of land use types. Figure 2.62 is a ternary plot of the composite phosphate distributions for all of site features, along with plots for Lums Pond (7NCF18) (Petraglia et al. 1998), a hunter-gatherer site in Delaware and Ruckers Bottom, (9EB91), a Mississippian village site in Georgia (Anderson and Schuldenrein 1985). The plots for these sites were chosen as proto-typical examples because the phosphate print records for village sites and hunter-gatherer locations are expectedly different. Moreover, the village prints isolate specific activity areas while the hunter gatherer records are unique in providing an amalgam of activity signatures that are recurrent in analogous sites across the northeastern United States. Each axis represents the percentage loading on each of the three phosphate fractions.

For the village sites, there are unique phosphate loadings on the diagram for house floors, postholes, refuse pits, stockade ditch fills and a general Mississippian sheet midden. For the hunter-gatherer site, there is a concentration of points outside the range of readings associated with the more distinct feature types associated with the village.

Examination of the phosphate fractionation plots distinguishes what are clearly two general clusters, for the village and hunter-gatherer site respectively. For present purposes
we consider “clusters” to comprise grouped fractionation signatures on the ternary plots. These are distinct from any formal univariate or multivariate statistical manipulation. Accordingly, the primary cluster (A; center right portion of Figure 2.62) is keyed to a heavy loading for Fraction I, with proportionately lesser weights on Fractions II and III. The cluster encompasses what may be considered a generic matrix of prehistoric village land use. Elsewhere, it has been demonstrated that the limits of the distribution are defined by residential land use and the preparation of fields for cultivation, as well as by floors and paths and by a mixed forest setting, possibly representative of pre-clearance vegetation (Schuldenrein 1995). Taken together, these activities circumscribe the range of expected village activities. They surround site wide prints--for example, the sheet midden--as well as occupation floor fills in the right hand portion of cluster A. Viewed quantitatively, the cluster offsets an extensive Mississippian occupation signature marked by phosphate loadings ranging from 35 to 70 percent on Fraction I, and 25 to 45 percent on Fraction II.

Hunter-gatherer activity areas are more directly addressed by the second print cluster (see Figure 2.62; Cluster B, center right). It is dramatically offset from the first with a high loading on Fraction II (50-70 percent), and proportionately minimal loading on Fraction III (<10 percent). The print appears to be indicative of a highly localized land use type. In general, systematic plots of the village feature prints suggest that perishable cultural residues can isolate and even group prehistoric activity areas that would be otherwise undetectable.

The hunter-gatherer prints seem to suggest highly localized activity settings that are remarkably similar between sites, irrespective of location. Comparisons between the phosphate fractionation plots for the Site 7NCF18 and Site 36AL480 series reveal nearly identical distributions, with two exceptions. One of the features (F205) in Site 36AL480 (from Area 3 South) overlaps onto the A cluster, suggesting perhaps a more specific land use pattern associated with a more intensive occupation. Second, the subset of cluster prints loaded heavily on Fraction II (Figure 2.62; extreme lower right) are indicative of the greater antiquity of the earliest phase (Middle Archaic) of the Area 2 occupation. More detailed examination of a larger set of activity loci at the site should help determine if there are shifts in prehistoric land use at Site 36AL480 through time (stratigraphically) or space (between Areas 1, 2, and 3 South). However, the phosphate analysis shows major promise for resolving activity function across the site.

**Micromorphology Results**

Micromorphological analysis for the present study was applied to two primary goals. These centered on identifications of: 1) soil formation process and 2) depositional mechanisms. The former objective was the target of inquiry for Areas 2 and 3 South since earlier phases of the investigation pointed to both subtlety and considerable variability across the T3 in the strength of weathering in the B horizon. For example, visual identifications of structure, cohesiveness and texture could not definitively segregate weak argillic (Bt) from relatively mature cambic (Bw) horizons. Additionally, fragic characteristics of Argillic soils were often isolated upon inspection but the determination as to whether or not these were formal fragipans or simply argillic horizons with fragic components could not be made in the field.
In addition to these two primary objectives, we proposed to apply micromorphology to address supplementary site specific concerns. The first was to help identify microstructures in the AC couplets in order to establish whether or not episodic (i.e. autogenic) flood events were registered in the stratigraphic column, for Area 1 in particular. The second was to distinguish the degree to which organic matter was incorporated into the matrix of these unique alluvial sediment matrices.

The following summary synthesizes the primary findings from the micromorphological study by Area. For detailed descriptions and identifications of sampled specimens, the reader is directed to Appendix J covering Areas 1, 2, and 3 South, respectively.

**Area 1 of the T3 (Photomicrograph #659)**

Sampling was performed on 10 specimens from finer grained overbank alluvium deposited along a levee margin of Area 1 adjacent to the relict Back Channel zone (Figure 2.63; Appendix J). Microscopic examinations confirmed a dominant, moderately well sorted, flood deposit of subangular to subrounded coarse silt to fine sand, sized quartz. While quartz was the primary mineral grain present, accessory minerals included clay sized materials (preliminary estimate based on general mineralogy [Appendix H]: illite, montmorillonite, 10-20 percent); muscovite mica (one to two percent), potassium feldspar (<one percent), and opaque minerals (hematite, magnetite, etc., <two percent). All specimens contained between one to four percent charcoal and diffuse carbonized and uncarbonized organic matter, including some seeds (probable amaranth and chenopods).

The moderate degree of sorting indicates that the sediments were deposited under moderate to high flow velocities by flood waters associated with the then active Back Channel. The AC horizons consistently exhibited higher silt and clay sized fraction than the slightly better sorted and sandier C horizons. In addition, the AC horizons exhibited: 1) strong redox of iron oxides; 2) vughs and infilled chambers probably associated with root rhizomes; and 3) a slightly higher organic matter content, including a higher percentage of carbonized wood remains. The observed thin sections support the contention that the AC-C horizon couplets document short lived periods of terrace stability (AC horizons) that favored organic matter accumulation and in situ weathering which were then interrupted by flood events (C horizon part of couplet). The latter impeded subsequent A horizon development and weathering. As flood waters abated with every flood event, the finer grained suspended load was subject to more subdued weathering represented by the AC horization. The BC horizon in Area 1 which overlies the AC-C couplets, exhibited much poorer sorting and a higher percentage of silt and clay sized grains (see Figure 2.63). This observation may signify a shift in the depositional regime away from the levee zone (adjacent to the Back Channel) and towards an accelerated sediment supply contributed by slow, continuous, low magnitude flood events from the main stem of the Ohio River. Extensive bioturbation was noted in the AC couplets as well. Finally, the provenance for the mineral suite dominant in the sands is eroded Pennsylvanian age sandstones, shales, and siltstones of the Conemaugh and Allegheny Groups.
Area 2 of the T3 (Photomicrograph #225)

The sample population for Area 2 was critical for understanding the site formation process at Site 36AL480, since this was the archaeologically richest portion of the site and an area in which cultural stratification intergraded with both alluvial strata and pedogenic horizons. A second objective was to determine the degree of weathering in the B-horizon since stratigraphic continuity, especially with Area 3 South to the south, was not often apparent. Area 2 was the primary location on the T3 in which AU-2 was subdivided into AU-2a and AU-2b. Finally, field observations indicated that relatively unweathered pockets of organically enriched alluvium were preserved in upper units, and the origins of these matrices would contribute to the reconstruction and chronology of the flooding regime.

According to the analysis (Appendix J) most of the samples, “have various shared and similar aspects of composition, texture, and types of pedofeatures.” Pedofeatures that were common in several specimens included, “infillings and coatings of voids with reddish brown clay, and/or dark brown dusty clay interbedded with or containing quartz silt.” Such elements are normally absent in cambic horizons (Aurousseau et al. 1985), even though field observations did verify some evidence for more pronounced weathering and, as discussed subsequently, the clay infillings (and oriented clay distributions at voids and discontinuities) elsewhere can be interpreted as evidence for more argillic type (Bt) soil horizonation. However, taken together with other depositional indicators, these pedofeatures, most prominent in the second meter of Area 2 (samples #230, #231, and #232) are attributable to alluvial origins. Many of these same samples also exhibit localized texturally depleted domains, in which fine material is lacking and the quartz silt fraction is slightly enriched. Such textural modifications are common in flood plain environments or those which have open, exposed surfaces that permit these materials to be mobilized (Courty et al. 1989). Only a few samples (e.g., #45 and #46; first meter) do not show any or virtually no textural features. Such samples are presumed to represent rapidly buried sediments, which were removed from the pedogenic environment. Additionally, several specimens were characterized by the presence of crumb structure and aggregates. Those displayed a high degree of biological reworking of the material, which would be typical of past A horizons. Some of the organic contributions to the matrix may be related to human activity as well.

Significantly, at least half of the total sample (n=20) did exhibit micromorphological features consistent with clay translocation and enrichment in the form of Bw or Bt horizons. The most striking of these is the presence of common reddish brown clay coatings whose thickness and prominence was more typical of Bt development (Figure 2.64). Some bleached faces were found but not in sufficient magnitude or extent to be considered a well-developed Btx horizon. This degree of pedogenesis was in greatest evidence in the third meter at Area 2.

While many of the textural pedofeatures observed in these samples were not strictly associated with pedogenesis in the classical sense, they were closely allied to the alluvial/floodplain environment in which episodic floods can redistribute and elutriate the fine material, accounting for vertical translocation in the sediment column. Such an interpretation would explain the coarse textural features, which are relatively rich in quartz silt and linked to coarser voids and chambers.
On the other hand, the reddish brown clay coatings and infillings are rather fine grained and well bedded, indicative of lower energy accretion, and are consistent with translocations promoted by classic pedogenic processes. Yet, the presence of silty inclusions and dusty clay argues again for translocation attendant to open alluvial surfaces (Courty et al. 1989). There is limited evidence for anthropogenic input in the organic matrices.

Area 3 of the T3 (Photomicrograph #79)

Micromorphological specimens were collected in Area 3 during the first season of field work and spanned the first three meters of the stratigraphic column. The characteristics of the A horizon were noted in the upper meter over the course of field work while varying levels of pedogenesis were observed in the second meter. It was unclear as to whether two or three cambic horizons were in evidence in the second meter. Soil development was also prominent in the third meter.

There were no great differences among any of the samples. All of the sediments consisted of silty clay in varying proportions. Sediments in the second meter were noticeably richer in clay – both depositional and post-depositional in origin – than the others but such textural variability is typical of alluvial surfaces. All samples exhibited analogous characteristics of porosity: typically vughs and chambers. These are most likely produced by roots and burrowing organisms on the terrace landform. No significant changes in porosity types were distinguished in the sample population.

Textural pedofeatures can be grouped as follows: a) reddish brown laminated clay, seldom with quartz silt inclusions; b) dark yellowish brown dusty coarse silt; c) silty intercalations and with isolated infillings; and d) depletion features from which the clays have been removed. While not all samples preserve these features, most features were recognized in most samples.

On the site specific level, the first meter alluvium exhibits some clear post-depositional features in the form of biological reworking (passage features and vughy porosity), and clay coatings, and infillings. The reddish brown type is clay-rich or locally interbedded with quartz silt. This would be more typical of coatings common to Bt horizons. The darker, coarser type would be more prolific below plowed or open surface horizon, although similar types of coatings have been documented from alluvial landforms (Brammer 1971). Clay coatings within voids in the charcoal indicate that some of these processes post-date charcoal deposition, which may represent an anthropogenic contribution to the matrix.

Second meter soils are characterized by prominent red-brown coatings consistent with a Bt horizon in a floodplain or terrace environment (Figure 2.65). The most striking examples are from samples 79-80. Nevertheless some variability was exhibited in the second meter profile, where an abundance of yellowish brown coatings documents continuity in the weathering profile, chiefly as the A/E horizon or upper Bt. In samples 126-129, yellow coatings diminish, again due to somewhat more sustained pedogenesis. Samples 151-152, provide evidence of unweathered matrix and enriched organics, possibly registering a flooding episode. Here, then, there are indications of a more cambic pedon within the second meter. By contrast, samples 181-184 are richer in clays and micromorphological indicators of
pedogenesis (slightly oriented clay films and more reddish coatings) pointing to more Bt-like characteristics. Finally, the third meter soils seem to feature renewed organic enrichment generally, probably attesting to the renewed presence of alluvium.

Remains of organic matter and charcoal were generally scarce and were slightly more abundant in the organic units that were recognized in the field. No evidence of root or organic mats could be observed in any of the samples. In light of the paucity of organic matter, it is not clear from the micromorphological observations if it is culturally derived or is simply surface material that was buried during flooding episodes.

In general, there does not appear to be any strong micromorphological evidence to distinguish Bt horizons recognized in the field from Bw horizons. Although clay translocation is commonly associated with or ascribed to pedogenic processes, it is well documented in flood plain environments. Typically clay settles out of suspension from either submerged surfaces associated with flooding. The coarse nature of the silty intercalations and depletion features, and the dark yellow brown dusty coatings are typically associated with translocation of material beneath open surfaces (some associated with cultivation; see Courty et al. 1989). Given the ubiquity of such textural features within these frequently inundated floodplain sediments it can be difficult or ineffective to recognize Bw from Bt horizons on micromorphological grounds alone.

In this connection we would stress that there are unequivocal criteria for differentiating the transition between Bw and Bt horizons on granulometric grounds (USDA 1994; Birkeland 1999). However, micromorphology does not offer such obvious quantitative thresholds. Clearly, one of the main criteria for distinguishing between the two is illuvial enrichment. Here, micromorphology simply indicates that illuvial enrichment has occurred and illustrates the relative degree to which this has occurred. The overall impression from the micromorphological study at 36AL480 was that variable clay enrichment occurred on site, depending on location (between and within Areas) and depth (in profile). In some cases clay concentrations were sufficient to be considered argillic (Bt) in others less so (Bw). There was considerable subtlety in pedogenesis, especially in Areas 2 and 3. Of particular note at this site is the case of welded soils (in which case Bw horizons are stacked) and deeper profiles which would argue for continuous Bt development. At 36AL480 patterns and degrees of soil formation are highly variable, even on the primary landform of occupation, the T-3.

In the present study it was found that the micromorphology helpful in establishing that illuviation as a critical weathering process generally, but that there was significant variation in the magnitude of illuviation across the site. That, in turn, limited the utility of using micromorphology as the sole criteria for distinguishing Bw from Bt horizons in all cases. In Area 1, there was minimal evidence for Bt formation (northern end of T-3), while in Areas 2 and 3-South (central and southern portions of the landform) there were complex expressions of generally more deeply weathered profiles. Bt’s were sometimes recognized, Bw’s were dominant, and intergradations between them were not uncommon (as in the case of welded soils on the proximal end of the T-3 in Area 2). These intergradations were also masked by localized evidence for organic enrichment promoted by occupation (Area 2), by discrete flooding events in which primary bedding structures were preserved (Area 1), and by

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the sloping morphology of the floodplain that eroded elements of the primary weathering profile (distal and southern edges of the profiles in Area 3-South).

**Radiometric Chronology**

The geomorphology team has compiled the most comprehensive radiocarbon data base available for Site 36AL480. This was done to insure that the site stratigraphy would be calibrated to the absolute chronology as securely as possible. In assembling these data, we drew upon previous reports, beginning with the initial exploratory studies undertaken on site.

Appendix B presents these data in systematic fashion, providing all provenience information as well as conventional and calibrated determinations. The 2-sigma calibrations are provided for the oldest and youngest dates. As a matter of protocol, radiocarbon years are reported as the presentation standard and calibrations are provided for purposes of scientific reporting and for comparative contexts. Standard deviations and material dated are also given. In all cases, the preferred material for dating was charcoal, but bulk sediment was also submitted in cases where it was necessary to provide order-of-magnitude determinations from subsurface contexts where charcoal was not available.

Contractor identifications are made to enable the reader to track the dates to appropriate reports and documents. For Phase III, the standard provenience or collection units are identified as Area 1, Area 2, and Area 3 South. Since the Scope of Work (USACE 2001) also required data collection from paleoenvironmental contexts, dates were obtained from two additional settings, the Back Channel: and the Casting Basin. Collection proveniences from the earlier phases of work were researched and, where possible, their contexts were assigned to Phase III locales in nearest proximity. Thus, for example, samples dated from Phase II trenches were pooled with Area 1 specimens for analytic purposes, if we could establish proximity as well as equivalent elevation and stratigraphic associations.

A total of 104 radiocarbon determinations were assembled with supporting provenience information. Included among these were nine from the Back Channel; 13 from the Casting Basin; 21 from Area 1; 38 from Area 2; and 19 from Area 3. Three determinations, apparently obtained during the Phase II geomorphology effort, could not be linked to appropriate proveniences, although the results of the assays are provided in Appendix B.

The majority of dates (n=78; 75 percent of the total) was derived from T3 excavation Areas 1, 2, or 3 South. Figure 2.66 illustrates the distribution of the dates by Area and shows that the 6,000 year interval, broadly equivalent to the Middle Holocene (ca. 7800-1800 B.P.), is the most extensively documented radiometrically. In general, dates preceding that time frame are derived from the Casting Basin, where the earlier exploratory efforts were directed to assess the antiquity of the sediments near the base of the Pleistocene gravels. Many of these determinations, typically those preceding 11,500 B.P., are of limited utility and may have been contaminated by groundwater or coal-rich materials transported in late glacial or early post-glacial meltwaters and entraining bedload.
Figure 2.67 presents the distribution of radiocarbon dates by allostratigraphic units (AU’s) as utilized in this report. The best dated sequences are those of AU-2 (in this case not broken out by sub-units 2a and 2b) which include the largest number of dates from Area 2, followed by Area 1. Area 3 South produced significant numbers of determinations from AU-3, in part because it occupied the highest elevations on the landform, which accumulated as a result of high discharge events during the late Holocene. The Casting Basin registered the most dates for AU-1 and Back Channel determinations were spread between AU-2 and AU-3. Dates from AU-2a and AU-2b are only derived from Areas 1 and 2 and refer to localized deposition of sands embanked against the extant T3 between 4500 and 3000 B.P. (Figure 2.68)

A clearer picture of the site formation chronology and depositional trends on the T3 is shown in Figures 2.69a and 2.69b (calibrated and uncalibrated respectively), depictions of the radiocarbon distributions on a millennial scale, beginning at 6500 B.P. The latter date was selected because it signals the accelerated phase of post-glacial T3 construction when lateral accretion changes to vertical overbanking. A bi-modal distribution of dates is apparent with a primary mode centered on the time frame 3500-2500 B.P., and a secondary mode at 5500-5000 B.P. A minimal radiocarbon record centered on 4000 B.P. would appear to signal disruption in the aggradational phase and probable erosion. As discussed elsewhere, these degradation phases are probably associated with a break in terrace construction during the middle of the Atlantic climatic episode and incision during the Sub-Boreal (see Table 2.3).

The bi-modal radiometric distributions are also co-incident with periods of peak occupation along the T3 during the Late Archaic florescence in western Pennsylvania, initially after the Middle to Late Archaic transition and subsequent over the course of Late Archaic to Transitional and Woodland periods.

Construction of the T3 is most comprehensively calibrated by the chronostratigraphy of Area 2, which is continuously dated over a five-meter depth (from ±215.0 to 210.0 m) of alluvial sediments and intervening soils (Figure 2.67). Distributions of the dates, from Area 2 in particular, converge on a reliable, vertical chronosequence of landscape construction for only the upper 3 m (to a depth of ±212.0 m) beginning around 6500-6000 B.P. or from the Middle Holocene onward. The time-depth spreads of antecedent dates, of Early Holocene age, is so broad as to be ostensibly inconclusive with respect to construction of the T-3 landform. For example, at ±210.5 m deposits were dated within a range of 4500->12,500 B.P. and at ±210.5m the range narrows slightly from 6500-12,000 B.P. (Figure 2.69a and 2.69b). These discrepancies may be accounted for by outliers that presumably represent errant dates. Questionable radiometric determinations are a not infrequent result of dating the organic fraction in soil. Of equal and probably greater likelihood, however, is the possibility that these anomalies in the vertical chronology reflect a floodplain geography of laterally zoned landforms in an emerging alluvial basin. The latter explanation is consistent with our proposed model of a braided to actively meandering channel of the Ohio that was still laterally constructing its alluvial plain in advance of the vertical stabilization of the T-3. Thus the dates beneath 212.0 m correspond to geomorphic events assigned to our unit AU-1, while the more vertical alignment of dates above this elevation conform to vertical floodplain construction as represented by AU-2
Equally provocative in the time-depth distributions of dates, again most prominently featured in Area 2, are co-eval sets of radiometric determinations separated by 1000-1500 years at identical elevations (Figures 2.70a and 2.70b). This unique distribution is concentrated within a 2.0 m accumulation of sediment between elevations 214.0 and 212.0. Initial aggradation occurred after 6500 B.P. In the upper 1.5 m, however, dates within the band are either clustered at 4500 B.P. or 3000 B.P. with no determinations within the intervening 1500 years. Bimodal distributions of dates at the same elevation reflect a significant disruption in the vertical accretion regime on the T-3, as a major erosional event swept away the proximal segment of the T-3 and resulted in the initial aggradation of the T-2. This geomorphic event is most clearly expressed in Area 2, as documented elsewhere, and is registered by a lateral unconformity, presented in our allostratigraphic model as the AU-2a and AU-2b interface. This interface is represented in the cultural sequence by two discrete archaeo-sedimentary packages in Area 2. Thus, the Late Archaic is preserved on the central portion of the landform in organic silty deposits, while at the same elevation on the proximal portion of the terrace, the succeeding Transitional component is housed in sandier matrices.

Figures 2.70a and 2.70b shows that this event was apparently localized. Accordingly, above elevation ranges of 214.5-214.0 dates clustering around 4000 B.P. are prolific for Areas 1 and 3-South, an indication that both the distal and southern portions of the T-3 were unaffected by the erosional event, and, further, that prehistoric peoples would have populated on those portions of the landform during the Terminal Archaic period. It is noteworthy that only the southwestern portion of Area 1, whose soil stratigraphy was continuous with that of Area 2, preserved the bimodal radiometric distribution patterns at an elevation of 214.0.

Finally, Figures 2.70a and 2.70b show the segregated spatial distributions of radiometric dates begins to converge above elevations 214.0-214.5 meters after 4000 B.P. (in Areas 1 and 3 South) ultimately extending to Area 2 by 3500 B.P. The merging of dates across the landscape suggest that the T-3 emerged a level and coalescent landform at this time, during which a uniform pattern of vertical accretion extended laterally and only high discharge flood events contributed suspended loads to the T-3. That stage of geomorphic development conforms to allostratum AU-3.

Consistent with these chrono-stratigraphic distributions, the evidence for upper Middle to early Late Archaic occupation is irregularly preserved in the bottom three meters of the T-3 in Area 2, and minimal evidence for early human occupation is registered at any of the other areas. As shown, the preponderance of the cultural materials for Areas 1, 2, and 3-South were preserved in the upper two meters of the landform, clustered in the interval 5000-2000 B.P. during the Late Archaic to Transitional and early Woodland periods.

**Summary**

Section 2.6 has presented the corpus of results from the geomorphological investigations. Both field and laboratory analyses are summarized above and provide the basis for the allostratigraphic model introduced at the beginning of this section. This refined AU system for Site 36AL480 also establishes a framework for comparison with local and regional sites that exhibit similar patterns of genetic development. These intersite analyses are discussed in detail in the following section.
LOCAL, REGIONAL AND EXTRA-REGIONAL IMPLICATIONS OF THE SITE 36AL480 SEQUENCE CHRONOLOGY: THE GENETIC STRATIGRAPHY PERSPECTIVE

Insofar as the geoarchaeological investigations at Site 36AL480 provided one of the most comprehensive sequence chronologies for the Upper Ohio drainage, as well as for the Middle Atlantic region, it follows that the stacked and buried landscape and archaeological records would have correlates locally, regionally, and even extra-regionally. The following section explores these potential correlates by expanding the interpretive scope of the Leetsdale sequences inductively and on progressively larger scales. Moreover, the theoretical foundation of our study—the genetic stratigraphy model—functions as a convenient construct for testing the goodness of fit between the Leetsdale successions and multi-component alluvial stratigraphies elsewhere.

In this connection, it should be reiterated that genetic stratigraphy is grounded in projecting the applicability of genetic units with respect to their lateral extent (see Section 2.4; Vento et al. 2008). For example, in the case of low-order drainages, strata in an alluvial succession can be expected to be autogenic, young, poorly developed horizons (Entisols) that are locally developed and, therefore, limited in correlative potential on the extra-local scale. Allogenic units, typically paleosols as applied in the Leetsdale study, have considerably broader geographic reach as pedogenesis reflects sustained intervals of landscape stability that are a product, in part, of regional climatic trends.

Since the Site 36AL480 strata registered both depositional and soil developmental histories on a major trunk stream landform, it has been demonstrated that its sequence stratigraphy has implications for localized (autogenic) events (the AC horizons), as well as for allogenic contexts that would include, for example, marker units (cumulic A, deeper Bw, Bt, or Btx horizons) regionally and beyond. Finally, it should be noted that a hybrid situation, one in which autogenic and allogenic units can be registered stratigraphically, would be expected at stream confluences of higher order drainages, where complex alluviation patterns may make the segregation of local and regional scale events difficult to unravel.

The degree to which these correlations can be demonstrated is the objective of this Section. Stratified archaeological sites were examined on the following scales and locations as follows:

• Local sites (three) for the Upper Ohio Valley at main stem confluences (Figure 2.71);

• Regional (Middle Atlantic) sites (four) for trunk drainages: the Ohio, Susquehanna, and Delaware valleys (Figure 2.72);

• Extra-regional sites (four) along the Ohio extending from Leetsdale to the Middle reaches of the valley (Figure 2.73).

Discussion of site sequences at each comparative scale is presented below.
Local Sequences of the Upper Ohio Valley (Ohio River Corridor, Allegheny County)

Leetsdale Sewerage Treatment Plant Study, Leetsdale, Upper Ohio River

The Leetsdale Sewerage study area was situated one km (.6 mi) east of Site 36AL480 on the same T3 terrace on which Areas 1, 2, and 3 South were located. Terrace elevations at the Sewerage project area were similar to Site 36AL480, at approximately seven to eight m (22-26.2 ft) above the active river channel, and only 120 m (393.7 ft) to the north. Neither segments of the T2 nor the T1/T0 landforms, however, were present along this reach (Vento 2007).

Upper sediments on the T3 terrace largely consisted of late-nineteenth and early-twentieth century fills, and the lower historic debris was analogous to that of Area 1 at Site 36AL480. The soil stratigraphy featured an A-Bw-Bx-C1-2AC-2Bx-2C succession in Trench 1, and an A-Bw-C1-2Bx succession in Trench 2 to depths of a meter and a half below fill (Vento 2007; Figure 2.74). The identified fragic horizon (reported as Bx) exhibited a dense, stiff, brittle, weak prismatic to strong subangular blocky structure. The 2C was a coarse-grained gravelly, pebbly sand splay deposit immediately underlain by bedded lamellar sands. These were the relict lateral accretion deposits of probable middle to early Holocene age.

Archaeological unit excavations produced late Woodland artifacts preserved in an A horizon capping a late Holocene soil-sediment package from the upper half meter. These would be equivalent to AU-3 at Site 36AL480. The slightly deeper Bw horizons were of probable early Woodland and Transitional Archaic age, and produced a sizeable inventory of artifacts. The timeframe corresponds with the Sub-Atlantic and terminal Sub-Boreal climatic phases. The 2AC-2Bx horizons were considerably older and contained artifact-rich horizons. These are probably dated to the Atlantic through Sub-Boreal climatic intervals (8000-3000 B.P.), and would appear to broadly correlate with AU-2 at Site 36AL480. The sedimentary sequence documents a sustained interval of slow, but continuous, vertical accretion on the terrace. Preliminary indications suggested that the fragic soils formed after 8000 B.P. Significantly, however, the sequence at the Leetsdale Sewerage Plant was more compressed than that at Site 36AL480, with aggradation rates on the order of 20-30 percent slower, since the thickness of the Holocene sediment package extended only 4 m (in contrast to greater than 5 m at Site 36AL480). The reasons for this discrepancy have remained unclear, but it is possible that accretion was higher at Site 36AL480, because the latter location may have had additional sediment contributions from lower order drainages at the confluence with the Ohio (i.e., Sewickley Creek).

North Shore Connector, Pittsburgh, Upper Ohio River

The North Shore Connector site was located about 25 km (15.5 mi) upstream of Site 36AL480, at the confluence of the Monongahela and Allegheny Rivers (Vento 2008). As noted earlier, this site constituted a stratigraphic context where the identities of allogenic and autogenic strata were difficult to distinguish.
Surfaces at the project area were identified at a nominal elevation of 220.7 m (724 ft) asl, or some 4.3 m (14 ft) above the active normal pool elevation of 216.4 m (710 ft) of the Ohio River. The active river channel occurred within 150 m (492 ft) of the project area (Vento 2008). At the North Shore Connector site, the height of the landform above the stream channel was more akin to the setting of the T2, rather than T3 landforms at Site 36AL480.

As at Site 36AL480 and the Leetsdale Sewerage Treatment Plant site, the upper portion of the North Shore Connector sequence contained historic (twentieth-century) structural remains and fill to a depth of 2.5 m (8 ft). The fills disconformably overlay a BC/2Bw succession that attained a nominal thickness of 1.5 m (5 ft), with the 2Bw weathered over nearly a meter of coarser grained (sandy) alluvium. Relict and coarser lateral accretion deposits (sands/sands and gravels) closed out the column profile to a depth of 7 m (23 ft) below surface (Vento 2008).

In isolated areas, the upper substrate was undisturbed, and featured a preserved and artifact enriched A horizon immediately beneath pavement. The horizon was interdigitated with cultural matrices of both historic and late prehistoric age, including archaeological features and flaked stone artifacts. The underlying silt loam BC and fine-grained Bw horizons were devoid of prehistoric artifacts to the depths of testing at 2.5 m below surface (Vento 2008).

The fine-grained and thick sediment package for the BC horizon indicated a somewhat lengthy phase of slow, but continuous, overbank deposition on the former floodplain (T2), apparently during the late Holocene. The nature of the deposits suggested emplacement via overbanking from low-magnitude flood events. The inferred late Holocene age for both the BC and underlying 2Bw horizon was based upon the latter’s relatively modest degree of pedogenic development that was characterized by weak ped structure attendant to modest weathering. This soil-sediment package was equivalent to AU-3 at Site 36AL480. The underlying C1 horizon was likely emplaced in a distal floodplain, possibly a lower lying slough. This horizon documented very low-energy, slack water deposition, while the basal C2 horizon indicated relict, coarse-grained lateral accretion, with deposits emplaced when the raised terrace was more proximal, or closer, to the active river channel (Vento 2008). The basal sediment package is of AU-2 age.

As noted, the topographic position of the North Shore Connector terrace (4.3 m [14.1 ft] above Ohio River water line), coupled with that landform’s sedimentology and stratification, presents a setting that is most analogous to the lower T2 terrace at Site 36AL480. Comparisons of geomorphic and archaeological associations between the North Shore Connector and the T2 at Site 36AL480—as exposed in the section between Trenches 5-1 and 5-2 at Leetsdale (see Vento et al. 2000: Figure A17)—illustrated nearly identical time-depth and soil forming sequences. Characteristically, the deeper early and middle Holocene (10,000-4500 B.P.) sequences were missing, since aggradation over the terminal Pleistocene outwash sands began shortly after 3500 B.P. Thus, the thickness of the Leetsdale T2 parent material (C horizons), and uniformity of the landform morphology, would signify construction of the terrace via continuous low-magnitude flood events between the later middle to late Holocene (4500-500 B.P.).
This site was situated immediately upstream of North Shore Connector, about 25 km (15.5 mi) from Site 36AL480, and marked the conjunction of the Monongahela and Allegheny channel trenches. Given this location, the site’s stratigraphic context was expected to preserve evidence of both allogenic and autogenic strata (Vento 2008).

Two primary landforms spanned the Point State Park Enhancement (City of Pittsburgh) project area (Figure 2.75). These landforms include a higher T1 terrace situated at a nominal elevation of 222.2-221.6 m (729-727 ft) NGVD. The lower T0 floodplain zone was located at an elevation of 219.5-220.1 m (722-720 ft) NGVD and had a more limited distribution. The T0 likely correlated with the higher T3 terrace identified at Site 36AL480 stratigraphically, although the terrace chronology at this location was different.

Accordingly, at Point State Park there was a thick package of Holocene-age vertical overbanking deposits capping relict lateral accretion deposits of late Pleistocene (and late Wisconsinan) and early Holocene. These oldest, relict, lateral accretion deposits were encountered at depths between 4.9-7.3 m (16-24 ft) below ground surface at the T0 landform. The present pool elevation of the Ohio River at its confluence with the Allegheny and Monongahela Rivers is 216.4 m (710 ft) asl.

On each of the terraces, the thickness of the Holocene age vertical accretion deposits was directly related to the terrace surface height above the active river channel. For example, on the higher T1 terrace, the thickness of the Holocene vertical accretion package could not be addressed, since evidence for elevations and extents of former surfaces were significantly obliterated by historic landscaping; there were some indications that they never exceeded accumulations of one meter. On the lower T0 landform, however, more than four meters (13.5 ft) of Holocene age vertical and lateral accretion deposits were registered. The Holocene deposits were consistently underlain by coarse-grained lateral accretion and outwash deposits of late Wisconsinan age. These basal deposits were likely part of a broad, braided river channel. While the Wisconsinan ice sheets had probably retreated out of Pennsylvania by 15,000-14,000 B.P., the large volume of meltwater discharge down extant and newly created channel trenches precluded development of a graded, meandering channel habit. In fact, between the terminal late Wisconsinan and the Younger Dryas (ca. 14,000-10,000 B.P.), the channel habit of the Allegheny and Ohio Rivers was braided (Kaktins and Delano 1999; Wagner et al. 1970). To date, no Late Quaternary sites along the major drainage lines in western Pennsylvania, including Site 36AL480, have provided evidence for even localized vertical accretion during the terminal late Wisconsinan period.

At Point State Park, the deeply buried and coarse-grained lateral accretion deposits emplaced during the Younger Dryas interval (11,000-10,000 B.P.) were variously overlain by lateral accretion (point bar sands) and vertical accretion deposits of early Holocene (Pre-Boreal) age. It was at the termination of the Younger Dryas (circa 10,000 B.P.) and the beginning of the Pre-Boreal climatic episode that the Allegheny and Ohio Rivers developed meandering channel habits, and began a phase of active terrace construction. The rather thick and well-developed soils (strong cambic B horizons as seen in trenches GS 24, WS11, and WS 15 at Point State Park; see Figure 2.75; Vento 2008) indicated a lengthy period of
continuous, fine-grained vertical accretion. The early Holocene through late middle Holocene soil horizons (10,200-3000 B.P.; AU-1 and AU-2 at Site 36AL480) on the T1 terrace at Point State Park showed a clear absence of any distinct sand horizons (autogenic events) prior to 6000 B.P., suggesting that large cyclones (hurricanes) could not penetrate into Pennsylvania, due to the blocking effects of the ablating ice sheets (Vento and Rollins 1989).

At Point State Park, the Late Archaic through Woodland occupations occurred within the upper 1.5-2 m (4.9-6.6 ft) of the included soil package (see Figure 2.75). This temporal occurrence of artifacts within the upper sola was similar to that at Site 36AL480, where the Late Archaic and Transitional Archaic period occupations were associated with the uppermost Bw horizon in Area 2, with the thick package of stacked AC-C couplets in Area 1 (AU-2), ASC Blocks 1-5, and the southern part of Area 3 South. The stratigraphy was broadly correlative with AU-2 and AU-2b (Area 2 only).

More specifically, the geoarchaeological sequence is described as follows for Point State Park. A well-developed cambic B horizon (Bw) formed beneath an over-thickened or cumulic A horizon. In most places, this horizon had been removed or truncated by historic land usage; in select locations, however, the horizon remained intact and offered a reconstruction of the terrace stratigraphy and flood history. The A horizon, where present, contained a compressed assemblage of Woodland prehistoric cultural materials, as well as early historic period artifacts (Vento 2008). This horizon spanned the period 3000 B.P. to present (Sub-Atlantic-Scandic-Neo-Atlantic-Pacific climatic episodes), documenting slow vertical accretion of the terrace, and was equivalent to AU-3 at Site 36AL480. Thus the AU-2 and AU-3 at Point State park are differentiated by a gradually accreted soil in which the rates of sedimentation and soil formation reached stasis. Excavations in Area 1, Area 2, and Area 3 South at Site 36AL480 further support evidence of general terrace stability and low rates of vertical accretion during the late Holocene, as most of the Woodland period artifacts recovered from excavations in Areas 1, 2, and 3 South are restricted to the upper sola (A-upper Bw).

Summary Statement

Elements of the allostratigraphy at the Site 36AL480 were apparent in each of the Upper Ohio Valley sites examined for comparative purposes. Sequence correlations could be projected on the local level, and within the overall perspective outlined by the genetic stratigraphy model. Correlative projections on the local level were based on the following site-specific observations:

The Leetsdale Sewerage Treatment stratigraphy mirrored the entire post-Pleistocene depositional and soil forming sequences of the T3 terrace at Site 36AL480. AU units 1-4 were represented at both sites. The primary difference in the two vertical records was the lower sedimentation rate at the former site. Autogenic mechanisms may account for episodic erosional phases that would have resulted in “net” deposition, while evidence of terrace attrition may be absent. Construction of the T3 terrace at Site 36AL480 may have been more sustained and regular.
The North Shore Connector site featured a T2 sequence that was nearly identical to its morpho-stratigraphic counterpart at Site 36AL480. Here AU-1, AU-3, and AU-4 were present, while AU-2 (representing the early through middle Holocene) was absent. No evidence for autogenic sedimentation was noted.

At Point State Park, all AU units were also present, but the morpho-stratigraphic relations were different from those at the other sites. At this upstream Ohio River location, the T0 landform accommodated the composite post-terminal Pleistocene succession in a seven-meter-thick depositional package identical to that of Site 36AL480. The sequence preserved the thickest and, by extension, most detailed evidence of the latter middle to late Holocene stratigraphic succession. The cumulic soil of AU-3 formed on a stripped surface of the AU-2, and provided clear evidence of a critical change in the homeostatic relationship between pedogenesis and alluviation at this time. While this geomorphic transition is clearly allogenic in scope and scale, the process may be considered autogenic as this location was the only one in which the minutiae of sedimentation and soil formation are so clearly in evidence. The location of the profile, at the conjunction of two higher order streams, indicated that allogenic influence overrides autogenic process, and may have been enhanced by it, given the detailed and well-preserved sedimentary and pedogenic signatures of the upper profiles.

**Regional (Middle Atlantic) Sites for Trunk Drainages: the Ohio, Susquehanna, and Delaware valleys**

Geoarchaeological studies have been widely applied to three of Pennsylvania’s trunk drainages, the Ohio, Delaware, and the Susquehanna, demonstrating the widespread potential of such investigations to inform on drainage-wide and inter-drainage parallels in landscape and cultural histories. In this discussion, we compare and contrast representative deeply buried sequences across the state of Pennsylvania, drawing on recent studies undertaken at select sites. The common denominators for these comparisons are:

- Each sequence is derived from a terrace, generally T2 or T3, which is morpho-stratigraphically equivalent to the settings at Site 36AL480;
- Sedimentary and stratigraphic columns extend to the base of Holocene deposits;
- Ages of primary vertical units are well dated radiometrically;
- Each column incorporates stratified soils and sediments that can be assumed to be representative of drainage wide soil chronologies and alluvial histories because of the lateral extent of its associated landform; and
- Each site preserves vertically ordered prehistoric components in discrete and separable stratigraphic contexts.
Collectively, these characteristics should have implications for assessing the applicability of the genetic stratigraphy model on the regional scale. Included are the following:

- Sandts Eddy (36NM12), Delaware River (Bergman and Doershuk 1994; Schuldenrein 2003)
- City Island, Harrisburg (36DA12), Susquehanna River, Main Branch (Schuldenrein and Thieme 1998)
- Memorial Park (36CN164), Susquehanna River, West Branch (Cremeens et al. 1998; Schuldenrein and Vento 1994)
- Mayview (36AL134), Chartiers Creek/Ohio River (Robertson et al. 1993; Schuldenrein 1992)

Of these locations, only Mayview is part of the Ohio River catchment. The site is located approximately 40 km southwest of Leetsdale, on Chartiers Creek, a third order tributary of the Ohio River. The Mayview site (36AL134) occupies a T-1 surface, 3-4 m above the stream bed but archaeological occupations grade to lower lying T-0 surfaces (2 m above water line). The terraces are hemmed in by colluvial and alluvial fan complexes. This location was selected to determine whether or not autogenic as well as allogenic influences affected the depositional column, since the stratigraphic column was registered on a lower order feeder to the Ohio; geomorphic processes here may have been at least somewhat localized.

The other three deeply stratified sites are all along the main stem of the two other regional trunk streams of Pennsylvania: the Susquehanna and Delaware rivers. Memorial Park (36CN164) is set atop a 5-6 m T-1 surface overlooking the south bank of the West Branch of the Susquehanna River. The terrace abuts the surface of the T-0. Surface elevations are on the order of 168-169 m NGVD above the active Susquehanna channel. The site landform has been mapped as a remnant terrace of the Late Wisconsinan Port Huron Substage terrace (Schuldenrein and Vento, 1994). City Island (36Da12), located approximately 180 km downstream from Memorial Park and within the main stem of the Susquehanna is set on the morphostratigraphically same landform (T-1), at an elevation of 102 m (Schuldenrein and Thieme 1998). Finally, the site of Sandts Eddy (36 Nm12) is set within the lower reaches of the Upper Delaware Valley immediately south of the glacial margin. Local topography is dominated by broad, moderately dissected valleys with undulating surfaces and the site is situated on a 5 m high terrace, flanked by a discontinuous T-0. The alluvial landforms are hemmed in by steep sided bedrock valley walls (Schuldenrein 2003). In terms of the Schumm (1977) drainage zones, all the sites and valley segments used for this comparison are contained within the transition from the sediment “production” or “transfer” zones. This drainage model may be conveniently applied to northeastern drainages whose basins extend at or near the glacial margins, where sediment mobilization is greatest because of the variety of alluvial materials contained within the valley fills.
Given the geographic controls on the depositional settings of these site, it is feasible to synthesize the geoarchaeological sequences at each from west to east. Figure 2.76 illustrates the similarity of development sequences across the trunk streams of Pennsylvania. Comparisons are made to the composite stratigraphic profile provided by Area 3 South because that central portion of the site provided some of the most representative depositional suites across the T3 terrace.

Composite stratigraphies for these sites are at least three meters in depth, with the exception of Mayview (36AL134) in which cultural deposits were only preserved within the upper meter and a half. As noted, that succession is also derived from a tributary that preserves a more incomplete stratigraphic record. Observations from Memorial Park (36CN164) were made on two representative columns that collectively recorded the entire depth of sediments to the Early Holocene sands.

Figure 2.76 depicts representative sections for each of these sites running west to east, from the Ohio to the Delaware River basins. For the Sandts Eddy sequence, a single column is representative of the site stratigraphy, since depositional and pedogenetic sequences were not markedly variable across the site. The Susquehanna River sites (Memorial Park and City Island) featured somewhat greater inter-site variability, as the latter was from the central valley and the former from the West Branch, farther upstream. Finally, the Mayview site was a useful supplement to Leetsdale, because only the later prehistoric record (younger than 2000 B.P.) was preserved at that location and much of the Late Holocene record at Leetsdale (especially on the T3 terrace) had been destroyed, both by erosion and historic landscaping.

The four primary allostratigraphic units that structured the Leetsdale chronology have been adapted for the inter-site comparisons. For purposes of this study the sub-divisions for AU-2 (AU-2a and AU-2b) are not used, as we have not yet tested this level of chronostratigraphic resolution beyond Site 36AL480. Conversely, we have been able to identify a significant sub-division for AU-1 (AU-1a and AU-1) since there appears to be a discrete disconformity breaking out the earliest Holocene post-glacial sands from overlying suites of weathering profiles (paleosols), as explained below.

On a gross level, the AU units accommodate the entire 12,000 years of alluvial history contemporaneous with the prehistoric record and each unit is broadly traceable for the sequences in question. They form the basis for the commonalities and differences in linked landscape and occupational histories. Further, since allostrata are segregated by unconformities, their persistence across the three drainages indicates changes in these histories that are synchronous and broad in scale. The relevant archaeological associations are depicted for each site, along with documented soil sequences; absolute dates (in bold), and projected dates (in italics). Projected dates are derived from diagnostic artifacts, features, and typologies. Cultural associations are depicted in terms of relative integrity, with three triangles reflecting optimal preservation (i.e., dense, in situ occupations), two triangles indicative of lighter but primary occupations, and a single triangle signifying more limited evidence and potentially displaced artifact contexts. The assignment of cultural components to each of the AUs is based on recovered artifact assemblages and reinforcing radiocarbon dates.
Beginning at the base, AU-1 represents the Early Holocene period from 11,500-6500 B.P. Basal sequences begin above Pleistocene gravels and are invariably characterized by deposition of massive sands that progress to graded sand sets in the upper third of the unit. Reviewing the stratigraphic records, it becomes apparent that the trend is consistent across the drainages and that graded bedding, in the form of lamellar beds (A-C successions), displaced massive sandy depositions everywhere after about 10,000 B.P. For this reason, the basal sands were designated AU-1a and the overlying graded sands were classified AU-1b. AU-1a represents the initial hydrographic overhauls of all of Pennsylvania’s drainages following the melting of the glaciers sometime within the range of the Pleistocene/Holocene transition (ca. 10,000 B.P.). The stream flow model constructed for that timeframe for Leetsdale, one of braided streams, connotes anastomosing channels for every trunk drainage (Schuldenrein et al. 2003). After 10,000 B.P. all streams experienced a transition to lower sedimentation rates, graded beds, and most significantly, the shift in channel morphology from a braiding to a meandering aspect. This transition is represented by AU-1b. Moreover, the AU-1a to AU-1b transition is marked by the earliest evidence for regional pedogenesis as soils formed on lateral accretion deposits at around the time of the Early to Middle Holocene transition (ca. 6500 B.P.).

As shown, for each of the major drainages, the net vertical accumulation for AU-1 accounts for between 40 to 60 percent of the terrace fills by volume. This reflects that landform construction, or the buildup of the T3 terrace, occurred during the Early Holocene. For the Ohio, and to a lesser degree for the Susquehanna drainages, however, the amount of vertical buildup was generally less than for the Delaware. The central and western valleys are considerably wider and accretion, both lateral and vertical, was a more complex process. It follows that the most dynamic geomorphic environments of the contemporary Pennsylvania valleys existed when AU-1 was laid down. An exception is the case of City Island where the base of a deep fragic soil extended well into AU-1b. The reasons for this are unclear, but there are indications that a major upper Early Holocene soil caps AU-1b and that manifestations of it (4Bt horizon at Memorial Park; 3Btx at City Island; 4Bw at Sandts Eddy) are present on primary T1 outcrops everywhere along the trunk streams.

Archaeologically, AU-1 is equivalent in time to the Paleoindian-Early Archaic periods (AU-1a) and Early Archaic-Middle Archaic periods (AU-1b). Figure 2.76 shows that evidence of cultural remains within AU-1a is missing everywhere, with the possible exception of Leetsdale. AU-1b cultural deposits have been documented at all sites, but these are thin and disparate. They are most widely represented at Sandts Eddy. The reason for the low expectations for sites of these periods is that the deposits containing them are high energy flood sands. These sands are erosive, mobilize cover sediments, and tend to bury cultural deposits only in well-defined microenvironmental settings. Finally, in this connection, it should be noted that while the depositional chrono-stratigraphy of AU-1 appears to be a widespread phenomenon across much of the Middle Atlantic trunk drainages, it is by no means universal and significant regional exceptions have been documented for particular primary streams and critical reaches of their drainageways (Wagner, personal communication).

AU-2 accumulated between 6500-3500 B.P., because of the greater width of the Ohio, it is thickest at Leetsdale (reconstructed as AU-2a and AU-2b) and thinnest at Sandts
Eddy. In general, however, net sediment accumulation during the Middle Holocene is diminished significantly as vertical construction of the T2/T3 terrace was a dominant process during this period. At the same time, stream flows were largely confined to stabilized channel trenches (after 6000 B.P.; see Ritter et al. 1973; Schuldenrein 1994). Stream levels were relatively lower (vis-à-vis terrace elevations), flooding was less frequent, and sediment contributions to up-building terraces were a function of channel overbanking (a vertical process) rather than channel migration (a lateral process). The contact between AU-2 package and AU-1 is sometimes marked by a period of non-deposition, generally between 6500-5500 B.P. for which there are both relatively few radiocarbon dates and reduced concentrations of archaeological deposits. This may be due to the erosive interval between the termination of point bar deposition and the initiation of vertical floodplain accretion.

After 5500 B.P., soil formation was clearly favored over sedimentation and the variability between soils is striking, both within and between sites. Soil subordinate horizons that are characteristic range from cumulic (in which sedimentation is ongoing but limited weathering is visible) to cambic (in which Bw formation suggests short-term cessation of flooding) to Argillic (wherein aggradation is minimal) and fragic (a context defined by brittle soil consistence, minimal organic content, and bleached prism facies). At Leetsdale, this entire range of soils was identified. Similar profiles were noted at Memorial Park and City Island, both of which had substantial indications of fragile soil formation in which brittle cracking was observed in the deep soil horizon (labeled Btx). No such soil was present at Sandts Eddy because the sandier parent alluvium impedes this type of development. However, the most important aspect of this range of soils, emerging at all of these sites, is that conditions favorable to soil formation, specifically relatively stable terrace surfaces rising well above flood levels, were also conducive to habitation and preservation of archaeological materials.

Figure 2.76 also shows that the AU-2 package preserves archaeologically rich deposits, especially near the top of the unit. The higher the setting, the less exposed it was to high discharge floods and inundations that may have obliterated the evidence for human occupation. Moreover, at most sites, several generations of soils are vertically stacked and some or all of them contained layers of archaeological deposits that are most typically associated with Late Archaic period features. In general, single occupations are contained within buried soils, suggesting that weathering occurred after abandonment and subsequent occupations followed after the creation of new surfaces. Site 36AL480 constitutes a slight exception to this rule, especially in Area 2, where cumulus soil formation tends to blend distinctions between laterally discrete cultural horizons. Here, ongoing organic enrichment and vertical translocation of organics and mineral components together with pedoturbation can act to blur pedo-stratigraphic boundaries. However, gross archaeo-stratigraphic units may be differentiated archaeologically (on techno-typological grounds).

In terms of general morpho-stratigraphy, it is noted that the T-3 exposures at Leetsdale (Ohio River) are equivalent to the T-1 sections at Memorial Park and City Island (Susquehanna River) and those of the T-1 at Sandts Eddy (Delaware River). At least three discrete soils are preserved at Leetsdale and a similar number at Memorial Park. City Island remains anomalous in this connection as there is only one soil present and it is related to a deeper fragic soil profile that extended well into AU-1b. The implication is that during much
of the Middle Holocene, aggradation of the central Susquehanna T1 terrace was even more attenuated than elsewhere and a strong soil-forming environment was favored. A similar alluviation pattern for this time frame has been noted for the interior Potomac River (Wagner, personal communication). The long term evolution of a fragic soil here may be a function of local climatic and hydrographic conditions, but this remains to be investigated. In any case, conditions for archaeological preservation within AU-2 for the upper Middle to Late Archaic periods are very high. This is in part because of the limited exposure of T1 elevations to erosive flood events, but it is also because of the density of archaeological materials associated with these periods of population growth and expansion along the flanks of major rivers.

The AU-3 unit is relatively thin for all terrace outcrops and exposures as a function of their higher topographic positions (at T-3 Leetsdale and T-1 elsewhere). This is also the period of the T2 terrace construction at Leetsdale, although these soils were not investigated in detail, and the reach and distribution of this landform across the other trunk drainages has not yet been explored in systematic fashion. Nevertheless, the period represented by AU-3 is the interval from 3500-1500 B.P. In some cases, there is a marked disconformity at the AU-2/AU-3 interface (at Leetsdale, the AU-2b/AU-3 interface) on the T3 terrace, which is a function of the stripping of the uppermost AU-3 soils by low frequency but high discharge floods. Only the most turbulent inundations would have overridden T3 surfaces; these would typically be 50 to 100-year floods. Stratigraphic evidence for these manifestations are thin, well sorted sands capped by thin A horizons. Several soil generations may be represented within AU-3, many of which contain archaeological materials. These soils are classified Entisols (more commonly) or Inceptisols (less commonly). As their parent materials accumulated over the past millennium, the soils were often truncated and did not have sufficient time to develop sola (B horizons). Significantly, this observation applies for the T2 terrace as well because the parent material for the soil was very sandy and did not allow for pedogenesis over the limited time range of the Late Holocene. Across the Ohio and Susquehanna valleys, the record of AU-3 sediment and soil formation on the higher terrace is remarkably uniform, with each profile containing two or three thin soils (less than 0.75 m total aggradation). These are nearly absent in the upper Delaware because that terrace was rarely overtopped by high discharge floods during the Late Holocene.

The AU-3 unit is generally rich in archaeological remains of the Late/Transitional Archaic to Woodland periods. Upper components (Middle Woodland or later) are often missing, as they are at levels that might have been removed by historic landscaping activity and/or high discharge flood events.

The capping unit, AU-4, contains evidence for a variety of filling and stripping events associated with the Historic period. Thicknesses can vary greatly, as in some cases, surfaces were re-engineered with heavy equipment to impede flooding. In others, mechanical stripping has re-contoured surfaces. At abandoned terrace segments and in areas where hydrography has been substantially altered, floods cause thick depositions because of high sediment yield and runoff. The potential for preserving prehistoric materials in these contexts is unpredictable.
Summarily, the principal four allostratigraphic units preserved at Site 36AL480 correlates in the collective post-glacial alluvial stratigraphies for a representative sampling of primary drainages in the Middle Atlantic regions. While these units are discrete and sedimentary and pedogenic cycles are largely in-phase across drainages, there are some unique aspects to the histories of the drainages. Thus, for example, while AU-1b at City Island (Susquehanna River) exhibited a deep Early Holocene fragic soil (3Btx), that pedogenic chronosequence is represented by a series of stacked, less developed soils along the Delaware and Ohio. Conversely, recurrent sequences of moderately-developed soils are typical of Middle Holocene (AU-2) profiles at Site 36AL480 (Ohio River) and Memorial Park (Susquehanna-upstream). The time-equivalent pedogenic expression at City Island (Susquehanna-downstream) is overprinting of the deep solum at the upper segment of the Btx and simple lamellar formation at the Delaware Valley site at Sandts Eddy.

In both cases, it would appear that divergent patterns of pedogenesis should be linked to variability in parent material with weaker B-horizonation reflecting sandier channel and terrace fills and paleoclimatic influences accounting for more basic changes in edaphic conditions and consequent flow regimes and depositional patterns. Significantly, progressive thinning of the vertically stratified AU units through time reflects increasingly incremental construction of as upper terrace landforms and surfaces stabilized with time. Taken together, these commonalities reflect a more dominant allogenic signature for the upper terraces along the trunk stream. Broadly parallel sub-surface chronosequences, and by extension, analogous and synchronous landscape and paleoenvironmental histories are unmistakably registered on this scale. These comparisons argue for confirmation and beneficial applications of the genetic stratigraphy approach.

**Extra-Regional sites: Upper and Middle Reaches of the Ohio River**

An additional parameter for assessing the practical application of the genetic stratigraphy approach is extra-regional in scope. It involves applying principles of fluvial systematics along the drainage basin to gauge spatio-temporal change in the stratigraphic record. Upstream sequence stratigraphies should be coupled with their downstream counterparts to determine if systemic mobilization of sediment loads can be tracked and monitored within the confines of drainage basin geography. In this regard, Schumm (1977) has proposed a widely accepted model that suggests that ideally a drainage basin will erode its upstream segment and transport sediment downstream. Schumm (1977) divides the basin into three zones: the watershed or sediment source area (Zone 1), a transfer zone (Zone 2), and a sediment sink or area of deposition (Zone 3). Schuldenrein (1994) abstracted the principals of this basic geomorphic construct to develop a stratigraphically based archaeological preservation model for the Delaware Valley. In this model, upstream archaeological sites on higher terraces and in steep terrain, especially in glaciated terrain, tend to be deeply stratified and older and located on landforms that provide source sediment in the downstream direction (Zone 1.) Stratigraphic sequences will tend to overthicken in a downstream direction along the axis of transport as gradients diminish, floodbelts broaden, and younger sites are more deeply buried (Zone 2). The flatter terrain also comprises a more diverse alluvial landscape with greater possibilities for archaeological burial (and preservation) in landforms that are zonally configured. Thus, a variety of archaeological components of different ages may occupy discrete landforms spanning a broader, laterally
zoned, alluvial terrain. This sedimentary trend, accompanied by terrain diversity, continues to the mouth of the drainage where the stream debouches into the higher order trunk stream and discharges the greatest quantity of both sediment and archaeological material (Zone 3).

The Ohio system is analogous to that of the Delaware, insofar as the upstream source of the river is in glaciated terrain and gradients flatten and broaden in the downstream direction. It follows that the oldest sequences will be housed in the upstream landform, and progressively more complex vertical and lateral stratigraphic and geoarchaeological relationships will be expressed in a downstream direction. Since the T3 terrace at Site 36AL480 preserved the most complete record of geological and cultural stratification for the Upper Ohio Valley known to date, its relationship to the better known downstream Ohio chronostratigraphies is worthy of comparison.

The comparative data base for the Ohio Valley included four deeply buried sites associated with the trunk drainage:

- The Pleistocene/Holocene T3 and Late Holocene T2 terraces at Site 36AL480 (this report);
- The T1 terrace and ridge complex at Gallipolis, WV (Mandel 1988);
- An older Pleistocene (T2) and Holocene (T1) landform sequence in Boone County, KY (Schuldenrein 2006);
- The Early Holocene T1 terrace and ridge complex at Caesars, IN (Stafford 2004)

Detailed geoarchaeological descriptions are provided in the associated references. For present purposes, discussion is confined to reviewing the stratigraphic relationships for the associated landform-sediment complexes in a downstream direction. Figure 2.73 illustrates the locations of these sites along the Upper and Middle reaches of the Ohio. In terms of the Schumm (1977) model only Leetsdale represents an “erosional” context (Zone 1) in which three terraces (T1, T2, and T3) are hemmed in by the steeper terrain of the Ohio Valley uplands. The remaining sites are all within the “transfer zone” (Zone 2) and the “deposition” segment is at the mouth of the Ohio and Mississippi Rivers. The prominence of terrain and stream gradient change is highlighted in Figure 2.77. The steep topography in the Leetsdale site area represents slopes in excess of three times greater than the average of the middle reach of the drainage (Lexington Plateau) in which the other sites are located.

Morphostratigraphic and soil-sediment relationships for each of the site settings are shown in Figure 2.78 and landscape and preservation contexts are presented in Table 2.17. Proceeding in a downstream direction, the T3 terrace at Site 36AL480 expectedly houses the deepest, oldest, and most complete record of post-glacial sedimentation. Over 11,500 years of alluviation are housed in that single landform, with most of the prehistoric components preserved in discrete alluvial sediment packages or within soil horizons. The T2 terrace is the late Holocene landform and contains approximately 3,000 years of deposition atop an erosional facies of Pleistocene sands. Most immediately downstream of Leetsdale, the Gallipolis site complex is comprised of a series of complex, laterally configured alluvial
landforms, the main one of which is a six-meter-high linear Holocene ridge or discontinuous terrace; it is flanked by a Late Holocene terrace. The former is an early Holocene landform and the latter is of Late Holocene age. The geomorphic relations at Gallipolis are somewhat similar to those of Leetsdale, but the oldest (T1) landform preserves an incomplete archaeological record. The broader and more diverse alluvial landscape has preserved a mosaic of landforms, highlighted by a ridge and swale complex that spans a broad range of Holocene times. Significantly, well preserved Holocene soils are contained in the Gallipolis alluvial sequence. That situation is only partially mirrored further downstream at Caesar’s Archaeological Project (CAP) sites, where segments of Middle Holocene and Late Holocene landforms represent lateral relicts of complex flow lines as the Ohio River broadened in the low gradient zone. Stafford (2004: 1065) notes that “Early Archaic components will be buried from one-half to as much as five meters below surface under higher Holocene geomorphic surfaces.”

Table 2.17. Landscape Contexts for Four Archaeological Site Complexes along the Ohio River.

<table>
<thead>
<tr>
<th>Location (Archaeological Sites)</th>
<th>Ohio Channel width (m)</th>
<th>Ohio River water line (m)</th>
<th>Local Morphostratigraphy</th>
<th>Primary Archaeological Landform</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leetsdale (36AL480)</td>
<td>360</td>
<td>210</td>
<td>T1 spurs and T2, T3 flanked by steep Wisconsinan terrace</td>
<td>7 m high T3 (primary) and 5 m high T2 (secondary)</td>
</tr>
<tr>
<td>Gallipolis Locks and Dam (7 sites)</td>
<td>390</td>
<td>165</td>
<td>T1 terrace and ridge and swale complexes bounded by higher Wisconsinan terrace; loessic hills on distal margins</td>
<td>6 m high T1 terrace</td>
</tr>
<tr>
<td>Boone County (15Be485, 15Be489)</td>
<td>530</td>
<td>145</td>
<td>Diffuse T1 spurs (historic) inset within T2 (Wisconsinan) terrace; loessic hillocks on distal edge of T2</td>
<td>T2 Ridge and Aeolian Hillock atop 15 m high Wisconsinan terrace</td>
</tr>
<tr>
<td>CAP (multiple sites)</td>
<td>480</td>
<td>130</td>
<td>Yazoo type T2 terraces of secondary drainages at distal valley edges; main stem T1 terraces proximal to Ohio channel</td>
<td>T2 (secondary) and T1 (primary)</td>
</tr>
</tbody>
</table>
This observation underscores the broad range of erosional and depositional mechanisms that are registered in Zone 2 of the fluvial system in the Middle Ohio. Better developed Alfisols are typically associated with Early Archaic landforms, while Mollisols tend to correlate with the Late Archaic geomorphic surfaces at CAP. The Boone County landscape is unique insofar as it does not preserve any evidence of an intact Holocene alluviation regime and the most prominent terrace of Wisconsinan age.

Preliminary indications are that there is a tendency for vertical stratification, clearly defined terraces, and cut and fill alluviation cycles for the Upper Ohio. Stable surfaces are offset by soils on and within the terraces. In the Middle and Lower Ohio, extensive meandering occurred over the course of the Holocene and resulted in the preservation of planar landforms that were subject to erosion and/or deposition by meandering stream action. Soils are generally preserved on landform tops (i.e. terraces and related ridge networks), but not necessarily within them or in buried contexts (see Figure 2.78). A modified version of the Schumm (1977) drainage basin model appears to apply to the geoarchaeological contexts of the Ohio. However, the widening of the Ohio valley trench downstream has resulted in selective preservation of landforms, landform segments, and evidence of archaeological occupation. Evidence for linked landscape and occupation records is likely to be laterally as well as vertically preserved in these settings. Autogenic mechanisms are clearly as critical as allogenic process in explaining the stratigraphic sequences along the valley axis for the duration of the Holocene.

Finally, it is suggested that drainage wide modeling of geoarchaeological preservation and alluvial landscape histories is a productive line of inquiry. Site expectation is tied to linked trends in prehistoric settlement geography and fluvial geomorphology. The previous discussion has explored investigative methodologies that offer interpretive potential. It is beyond the scope of the present study to advance comprehensive geoarchaeological models of site expectation on a valley wide scale. However, the incorporation of extant Ohio Valley geoarchaeological data sets (from CRM reports and related research studies) is recommended to help refine further lines of investigative inquiry.

Summary

There is a striking similarity in terrace and floodplain histories for all the drainages of Pennsylvania. The sites closest to Leetsdale (the Sewerage Treatment Plant, North Shore Connector, and Point State Park) illustrate the terrace formation and soil development sequences common to the immediate Upper Ohio River region. The sewerage facility, in particular, demonstrated the potential for deeply stratified and well developed soils with preserved prehistoric cultural materials. Upstream, the Point State Park and North Shore Connector sites confirmed segments of the younger, less developed, soil-sedimentary packages seen at Leetsdale with the recovery of Late Archaic through Historic materials from the upper two meters of stratigraphy.

For state-wide trunk stream comparisons, the allostratigraphic system, in which four key stratigraphic units define major changes in the 10,000-12,000 year history of the valleys, is a convenient measure for monitoring linked cultural and landscape histories. The Leetsdale succession is, to date, the deepest sequence identified and suggests that the
potential for recovering key elements of the composite archaeological and geomorphic records is very high. Leetsdale had demonstrated its predicted potential for preserved archaeological remains, although in general, preservation contexts are poorest in the deep coarse sandy deposits. All sequences indicate that the main terrace landforms became high and dry settings that sealed archaeological evidence during the Middle Holocene, (ca. 6500-3500 B.P.). Finer sediments (fine sands and silts) sustained soil formation and erosion was minimal during this period. The archaeological record after 5000 B.P. (Late Archaic period) is prolific, and expectations for in situ occupations is high, for the upper two meters of deposits for all high terraces. Archaeological materials of the Transitional Archaic and Woodland periods are contained within a slightly different sedimentary context (thin floodplain soils with sandy parent materials). The frequency of such contexts is reduced because of the general tendency for upper surfaces to be disturbed by contemporary landscaping activities.

In sum, correlating sequences the length of the Ohio is a more complex challenge. Allogenic units are readily synthesized on the local and regional scales but are less applicable when they are projected extra-regionally, as the drainage basin study has shown.

GEOARCHAEOLOGICAL SYNTHESIS

Overview of Phase III Investigations

Early geoarchaeological interpretations at Site 36AL480 were based on the results of two primary sets of investigations. The first was an extensive Phase II testing program structured on five transects that cross-cut the two principal terraces (T2 and T3) and the flanking Back Channel at Site 36AL480 (Vento et al. 2001). The second utilized detailed stratigraphic and archaeological information from one of the three excavation tracts –Area 3 South – to propose an initial landscape reconstruction and site formation model that linked the occupation history to landform changes over the course of the Holocene period (Schuldenrein et al. 2003). Because the most detailed stratigraphic observations had been made at Area 3 South, the landscape construct was derived from sequences observed in that portion of the T3 landform directly underlying Area 3 South. As presented in that report, the T3 was underlain by a two to three meter thick Bw/Bt/Btx horizon that articulated with stratified archaeological components.

Initial drafts of the Area 2 (Miller and Marine 2005) and Area 1 (Barse 2003) studies expanded the window of observation to the northern and western segment of the T3 and to the greater T2, which extended to the north (downstream) of Area 3 South and had been minimally examined. The T2 is inset into the T3 along its perimeters to the west where it flanks the Ohio River and to the east, where it grades into the Back Channel. Area 2 includes an intact segment of the T2 at its western end, and Area 1 is largely positioned on that landform to the east, effectively clipping the edges of T3 and overlooking the Back Channel near the confluence of T2 and the historic course of Sewickley Creek.

An early revision to the terrace configuration and landform map (Schuldenrein et al. 2003; Figure 2.5) incorporated additional stratigraphic and sedimentological information from Area 2 to refine the mapping of the T2. It became clear that the Bw, Bt, and Btx
horizons were the signal pedostratigraphic markers for the T3 landform. Bw horizons, even thick and moderately well-developed variants thereof, were preserved within the T2; a classic example was in Trench 4-2 (Vento et al. 2001: Figure A8). However, Bw horizons were also housed in the upper meter of the T3.

In addition to providing a more comprehensive perspective on the composite landform complex of the Site 36AL480 meso-environment - or resource landscape - the geoarchaeological investigations at Areas 1 and 2 drew on micro-stratigraphies at both sites. Both areas preserved elements of the Area 3 South (T3) sequences, but Area 1 was largely excavated into a series of episodic early to late Holocene flood sands that registered minimal soil formation. Area 2 straddled the western limits of T3 where late Middle Archaic and Late Archaic features were preserved within the Bw/Bt/Btx paleosol. Significantly, that horizon was somewhat “overprinted” and enriched in organics because of variable contributions of anthropogenic sediment. The riverward portion of the Area 2 block was underlain by lamellar sands and AC couplets of the Late Archaic/Transitional to Woodland timeframe. That landform segment was on the order of 2,000 years younger than that to the east. Accordingly, the “geoarchaeological signature” of Area 2 bridged the T3 and the T2 landforms and contained a stratigraphy that was not previously recognized in the higher elevations of the T3, but contained depositional elements (e.g., sandy beds and AC couplets) that were more similar to the observed sequences in Area 1.

Variability and subtlety in landform relations was reflected in soil-sediment packages and ultimately pointed to the complexity of a Holocene depositional history that began with the post-glacial evolution of the Ohio River drainage. In order to understand the chronology of the composite sequence and its relation to the changing occupations across the T2 and T3 landforms it was necessary to reassess the basal Holocene sequence and to document how changing stream geomorphology and alluviation resulted in the differentiated and highly zoned flood-basin environment. This was initiated through landscape reconstruction beginning with earliest documented chronologies—for the Casting Basin and Back Channel—which simultaneously informed on initial channel geometry and terrace configurations and chronologies. Ultimately changing fluvial regimes, climatically forced (in part), accounted for distributions of the pivotal microenvironments and resource zones tied to discrete prehistoric subsistence and settlement loci on the various portions of the T2 and T3 (represented in Areas 1, 2, and 3-South).

The next two sections address the chrono-sequences of the emergent fluvial environments and proceed to detail the specific history of terrace formation. An underlying assumption here is that threshold changes in fluvial history underpin the chronology of landscape change at Leetsdale so that a classic diachronic account of events supplements rather than explains the nature of landscape history here.

Chronostratigraphy and Landscape Archaeology

Channel Environments and Aquatic Biomes

At the close of the Pleistocene, the Ohio River was a braided fluvial system with largely sandy-gravel bedload based channels (AU-1). While differentiated basin landforms
clearly broke up the terrain, ongoing high-energy fluvial activity eroded most of the remnants of the finer-grained back-basin settings (i.e. swales and aquatic zones) well into the Early Holocene. As documented in this study, bulk dating samples and pollen profiles from paleo-biotically diagnostic strata in the Casting Basin and Back Channel helped structure the chronology and paleoenvironments of the Holocene micro-environments at Leetsdale. Accordingly, Jones (2006) demonstrated that slackwater and aquatic settings emerged in the vicinity of the Casting Basin (in proximity of the present Ohio River channel) during the middle Holocene (8000-6000 B.P.) and shifted to the Back Channel during the later Holocene (4500-2500 B.P.). As discussed in Sections 2.4 and 2.6, these intervals reflected shifts in Ohio River channel geometry probably accompanied by reduced competence in channel flow. These interpretations are partially reinforced by the radiocarbon distribution trends that show minimal numbers of dates for these periods, perhaps reflecting the geomorphic thresholds and the passage from higher velocity to more quiescent stream flows. Dateable matrices would not be expected to survive in coarser sediment matrices diagnostic of earlier turbulent stream flows, but would be expected to be housed in finer grained, organically enriched sediments associated with suspended load sedimentation and vertical aggradation. Thus, the peat and organic silts that calibrate these time frames and attest to periods of wetlands florescence are associated with intervals of low net deposition and soil formation on the T3 and, to a lesser degree, with diminished deposition on the T2. Finally, the pollen column of the Casting Basin shows that by 6000 B.P., this portion of the landscape was transformed from a wetland forest mosaic to an active channel, as arboreal concentrations declined precipitously; this marks the AU-1 to AU-2 transition (Jones 2006; see Figure 2.49).

In the Back Channel, Jones (2006) notes that the basal section of the phytolith sequence, coincides with pedogenic horizons identified by Vento et al. (2001) as belonging to AU-1, indicating that the area was heavily forested. This is taken to represent a moister interval, which is completely consistent with the phytolith record. The middle interval of the phytolith sequence records a gradual decrease in forest indicator phytoliths, and a slight increase in grass types. This interval matches up with AU-2, a drier period marked by one or more major drying events (Jones 2006).

Summarily, paleoenvironmental reconstructions suggest that the Casting Basin sustained an aquatic resource zone during the Middle Holocene after which (i.e., post-6000 B.P.) it was transformed to a riverine environment. The Back Channel probably functioned as an active stream artery during the Early through Middle Holocene, and was transformed to a more quiescent biome after 4500 B.P and extending well into later Holocene times. Thus, the changing fluvial dynamics of Ohio River during the Holocene generated significant transformations in the microenvironments surrounding Site 36AL480. The earlier Holocene or aquatic setting is currently under the footprint of the Casting Basin, while its later Holocene counterpart is the current Back Channel. Locally, then, the Ohio River channel lines migrated extensively over the course of the Holocene, resulting in a situation where the chronologies of the riverine-aquatic succession in the Casting Basin and Back Channel were effectively reversed. These complex channel migrations and their diachronically documented impacts on floodplain zonation help to explain the emergence of the T-3 as the primary settlement locus at Leetsdale and the changing geography of occupation through prehistoric time.
Terrace Chronologies and Allostratigraphy

The following discussion examines the intra-site and inter-site soil stratigraphic relationships on the T-3 and environs, between excavated areas (Area 1, Area 2, Area 3 South, Casting Basin, Back Channel, and ASC Block Units). Figure 2.79 is a block diagram providing a three-dimensional perspective on topographic and stratigraphic variability for the principal investigated occupation loci (T-3) and surrounding, lower lying landforms.

The initial cultural resource testing during Phase I was undertaken across the T1, T2, and T3 surfaces. Discernible topographic differences offset the individual terraces from one another: The T1 terrace included surfaces between 211.7 and 213.5 m (688 and 694 ft); T2 generally (but not always) spanned elevations 214.8-216 m (698-702 ft); and T3 incorporated heights of 216.9-218.5 m (705-710 ft). The terraces were sub-horizontal “treads” that were separated from each other by risers, or sloped “steps,” with a vertical rise of 0.3-0.92 m (1-3 ft). Across most of the project area, the historic re-landscaping appears to have conformed to the original elevation grades.

The recorded sediment stratigraphy begins with terminal Pleistocene sequences. Basal lateral accretion deposits are of late Wisconsin age and correspond with a climatic deterioration termed the Younger Dryas (11,000-10,100 B.P.). The Younger Dryas was a period of climatic conditions that were colder and dryer than the warmer and more mesic, Bölling-Alleröd climate phase. During this time, the Ohio River began a phase of active lateral channel migration, and possibly a return to a braided or sub-braided channel habit. The basal lateral accretion deposits, or the lower portion of Allostratigraphic Unit 1 (AU-1), were typically encountered at a depth of 207-208 m (679-782 ft) above mean sea level. 14C dates ranging from 13,000-10,000 B.P. firmly place the upper part of the lateral accretion package to the Younger Dryas interval.

The thick (2-4 m) package of lamellar sands that comprise the upper part of AU-1 dates from 11,500-6500 B.P. and was emplaced under relatively frequent high flow velocities. These stacked AC/C horizons document the initiation of Holocene vertical accretion to the terrace, the establishment of a meandering channel habit, and the beginning of more mesic (warmer and dryer) conditions of the Pre-Boreal climatic phase. At this time, the Back Channel zone was active and the surface of the T3 terrace was likely a series of undulating bars with sparse vegetation. The incipient AC horizons, which have yielded prehistoric features, are short-lived surfaces, bound above and below by variably thick sands. At this time, the T3 terrace surface was probably no more than 2-3 m (6.6-9.8 ft) above the thalweg of the Ohio River.

Concomitant with the establishment of a meandering channel habit during the beginning of the Holocene (dates B.P.), the T2 terrace was essentially a point bar or small island with a Back Channel lying to the east and the main channel segment to the west. This Back Channel zone remained an active river channel until at least 5500 B.P., and was transformed to an aquatic setting around 4500 B.P. It also served as an outlet for flood waters for much of the late Holocene. In Area 1, the renewal of sandy alluviation during the Middle Holocene, expressed as stacked lamellar sands and dated 5500-3500 B.P., may have included levee deposits. These were laid down during the terminal phases of active channel
flow and also featured spillwater sedimentation and episodic flooding during periods of
overflow attendant to high discharge events. Excavations by the ASC Group in Blocks 1 and 5, which lie along the eastern margin of the terrace, also contain contemporaneous lamellar sands.

Allostratigraphic Unit 2 (AU-2) in Area 2 includes, from top to bottom, the Bw-2Bw-2BC/2CB-3BC/3CB horizons, and overlies the stacked lamellar AC/C horizon couplets that define the upper part of AU-1. In Area 2, the basal levels of AU-2 date to approximately 6000 B.P., while the upper part of the unit dates to approximately 2800 B.P. In Area 2, there is an erosional disconformity in the southwestern portion of the block in which a package of younger, sloping alluvial deposits has been inset into the edge of the T3 terrace. The horizons that comprise AU-2 in the southern portion of the block are decidedly younger than to the north and northwest, and consist of stacked AC/C couplets that date from as early as 4480 B.P. For this reason, the AU-2 unit was subdivided into AU-2a, a facies that is exclusively associated with the T3 terrace (north and west part of landform), and AU-2b the younger facies of the aggrading T2. It is noteworthy that the timing for this episode of erosion and the emplacement of the AC/C couplets in the southern portion of Area 2 is time equivalent with the deposition of the AC/C horizon couplets characteristic of the eastern margin of the terrace in Area 1, adjacent to the Back Channel. That set of depositions was reclassified over the course of these investigations as AU-2b.

In Area 1, features encountered in the stacked AC/C couplets in Block 3 and the BC horizon in Block 2 date from between 4000 and 3000 B.P. In Area 3 South, AU-2 consists of a package of two distinct soil generations: 5A-5Bw/5Bt and 4A-4Bw/4Bt. Culturally, these stacked sola range in age from Late Archaic to a possible terminal Middle Archaic. Each of these soil generations documents periods of relative terrace stability. Subsequent humification (A-horizon enrichment) and surface stability (weathering in the B horizon) is punctuated by incremental sedimentation, attributable to low magnitude overbank deposition. The cumulic A horizons (3Ab1, 3Ab2, 4A, 5A) correspond with warmer and moister intervals of the Atlantic climatic phase.

The basal soil generation unit for Allostratigraphic Unit 2 (AU-2) is the 5AB-5Bw-5BC soil. No artifacts or prehistoric cultural features are recorded for these horizons. The finer grained texture, evidence of greater stability, and deeper weathering of these soils stand in marked contrast to the lamellar sands deposited in the upper part of AU-1. This occurrence suggests a change from higher flow velocities and more rapid vertical accretion associated with AU-1, to lower rates of vertical accretion and in situ soil formation for AU-2.

In Area 3 South, the boundary between AU-2 and AU-3 is problematic, largely because it is difficult to separate the B horizons for Soil Generations 3, 4, and 5. One interpretation favors separation of three cambic soils (3Bw-4Bw-5Bw). A second interpretation recognizes 3Bw as the base of the succession of Inceptisols (AU-2), thereby marking the unconformable surface of the underlying vertical accretion of deposits and soils that built up the T3 terrace.

In most of Area 2 and Area 3 South, AU-2a displayed soils with moderate to strong development indicative of a lengthy period of slow and continuous vertical accretion and in
situ weathering. The soil horizons all exhibit progressive pedogenic structure with depth, as peds grade downward from strong subangular to prismatic structure, featuring continuous to discontinuous silt skins on ped surfaces, with occasional weak mottles. Matrices are extremely dense and texturally, the soil can be classified as a silt loam. It is still unclear as to whether or not several generations of cambic (Bw) soils or a deeper more prominent argillic (Bt) soil is characteristic. In the former case, the A horizon, which should be associated with the 4Bw and 5Bw horizons, would have been leached and weathered with minerals illuviated into the developing profile. To support the latter case, a weak 4AB profile was identified in portions of the site, overlying the Bt horizon. The Bt horizon soil had a brittle consistency and weak, bleached cracks in profile, indicating an incipient fragic (Btx) horizon; this was seen elsewhere on site (Vento et al. 2001). In either case, there is strong evidence of extended weathering and stabilized surfaces in AU-2a. It is possible that additional radiometric, sedimentological, and geochemical analyses of the individual sola may demonstrate more conclusively whether or not the thinner AC couplets on the proximal portions of the T2 merge as a welded soil (Holliday 2004) on the T3; this would allow for a more accurate assay of soil history and chronology.

Finally, in Area 2, AU-3 is mapped as a truncated Ap horizon, while in Area 1, the AU-3 is mapped in Block 3 as a truncated BC horizon. In Block 2, it is described as an organically enriched AB horizon. In Area 3 South, AU-3 attained its thickest expression. It is mapped from the top of the 4Bw horizon and includes, from top to bottom, the AB-2BC-3Ab1/3Ab2-3Bw horizons, which contained diagnostic artifacts and features that date from the Late Archaic to Early Woodland periods. AU-3 registers continued and sustained slow rates of vertical accretion of the T3 terrace, which began during AU-2 time (ca. 6500-3000 B.P.). The AB horizon in Area 1 and the 3Ab1/3Ab2 horizons in Area 3 South document a period of terrace stability at approximately 3000 B.P., and likely correspond with the Sub-Atlantic climatic phase (3000-2000 B.P.). The weak B horizons within AU-3 are clearly cambic, and exhibit a weak to moderate subangular blocky structure with an absence of silt or clay skins on ped surfaces.

Allostratigraphic Unit 4 (AU-4) consists entirely of historic fill material emplaced as a result of historic land use modifications to the T3 terrace. In Area 1, most of the disturbance was the result of activities associated with the brick works that formerly occupied the site. The thickness of the fill deposits varies drastically across the investigated portion of the T3 terrace. In Areas 1, 2, and 3 South, between 0.6 and 0.9 m of fill was removed prior to the Phase III data recovery excavations.

Figure 2.80 indexes the rates of sedimentation across the T3 and underscores the reduction in accretion levels on the southern end of the landform (Area 3-South) over the interval 5000-2000 B.P. By the same token, accumulation rates are over 2.5 times as high for that same time frame on the central and northern ends. Significantly, the highest rates of alluviation are evident between 6000-5000 B.P. which was apparently a phase of landform building. The data for the northern end of the landform argues for expansion of the T3 in that direction well into the late Holocene (Area 1).

Progressive stabilization of the T3 was a clear Middle to Late Holocene trend, as the landform became a locus for overbank deposition, while the existing Ohio River stream was
increasingly entrenched in its channel. After 4500 B.P., the Back Channel became the primary aquatic resource for Late Archaic populations, who favored stable landforms flanking biotically rich and diverse microenvironments. Later prehistoric occupants (occupations associated with AU-2b; see below) would have considered this type of setting to be optimal. The pollen study demonstrates that after 2500 B.P., siltation was a dominant process in the Back Channel (Jones 2006), effectively creating a “silt plug.” Poor pollen preservation confirms this may be attributable to accelerated erosion along the T3 backslope. The increased population on the terrace, as documented by the rich Late Archaic archaeological record, may have partially accounted for such erosion. By contrast, lower density occupations are registered Late Archaic peoples (AU-2a) who occupied a lower and less extensive landform that was still being constructed. They may have utilized the aquatic biomes registered stratigraphically on the west side of the T3. The absence of any heavy and silt-rich later Holocene deposition suggests that only the natural migration of the trunk line accounted for the disappearance of this setting.

The T-2 to T-3 Interface and the Archaeo-stratigraphy of AU-2a and AU-2b

As noted, the Area 2 archaeostratigraphy and the radiocarbon record demonstrate the presence of two discrete feature clusters separated by a (lateral) unconformity dated to ca. 4500 B.P. (Figures 2.38, 2.76). On the basis of these discrete spatio-temporal associations two stratigraphic sub-units were differentiated as AU-2a (6500-4500 B.P.) and AU-2b (4500-3000 B.P.).

AU-2a features occupy the T3 exclusively and include all cultural deposits of Middle Archaic antiquity to the early Late Archaic. They house cultural materials between elevations of 212 and 214 m. Generally archaeological features of this age are preserved in the deepest (3 m) portion of the paleosol (Bw/Bt/Btx) of Area 2 at a time when the T3 landform was still aggrading, albeit slowly. They pre-date the 4500 B.P. unconformity. In Area 3 South, the younger occupations (Late Archaic and Transitional) are in the upper portion of the paleosol. Several dates from the southwest corner of Area 1 are associated with AU-2a as well, but these are topo-stratigraphically at the interface with paleosol and are at the same elevation as AU-2a features of Area 3 South and Area 2.

AU-2b records features of terminal Late Archaic to Transitional and Woodland age that are preserved below 214 m elevation on the T2 landform, as well as features above that level on T3. Since T2 is inset into the T3 landform, topographically equivalent features of that landform post-date those of the older landform by 2,000 years. Only a single feature from Area 3 South is ascribed to AU-2a,” demonstrating that the occupations on the southern portion of the T3 were typically younger than those to the north. Sedimentation rates along the crest of the T3 landform slowed progressively over the past 5,000 years (see subsequent discussion). Accordingly, that location was “high and dry” subsequent to Middle Holocene times and was an optimal location for sustained settlement from Late Archaic times and later.

Landscape History, Human Ecology, and Site Formation

The varied soil-sediment packages on the T3 terrace, and to a lesser degree the T2, represent the residual components of a floodplain environment that was dynamic during the
course of the 12,000 years following the Pleistocene to Holocene transition. Each of the allostratigraphic units (and sub-units) represents internally consistent environments across the landscape. The fact that four such primary units were recognizable indicates that there were at least four major transitions in the environmental history of the valley during the Holocene. These transitions can be generally dated by the archaeological and radiocarbon evidence, and critical information has been added for the later prehistoric record (Late Archaic and Woodlands periods) by the present investigations. Coupled with previous work, it is possible to outline a model of landscape evolution that can be tested by future research in the Upper Ohio Valley. Ultimately these observations guide the formulation of site formation construct that ties the site’s alluvial and occupation histories to climate change, per the genetic stratigraphy model.

Figure 2.81 depicts the morphology of the T3 and T2 surfaces as they have changed through time. Seven stages of landform evolution are depicted, beginning with the pre-Pleistocene landscape.

Baseline topographic elevations for this reach of the Ohio River relate to the Parker Strath, the regional erosional bedrock surface of Illinoian age (Wagner et al. 1970). The Parker Strath is recognized at elevation of 272 m (approximately 900 ft) and forms the margins of the greater upper Ohio Valley (Stage A, see Figure 2.81).

The basal sediments underlying the T3 terrace began to accumulate following the deep incision of valley train sediments during the late Wisconsin Woodfordian sub-stage (ca 22,000-11,500 B.P.). The incision extended to depths of 20+ m below the present thalweg of the Ohio River. During the period, the river aggraded its bed and developed a broad, shallow channel with numerous anastomizing, braided channels forming by 11,500 B.P. (Stage B, Figure 2.81). This period is approximately contemporaneous with the Younger Dryas, a cold and dry pulse immediately predating the close of the Pleistocene.

Subsequent amelioration of the climate following the early Holocene adjustment to a less dynamic post-glacial environment and reduced discharges resulted in decreased competence for Ohio River stream flow. Channel floors became more graded, and the stream geometry changed from a braided to meandering channel habit (Stage C, 11,500-6500 B.P.; Figure 2.81). This depositional history is registered in the coarse to medium sands and AC couplets preserved in the 4-m-deep sequence of AU-1. Radiocarbon dates between 13,000 and 10,500 B.P. establish the age for the basal channel lag and subsequent gravelly sands. Isolated dates for the overlying AC couplets (or lamellar bands) are in the range of 12,000-9000 B.P. and should be considered provisional. By 9000 B.P., the climate had warmed appreciably and the terrace was undergoing a rather slow phase of continued meandering and lateral accretion. There is limited evidence of terrace erosion occurring at approximately 9000-6500 B.P. (closer to the latter) with development of the T2 terrace tread. It is possible that Early Archaic period deposits are preserved in the base of this unit, but preliminary indications are that stream competence was still too great at the beginning of this period to have preserved evidence of sustained occupation. As previously discussed, the top of AU-1 contains the earliest evidence for prehistoric activity.
A major break in the sequence occurred between the accumulation of AU-1 and AU-2 (Stage D; 6500-4500 B.P.; Figure 2.81). The principal change was the abandonment of laterally migrating habit, the entrenchment of Ohio River flow in its present trench, and the beginning of semi-continuous T-3 construction. The timing of the transition is not unequivocal but preliminary indications are that this phase was initiated by 6500-6000 B.P. By 5800 B.P. the preponderance of vertically stratified radiocarbon dates is compelling. The early to middle Holocene transition would appear to mark an erosional phase during which the shift in fluvial dynamics took place. The erosional phase may be a regional climatic phenomenon. Between 6000 and 5000 B.P., the Laurentide ice sheet had retreated far enough north to allow for the penetration of meridional cyclonic storms originating in the Gulf of Mexico and south Atlantic. Clear evidence of these large storm events can be found from the fining upwards sequences of 6AC-6BC-7AC that mark the unconformity of the lateral accretion and vertical accretion sediments at the AU-1 to AU-2 interface.

When the T3 terrace began to aggrade, the depositional suite changed from an upward fining succession to overbanking of the progressively stabilized channel banks. The T3 terrace was now anchored as the dominant landform. Prior to T3 buildup, the landforms across the floodplain were a series of point bars. The T3 emerged as the highest landform on the floodplain between 6,500 and 4500 B.P. (Stages D and E, Figure 2.81). Variability in the sedimentation rates and different thicknesses and developmental histories of stacked soils (3Bw-4Bw-5Bw/4AB-4Bt1-5AB-5Bw) attest to surface changes on the T3, but these represent incremental shifts and not landscape overhauls.

Over the course of the Area1 and Area 2 investigations it became clear that events accounting for AU-2 were complex and lateral planation across the aggrading floodplain undercut the bank line of the T3. Accordingly AU-2 was divided into two facies. The top of AU-2a is an overbank sediment that aggraded onto the T3 (Stage D, Figure 2.81) dated to ca. 4500 B.P., at which time the T3 terrace was flanked by the Back Channel. A date of 3800 B.P. for Back Channel sediments indicates that this segment began to be formed into a continuous landform with the T3 after that time. Archaeological data confirm that Late Archaic period activity is preserved in the soils and sediments of AU-2a. The data converge around the emergence of a stabilized terrace environment.

After 4500 B.P., the geomorphology of this portion of the Ohio River Valley was transformed again. Two prominent landscape events mark the period 4500-3000 B.P. (Stage E, Figure 2.81). First, the abandonment of the Back Channel formed a laterally extended T3 landform. Second, following lateral planation and erosion, the T2 base levels rose, leading to aggradation of a new terrace (T2), inset into the eroded shelf of the T3 landform. Radiocarbon dates suggest that these events were nearly contemporaneous, as the upper dates of AU-2a are on the order of 3500 B.P. and the abandonment of the Back Channel is ca. 3800 B.P. It is possible that the T2 terrace may have emerged earlier, but supporting radiocarbon dates are lacking.

The significance of these findings for archaeology is critical insofar as the local environment was transformed into a complex riverine environment that featured three surfaces: an emerging new floodplain (T2); a raised surface sustaining considerable
prehistoric activity (T3); and an aquatic component (the Back Channel) on the distal edges of the T3 terrace.

Not coincidentally, the late Holocene landscape sustained the densest evidence for prehistoric activity (Stage F, Figure 2.81). From the Transitional Archaic through the Woodland, occupation extended on two graded surfaces obscuring the riser that once separated the T2 from the T3. AU-3 consists of a series of short term soils (Entisols or Inceptisols) that are laterally and vertically zoned. These soils contain feature concentrations and indicate highly variable land use.

The last major phase of landscape modification occurred over the past 1,000-1,500 years (Stage F, Figure 2.81), but the stratigraphic record is discontinuous. Across both T3 and T2 surfaces, there is evidence for high discharge flooding, a function of increased sediment yield during the Historic period (post A.D. 1,600). These sediments are disconformable in places and attest to extensive erosion of uppermost prehistoric components (i.e., Middle and Late Woodland). More significantly, continuous grading and filling has created artificial topographies and obscured the most recent natural record of floodplain activity. The T1 represents the nascent and discontinuous historic floodplain, an artificial landform that is the product of runoff and discharge from secondary drainages discharging into the main stem of the Ohio.

Finally, it is stressed that the archaeological record across the Leetsdale terraces reflected the interaction of a series of site formation processes. In alluvial sites, the articulation and preservation of the prehistoric record is a function of both cultural formation process (i.e., the nature, size, and perishability of the artifact record) and geological agencies acting to modify that record (i.e., soil formation, stream erosion, and alluviation). Figure 2.82 highlights variability in the formation contexts of the preservation record across the three excavated Areas (1, 2, and 3 South) by cultural component. For example, soil horizons comprised the preservation matrices for cultural deposits in areas 2-North and 3-South, with the former housing its archaeological record in soils comprised of either well developed cambic or cumulic horizons, and the latter containing featuring argillic horizons. By contrast all components in Area 1 were contained in dominantly alluvial sediments that were only mildly weathered (BC,AC horizons). This figure functions as a guide to explaining the subsurface preservation contexts for the stratified archaeological record at the Leetsdale site.

The Genetic Stratigraphy Model

The genetic stratigraphy model incorporates all elements of the inter-disciplinary approach to the Leetsdale study. The Allostratigraphic system is the mechanism for ordering individual successions—geological, geomorphic, cultural, climatic, and chronometric—into a comprehensive model for environmental and human ecological change for the past 11,500 years or since the Pleistocene/Holocene interface and through the present. Table 2.18 organizes these data sets chronologically and structures the succession of events as they are represented in the subsurface records that comprise the site known as 36AL480.
<table>
<thead>
<tr>
<th>AU</th>
<th>(^{14}\text{C} ) Age</th>
<th>Climatic Episodes</th>
<th>Climatic Conditions</th>
<th>Description</th>
<th>Landform Association</th>
<th>Site 36AL480 Occurrence</th>
<th>Cultural Chronology</th>
</tr>
</thead>
<tbody>
<tr>
<td>AU-1</td>
<td>11,500-6500 B.P.</td>
<td>Younger Dryas, Pre-Boreal, Boreal, Early Atlantic</td>
<td>Cool, dry to Warm, dry.</td>
<td>Basal coarse sands and AC/C couplets.</td>
<td>Braided stream with multiple, mid-channel islands transitioning to early meandering habit.</td>
<td>All areas, Casting Basin; Back Channel; often below 210.00 m ASL.</td>
<td>Early to Middle Archaic</td>
</tr>
<tr>
<td>AU-2</td>
<td>6500-3000 B.P.</td>
<td>Atlantic through Sub-Boreal</td>
<td>Warm, dry, to Warm, moist, to Warm, dry</td>
<td>Fragile/argillic/cambic soils with local infilling sequences.</td>
<td>Development of stream terrace system with deeply weathered soils, local overbanking and inset/infill; Casting Basin becomes part of primary channel line (6000 B.P.); abandonment of Back Channel by 4500 B.P.</td>
<td>All areas.</td>
<td>Middle Archaic through Transitional Archaic</td>
</tr>
<tr>
<td>AU-2a</td>
<td>6500-4500 B.P.</td>
<td>Atlantic</td>
<td>Warm, dry to Warm, moist</td>
<td>Deeply weathered, stacked cambic (Bw), argillic (Bt), and fragic (Btx) subsoils.</td>
<td>Development of stable stream terraces for repeated occupation; intermittent phases of slow and accelerated accretion of flood deposits (northern migration of T-3); in situ weathering of soils.</td>
<td>Southwest corner of Area 1; Northeast corner of Area 2.</td>
<td>Middle Archaic to Late Archaic</td>
</tr>
<tr>
<td>AU-2b</td>
<td>4500-3000 B.P.</td>
<td>Sub-Boreal</td>
<td>Warm, dry</td>
<td>Stacked, incipient AC/C short-term</td>
<td>Episodic terrace accretion (T-3), Incision and initial</td>
<td>East side of Area 1 (Block 3 first meter and below); Southwest</td>
<td>Late Archaic, Transitional</td>
</tr>
</tbody>
</table>
### Table 2.18 Revised Site 36AL480 Allostratigraphic Sequence.

<table>
<thead>
<tr>
<th>AU</th>
<th>(^{14})C Age</th>
<th>Climatic Episodes</th>
<th>Climatic Conditions</th>
<th>Description</th>
<th>Landform Association</th>
<th>Site 36AL480 Occurrence</th>
<th>Cultural Chronology</th>
</tr>
</thead>
<tbody>
<tr>
<td>AU-3</td>
<td>3000-500 B.P.</td>
<td>Sub-Atlantic, Scandic, Neo-Atlantic, Pacific</td>
<td>Warm, moist to Cool, moist to Warm, moist</td>
<td>Thin flood deposits capped by incipient surface horizons.</td>
<td>Continued overbanking across the T2 and T3 terraces.</td>
<td>Discontinuous across top of T3 landform (not found in Block 6); otherwise thin.</td>
<td>Early Woodland, Middle Woodland</td>
</tr>
<tr>
<td>AU-4</td>
<td>Younger than 500 B.P.</td>
<td>Neo-Boreal (&quot;Little Ice Age&quot;); Modern</td>
<td>Cool, moist to Cool dry</td>
<td>Lead-contaminated historic/modern fills; stripped 0.61-0.81m.</td>
<td>T2 and T3 surfaces heavily modified by historic brick works and modern re-contouring.</td>
<td>All areas.</td>
<td>Late Woodland, Historic</td>
</tr>
</tbody>
</table>
Geoarchaeological Synthesis: A Forward Look

This synthesis of the environmental context for the Leetsdale prehistoric Site 36AL480 represents a comprehensive, complete, and stand-alone document in fulfillment of requirements for the Scope of Work.

However, additional avenues of research can be explored. Additional work should be undertaken to refine diachronic change and spatio-temporally variability in patterns of lithic resource procurement and steatite utilization as proposed in our supplementary studies (see Appendices C and D).

Another approach that offers strong potential for site reconstruction is historic maps. Figure 2.83 is a GIS-enhanced version of a historic (1911) 2 ft. contour map of the Leetsdale project tract with the individual areas superposed. While there is ample documentation that much of the area had already been disturbed by industrial development, the re-landscaping still left much of the native topography intact. Accordingly, Area 2 straddles the 702-704 ft. contours in the southwestern portion of the block, providing early indications that its original riser demarcated the T2 and T3 landforms. That construct accounted for the remapping of the landform and is also key to explaining the AU-2a/AU-2b stratigraphic break. In the southern portion of Area 1, a road bed had already reconfigured the local topography; it should be possible to adjust for topographic displacements if and when benchmarks are presented in the Area 1 report, which also contains information about the historic land use across the tract.

Finally, Figure 2.84 is a three-dimensional GIS projection of the same 1911 map amplifying the topography and underscoring the sinuous channel of Sewickley Creek. Here again, the location of Area 2 is shown as grading down from the T3 landform, and extending into surfaces that have been shown to have formed on T2 stratigraphies on their southwestern margins. By anchoring these maps to absolute data points, it will be possible to refine the model advanced in this study.

CONCLUSIONS

The research objectives of this study were four-fold per the original Scope of Work (see Section 2.2.2). These included:

1. Development of an environmental context for the site.
2. Synthesis of the environmental history of the site.
3. Generation of inter-site comparisons through a regional stratigraphic model
4. Assessment of specific environmental research questions.

In this concluding statement we propose that the allo-stratigraphic model is the centerpiece and organizational framework for documenting environmental context because it establishes the overarching parameters for Holocene landscape change at Site 36AL480 and
offers a baseline for structuring such change both regionally and beyond. The model is at the core of a genetic stratigraphy that features climate dynamics as a forcing mechanism that pilots environmental change and, to a significant degree, subsequent cultural adaptation. The allostratigraphy encapsulates measures of environmental change both on-site and synthetically (i.e. through the alluvial succession and procession of stable environments that are calibrated radiometrically) (Objectives 1 and 2). Given this foundation, we are able to project the constructs for Leetsdale inductively and on a scalar basis, locally, regionally, and extra-regionally (Objective 3).

The discussion below summarizes the key observations generated by this study for contextualizing our paleo-environmental model to fulfill these objectives. The subsequent section addresses the eight (8) specific research questions posed in Section 2.2.3.

The Allostratigraphic Model: Baseline for Paleo-environmental Context, History and Intersite Comparisons (Objectives 1, 2, and 3)

Geoarchaeological research at Site 36AL480 produced a comprehensive paleo-environmental and human ecological reconstruction of the past 11,500 years for the Upper Ohio Valley. The glaciated terrain of the Ohio is terra incognita for prehistoric landscape studies, despite the wealth of comparative data for downstream reaches of the drainage. Accordingly, the Leetsdale study should emerge as the baseline for establishing upstream Late Quaternary correlations for one of the primary trunk valleys for both the Mid-continent and the Middle Atlantic physiographic areas.

A genetic stratigraphic approach was utilized to structure and bridge sequence chronologies that merged the disciplines of geology, pedology, alluvial sedimentology, climatology, and archaeology. That approach was implemented through the application of allostratigraphy, a flexible system for Quaternary research that invokes disconformities to isolate breaks in sequences. In this way, it is possible to identify synchronous patterns of change across disciplines, to isolate coeval trends in specific Late Quaternary time frames, and ultimately, to identify the forcing mechanism accounting for primary patterns and transitions in preserved sequences.

A four-stage allostratigraphy was developed at Leetsdale that accommodated the major transitions and turning points in the Holocene alluvial and occupation records. Key thresholds, represented by disconformities and supplementary stratigraphic indicators, were registered at 11,500 B.P., 6500 B.P., 4500 B.P., 3000 B.P., and 500 B.P., all breaks recorded in alluvial landscape morphology, sediment stratigraphy, pedogenetic history, and prehistoric culture chronology. Moreover, these breaks coincided with paleocirculation thresholds reflected in the Blytt-Sentander climatic scheme and suggested that dynamic Holocene circulation systems drive fluvial systems.

At Site 36AL480, a near continuous archive of Holocene landscape change is preserved in the 7-9 m deep alluvial sequences of the T3 landform to which the four-part allostratigraphic scheme was applied. The Early Holocene stream habit was braided and progressively gave way to lower energy stream environments as the T3 stabilized. Thus, the braided, bedload-rich antecedent Ohio was succeeded by a meandering stream, and then by
an overbanking channel environment, which signaled stabilization of the terrace landform by 6500 B.P. Prehistoric occupations before that time were sparse (Middle Archaic) and concentrated on the former floodplain of the Ohio. A subsequent period of cutting and filling resulted in the emergence of a second landform, a T2, whose surfaces blended, in places, with the older surfaces of the T3. The T2 housed Late Archaic through Woodland occupations. High discharge events produced aperiodic additions to the T2 and T3 terrace tops over the course of the Late Holocene, thus rounding out the depositional history of the landscape.

The four-stage allostratigraphic model was also pivotal in expanding the reach of the intra-site construct. Local, regional, and extra-regional correlations were attempted to assess the lateral reach of the model. On the local level, it was possible to link the T3 and T2 surfaces to upstream Ohio River locations within 25 km of Leetsdale. Most of the allostra were represented at morphostratigraphically equivalent landforms, although localized variability (autogenic events) accounted for some variation in the representation of individual allostrata by depth and extent. More significantly, however, the model was of broad correlative utility when applied across regional trunk stream stratigraphies across Pennsylvania. Here, all major allostra were registered by depth and extent, implying similar patterns of alluviation, synchronous periods of soil formation, and by extension, invoking contemporaneous climatic episodes to account for the forcing mechanism that drove the fluvial systems. Along similar lines, the four-stage systems accounted for similarities in depositional histories the length of the Ohio Valley. Here, however, simple correlations between allostrata and terrace histories were complicated by local hydrographies that accounted for more complex landform arrays and autogenic contributions to those landforms. In general, the genetic stratigraphy model was highly applicable for regional correlations (between trunk streams at similar latitudes), somewhat applicable for extra-regional modeling, and less so for local sequences, where autogenic (sediment) contributions are increasingly significant.

**Research Questions**

These are highlighted as follows:

- **How did the environmental setting, including climate, sedimentation, and soil formation on site change during the Holocene?** In general the allostra are correlated with discrete climatic episodes beginning with the terminal Pleistocene and extending well into historic times. AU-1 spans the Pre-Boreal, Boreal, and Early Atlantic; AU-2 extends from Atlantic through Sub-Boreal; AU-3, Subatlantic through Pacific; and AU-4 encompasses the “Little Ice Age” and Modern times. Sedimentation was laterally extensive during AU-1, vertically accelerated and horizontally complex during the Middle Holocene (AU-2, 2a, 2b); and minimal during the last 3000 years (AU-3, 4). Soil formation was most pronounced in the Middle Holocene (AU-2).

- **How do changes in climate, deposition, stream flow, fauna, and vegetation relate to settlement activities that occurred at the site?** Settlement patterns on site were affected by channel and stream basin geography. Accordingly,
channel migration to the present trench of the Ohio River, 6000 B.P., is accompanied by the initial large scale occupation of the T-3 during the Middle Archaic. Abandonment of the back channel is associated with a second peak in occupation during the Late Archaic (after 4500 B.P.) when both the active channel and backswamp became active resource procurement zones. This extended into the Woodland period, after which siltation (of the back channel) and probable terrace erosion through slope stripping, resulted in slight depopulation of the T3.

**How did flooding of the T3 terrace affect the archaeological evidence of various occupations? Was there any evidence of scouring present?** The overbanking and accretion registered by AU-2, during the cyclic warm-dry, warm-moist conditions of the Atlantic through Sub-boreal climatic episodes, resulted in construction of the existing T-3, and its eventual topographic elevation above 50 year floodlines. The stacked Middle to Late Holocene archaeological record—manifest in progressive accumulation of dense and sealed archaeo-stratigraphic sediment packages—is evidence of intensive occupation (Areas 2 and 3). Scouring clearly occurred during the drier Sub-Boreal when AU-2b was laid down.

**What were the Holocene climatic, depositional, and environmental histories of the Upper Ohio River Valley in the site vicinity?** In general, higher order drainages exhibited similar depositional regimes as those of Leetsdale, with a major transitional phase to progressively slowing vertical accretion and sustained soil development after 6000 B.P. Geomorphic thresholds stabilized between 6000-4000 B.P. as stasis resulted in more sustained soil development (Bw to Bt horizons), a trend that is registered both in the Upper Ohio Valley and its downstream reaches as well as across similar latitudinal settings in the Susquehanna and Delaware Valleys. Again, these fluvial dynamics are associated with higher frequency climatic oscillations of the Atlantic through Sub-boreal climatic episodes. By the time of the Sub-Atlantic moist phase, more dynamic stream activity was re-invigorated.

**Bw/Bt/Btx horizon or soil package date ranges appear more recent than similar soil horizons in the Susquehanna and Delaware River valleys. Does this more recent date range hold true based on the data recovery investigation? If so, what implications does this have for climatic conditions in southwestern Pennsylvania as opposed to central and eastern Pennsylvania?** In general, the pedogenic trends of the Upper Ohio (as exemplified at Site 36AL480) appear to be more variable than they are in central and eastern Pennsylvania. Fragic properties are generally 1-2000 years “younger” in the time-equivalent sola (Bt horizons). Whether or not this is a climatic phenomenon or simply a function of lateral variability in the composition of the parent material (and vertical expression of the wetting front) is not clear from the limited sample provided by Site 36AL480. No other sites in the Upper Ohio Valley have been subject to such intensive soil-sediment analyses such that it is difficult to develop even a preliminary pedo-
stratigraphic model for this part of the Ohio drainage. There is no question that both depth of soil expression and prominence of weathering features are highly variable even across the limited confines of the T3 on site.

Three additional questions were provided in the Modification Proposal from 2002 that consider the following specific issues:

- **Was the C Horizon emplaced at 4500 B.P., and recognized at sites locally, traceable to the same large cyclonic storm event, or does the Ab horizon at Site 36AL480 temporally correlate with other late Holocene paleosols found throughout the eastern United States?** There is no question that the C-horizon was emplaced at 4500 B.P. and that this event is linked to the warm-dry Sub-Boreal climatic phase. Preliminary indications are that this soil may correlate with other Mid-Atlantic T-2 and T-3 terrace construction regimes in which lateral scour events may disrupt vertical terrace architecture because of renewed sinuosity and channel migration triggered by climatic disruption. However, currently sample sizes of trunk stream chronologies are minimal.

- **Does the high sedimentation rate during the Middle Archaic Period correspond with warm and dry episodes associated with zonal atmospheric circulation?** This would appear to be true and may be the most unequivocal finding of the present study. Along the Delaware and Susquehanna equivalent Middle Holocene terraces appear to aggrade at unprecedented rates of construction around the time of latter Middle Archaic. This is also the time at which contemporary terrace configurations assume their present alignments along the flanks of stabilized trunk streams (after 6000 B.P.).

- **Was the abandonment of the Back Channel zone related to changes in the regime of the river, climate, and associated variability in sediment load?** Present evidence suggests that this transition occurred around 4500 B.P. at approximately the time that the T-3 was scoured by a migrating Ohio main stem (AU-2b). Here again, the warm-dry Sub-Boreal appears to have impacted the dynamics of the fluvial system.

**Concluding Thoughts**

This study demonstrates that a detailed reconstruction of the Leetsdale prehistoric site should provide a wealth of information on prehistoric landscape change and cultural succession for the Upper Ohio Valley. It preserves the most comprehensive and best dated alluvial sequence in the unglaciated terrain of western Pennsylvania. It is hoped that this comprehensive endeavor will provide a broad comparative framework for regional research on the Holocene geography of this part of the world for years to come.
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