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GEOARCHAEOLOGICAL INVESTIGATIONS OF STRATIFIED SAND RIDGES ALONG THE TAR RIVER, NORTH CAROLINA

Christopher R. Moore

I. Randolph Daniel, Jr.

More than 25 years have passed since the late David Sutton Phelps wrote his seminal paper on the archaeology of the North Carolina Coastal Plain (Phelps 1983). In that paper, Phelps (1983:50) noted that among the more germane issues facing Coastal Plain archaeology were the need for the "...discovery and excavation of either single-component or stratified Paleo-Indian and Archaic period sites..." Over the last few years, archaeological research at East Carolina University has focused on understanding the geologic contexts of site burial and stratification in the upper Coastal Plain of North Carolina (e.g., Daniel et al. 2008; Moore 2009a, 2009b). The identification of stratified Archaic period sites in the Coastal Plain has great importance for our ability to place the Coastal Plain in its appropriate cultural-historical and environmental context. While it is beyond the scope of this paper to refine the cultural chronology for the region, the discovery and excavation of stratified sand ridges along the Tar River offer the potential to refine a Piedmont-based cultural chronology that is too often uncritically applied to the North Carolina Coastal Plain (Daniel et al. 2008, Phelps 1983).

Recent geoarchaeological investigations in the North Carolina Coastal Plain have shown the potential for locating stratified sites within relict aeolian and fluvial landforms (Choate 2011; Daniel 2002a, 2002b; Daniel et al. 2008; McFadden 2009; Moore 2009a, 2009b; Seramur and Cowan 2002; Seramur et al. 2003; Seramur 2003). Such sites offer the potential for refinement of the cultural-historical sequence for the Coastal Plain and the ability to begin to address substantive issues as diverse as climate change and human adaptation, technological change, subsistence, site function, geochronology, and site formation processes.

While the widespread occurrence of dune fields in Georgia and the Carolinas (Markewich and Markewich 1994; Ivester and Leigh 2003; Ivester et al. 2001) has been the focus of many geological studies—particularly in regards to their paleoclimatic implications—the archaeological potential of these landforms remains unrealized in North Carolina. Evidence for aeolian or wind-blown sedimentation processes has been observed along other Coastal Plain rivers within the Southeast. These studies suggest that dune deposits may be a significant locus for archaeological site burial within coastal riverine environments. On the northern Coastal Plain of North Carolina, archaeological studies of these relict landforms along the Tar River are aimed at contributing to the knowledge of past aeolian/fluvial environments as loci of prehistoric activity in the region (e.g., Daniel et al. 2008; Moore 2009a, 2009b). In particular, it is likely that the sediments and archaeological remains contained within these relict sand bodies are proxy measures of past climates and human activity. The significance of these landforms as a focus of archaeological study lies in their witness to the types of fluvial and climatological changes that occurred during the late Pleistocene and Holocene and the influences these changes had on prehistoric settlement in the area. That said, questions remain regarding the archaeostratigraphic integrity of these landforms and the ages of their cultural deposits. Below, we provide a brief background on the geology and geomorphology of the Tar River Basin along with source-bordering dunes and dune research in the Southeast. Following this, we describe some of the

recent geoarchaeological research conducted by East Carolina University on stratified relict aeolian and fluvial sand ridges along the Tar River and will attempt to place these sites in a broader environmental and geoarchaeological context. Finally, we conclude by summarizing our findings and offering suggestions for future research.

LATE QUATERNARY GEOLOGY OF THE TAR RIVER BASIN

The Tar River has received limited geological studies of stratigraphy and terrace sequence development—most recently in the form of geological Masters Theses (e.g., Maddry 1979; Fournet 1990; Johnson 2007) and studies of flood dynamics in the wake of Hurricane Floyd (e.g., Riggs 2001). Many other studies are ongoing and have attempted to broadly define the sequence stratigraphy of the lower Coastal Plain and Tar River with specific reference to relict coastal terraces and scarps reflecting sea-level oscillations during the Quaternary (e.g., Ferrell et al. 2003). Of particular interest for this paper, Maddry (1979) illustrates stratigraphic cross-sections for areas along the Tar River in Greenville and just east of Rainbow Banks that show what appear to be aeolian dunes or aeolian drapes over fluvial braid-bars (referred to as stratigraphic unit Q6a) (Maddry 1979: Figure 1-17). This unit is composed of sand ridges (within the lower paleo-braidplain) that are described as, “...slightly weathered, structureless, light brown, fine to medium quartz sand” (Maddry 1979:49). Underlying unit Q6a is unit Q6. Stratigraphic unit Q6 is described as a sequence of slightly weathered fine to coarse sand and containing pebbles along with minor amounts of cobbles and boulders. This unit is also described as exhibiting braided topography and in many areas appears to be the stratigraphic unit comprising the paleo-braidplain of the Tar River.

The Tar River drainage basin has undergone dynamic changes throughout the late Pleistocene and early Holocene Epochs. These have included fluvial/hydrological changes, changes in sediment flux and discharge, changes in base flow (related to sea level), tectonic changes (e.g., isostatic adjustment) and changes resulting from climate. Within this framework of dynamic processes and constant change, the Tar River has produced a complex sequence of stacked braided and meander-plain terraces, a modern floodplain, and a river channel that is incised into underlying Cretaceous and Tertiary- sequences (Figures 1-1 and 1-2). All of these riverine terraces are superimposed on top of ancient fluvial, estuarine, and marine sequences of the North Carolina Coastal Plain that locally include various Cretaceous and Tertiary formations (e.g., Black Creek, Pee Dee, and Yorktown Formations) (Maddry 1979). Overlying these Cretaceous and Tertiary deposits is a thin cover of Quaternary sediments. These relatively thin Quaternary cover sands have been altered by fluvial and aeolian processes, episodic drought, and vegetational changes. The asymmetry of the Tar River valley is due to the fact that the river has been migrating to the south/southwest, preserving Pleistocene and Holocene sediments east and north of the river—possibly in response to regional neo-tectonic uplift (O'Driscoll et al. 2010).

Source-bordering dunes (discussed below) and/or fluvial (i.e., overbank levee) sand-sheets are present along terrace boundaries or escarpments overlooking either the paleo-braidplain or the modern meandering floodplain of the river. These terrace edges appear to have been vegetated and capable of capturing wind-blown and flood-deposited sediments from exposed braid-bars and meander point-bar deposits during times of drought or after large inputs of sand from storm events. Several smaller terraces are visible along sections of the Tar River

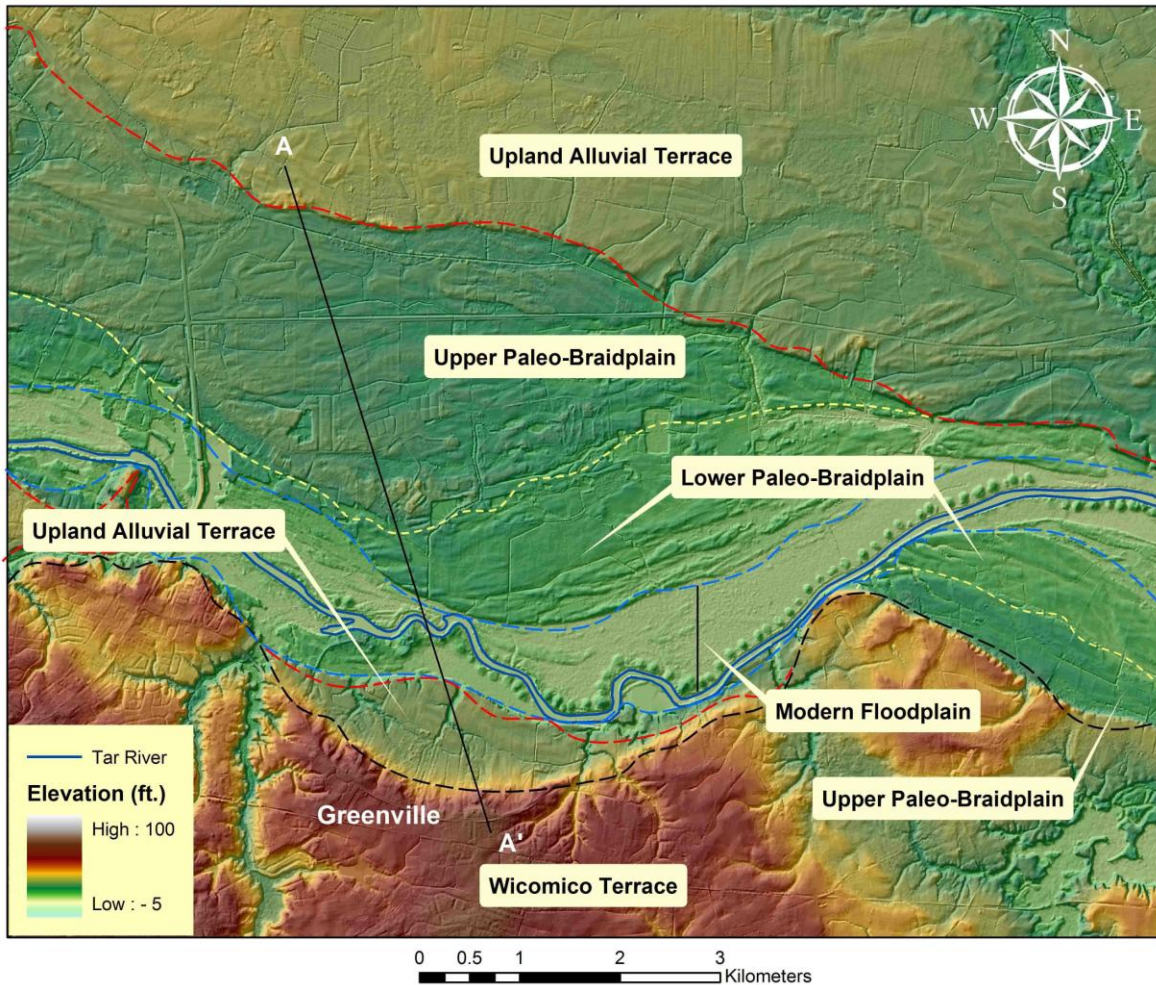


Figure 1-1. A geomorphic map of the lower Tar River Basin in the vicinity of Greenville, NC (Pitt County) based on analysis of LiDAR elevation data for the Tar River Basin produced by the NCDOT Floodplain Mapping Program (<http://www.ncfloodmaps.com/>). Riverine terrace sequences include: 1) upper alluvial terrace, 2) upper paleo-braidplain, 3) lower paleo-braidplain and 4) modern Tar River floodplain.

Note: Transect A to A' used to develop a generalized topographic and geologic schematic for the Tar River near Greenville, NC (Figure 1-2).

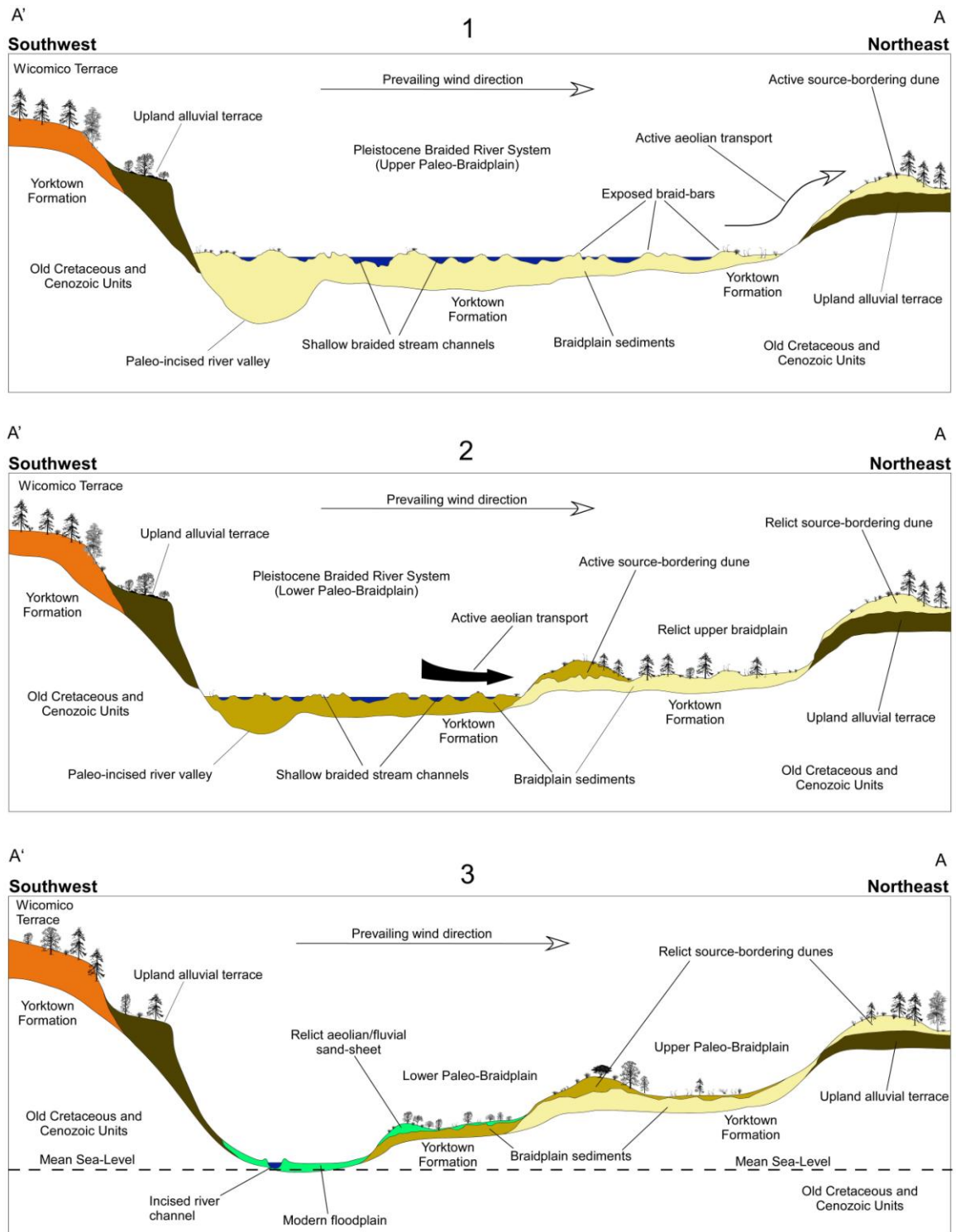


Figure 1-2. A generalized topographic and geologic schematic representing the evolution of the Tar River Basin in the upper Coastal Plain during the 1) Pleistocene, 2) Late Pleistocene and 3) Holocene. (Map is not to scale).

and may represent time-transgressive downcutting with shifts in the fluvial system related to sea level and/or climate change (affecting vegetation and sediment load to the river). These hydrologic and fluvial channel shifts have associated dunes along terrace escarpments that formed during several successive braided river episodes. Terrace deposits, including aeolian dunes and levees decrease in age with decreasing distance to the current location of the river (i.e., more recently deposited aeolian and fluvial sediments are situated on more recent riverine terraces).

Soller (1988) describes aeolian processes and dune fields overlying alluvial terraces for the Cape Fear that are analogous to those along the Tar River and may be of similar ages. Soller also uses radiocarbon (^{14}C) dates from peat and macerated wood to show that younger (early to mid Holocene) dunes are present very close to the current position of the Cape Fear while dunes farther away from the river appear to be much older (i.e., >40ka). This suggests at least two periods of dune formation and may reflect both climate change and changes in flow regime of the river at the time of deposition (i.e., braided vs. meandering) (Figure 1-3). Together, these geological studies provide a baseline for understanding the underlying stratigraphy and geometry of relict terraces along other southeastern rivers and suggest mechanisms for reworking of surface deposits into relict aeolian and fluvial landforms capable of stratifying archaeological occupations.

AEOLIAN DEPOSITION AND SOURCE-BORDERING DUNES

In the Southeast, relict (source-bordering) dunes and sand-sheets occur intermittently along coastal rivers (Markewich and Markewich 1994) (Figure 1-4). Geologists have recognized relict aeolian landforms along southeastern rivers as a potential source of paleoenvironmental data (e.g., Daniels et al. 1969; Ivester et al. 2001). The climatic conditions and processes that led to dune formation, as well as the age of aeolian deposits, have been the subject of recent investigations by both geologists and archaeologists in the region (Gunn and Foss 1992; Ivester et al. 2001; Otvos and Price 2001; Seramur and Cowan 2002, 2003; Seramur et al. 2003; Soller 1988; Zayac et al. 2001). For example, in parts of the Southeast, large-scale aeolian transport was very common between 30,000 and 15,000 years ago (Ivester et al. 2001). This time period is associated with the late glacial period of the Wisconsin and represents a time when the climate was very cool and dry. The Wisconsin glacial environment was characterized by strong unidirectional winds (common to both glacial and transitional glacial-interglacial climates) (Carver and Brook 1989). The combination of a cool/dry climate and strong unidirectional winds resulted in the development of large source-bordering dune complexes immediately adjacent and parallel to many of the coastal rivers in the Southeast (Markewich and Markewich 1994). Relict source-bordering dunes typically formed adjacent to streams and quite often near the confluence of tributaries and major river channels (Daniels et al. 1969; Markewich and Markewich 1994). Typical source-bordering dunes/sand-sheets average from 1-7 meters in height and less than 1 kilometer in length. These aeolian landforms are composed of highly permeable medium to fine quartz sands (Markewich and Markewich 1994).

During the late Pleistocene, the sand source for relict dunes came from sediments carried within the bedload of coastal rivers and from accumulations of sediment as braided stream deposits within river floodplains (Ivester et al. 2001; Leigh 2004, 2006, 2008). Variable and fluctuating discharge would have provided fresh sediment to the floodplain during wet climates or during seasonal monsoonal events (e.g., Goman and Leigh 2004). These sediments may

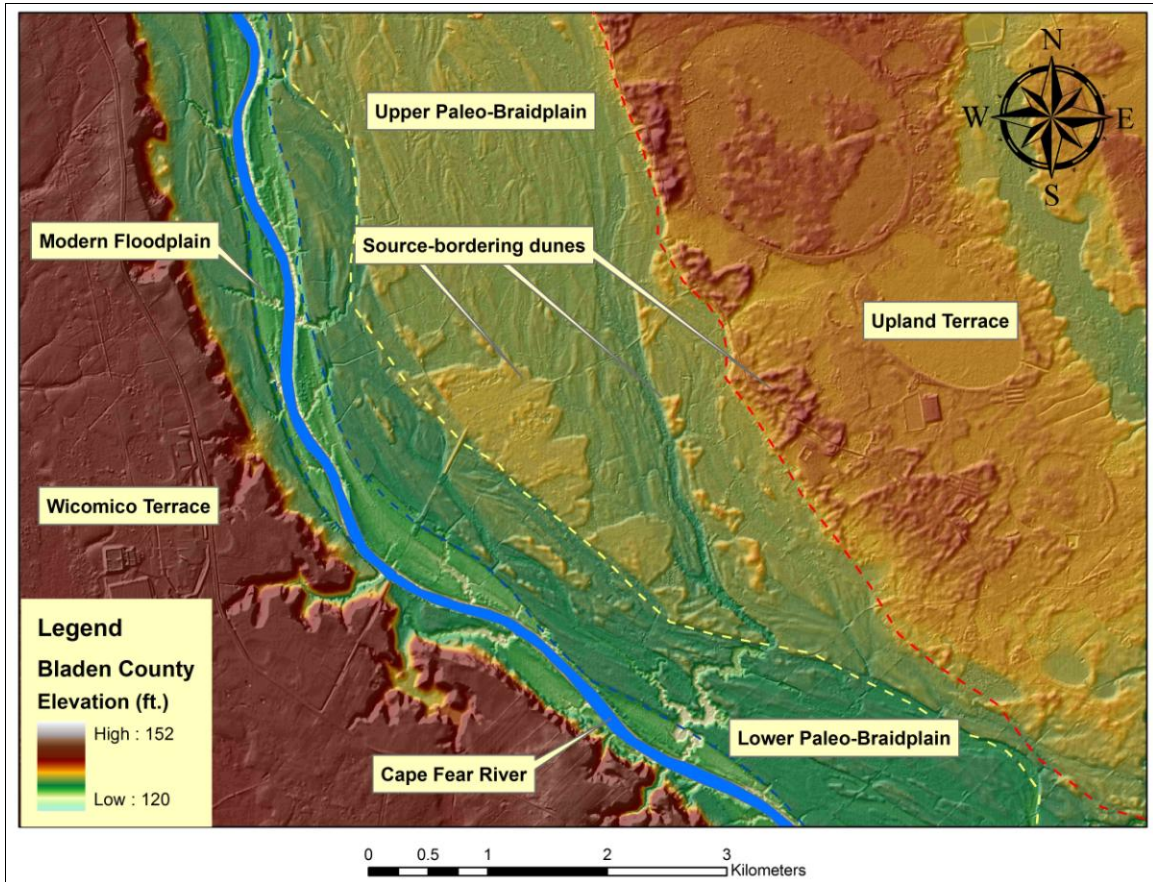


Figure 1-3. A spectacular example of relict source-bordering dunes on river terrace escarpments along the Cape Fear River, Bladen County, North Carolina.
 Note: Large parabolic, infilled parabolic, aeolian sand-sheets along terrace escarpments, Carolina bays, and extensive braided river topography are clearly visible on this LiDAR image. LiDAR data were obtained from the North Carolina Floodplain Mapping Program.

remain largely inactive (i.e., locked in by vegetation) except during periods of pronounced climate change events or climatic disequilibrium (e.g., drought, fire, or after large flood events) (e.g., Marlon et al. 2009; Viau et al. 2006). Subsequent droughts or seasonal reductions in water discharge resulted in exposed sediments that provided a source of sand for transport onto adjacent terrace escarpments. Centimeter-scale depositional events may have been localized along lower paleo-braidplain scarps during much of the mid to late Holocene—with little to no aeolian transport away from local point-sources of sands along the river (i.e., thin, source-bordering deposits).

In this scenario, terrace edges would likely be the first place where standing vegetation would be encountered by winds blowing across an otherwise unvegetated braidplain (during the late Pleistocene) or more recently deposited overbank sands or point bars (during the Holocene). Vegetation along terrace scarps would cause sand to settle out and accumulate along the terrace edge as source-bordering aeolian dunes/sand-sheets. This scenario has been argued to be the primary reason why southeastern dunes so often lack any discernable internal aeolian sedimentary structures or layers that represent different depositional events (Daniels et al. 1969; Markewich and Markewich 1994:23). A lack of observable sedimentary structure may also be due to textural homogeneity with dune deposits consisting almost entirely of medium to fine sand.

Depositional events likely varied in both scale and intensity throughout the late Pleistocene and Holocene and in response to cycles in climate. The exact nature of this environmental change, however, remains to be determined. For example, whether depositional events were a result of periodic aridity in the eastern United States during the late Pleistocene to mid Holocene (e.g., Cronin et al. 2005; Zayac et al. 2001), early to mid Holocene increased storminess or overall wetter conditions than present (e.g., Goman and Leigh 2004) (large-scale flood events and aeolian reworking of flood deposited sediments) or Holocene millennial-scale climatic cyclicity (e.g., Bond et al. 1997, 1999, 2001; Mayewski et al. 2004) is uncertain. In any case, climate change was likely involved.

Although the nature of dune development and aeolian processes during the Holocene was on a smaller scale than that which existed during the late Pleistocene (Ivester et al. 2001), limited aeolian activity has been proposed as a significant burial mechanism for archaeological sites within river drainages of the Southeast (e.g., Daniel et al. 2008; Gunn and Foss 1992; Seramur and Cowan 2002, 2003; Seramur et al. 2003; Wagner and McAvoy 2004). While many of the larger dunes are Pleistocene in age (Ivester et al. 2001; Ivester and Leigh 2003), many others appear to be younger with the most recent aeolian activity in the southeast occurring from ~15,000 to 3,000 radiocarbon years ago (Markewich and Markewich 1994; Soller 1988; Zayac et al. 2001). Archaeological and geophysical data (GPR) from the Tar River suggest that many of these aeolian deposits occur as relatively shallow “drapes” of wind-blown sediment overlying remnant Pleistocene stream braid-bars (Moore et al. 2006; Moore 2009b). Evidence that will be discussed below suggests that riverine terraces preserved to the east and north of the Tar River exhibit relict aeolian and aeolian/fluvial deposits of sufficient thickness to have sequentially buried and stratified archaeological cultures spanning the late Pleistocene and Holocene.

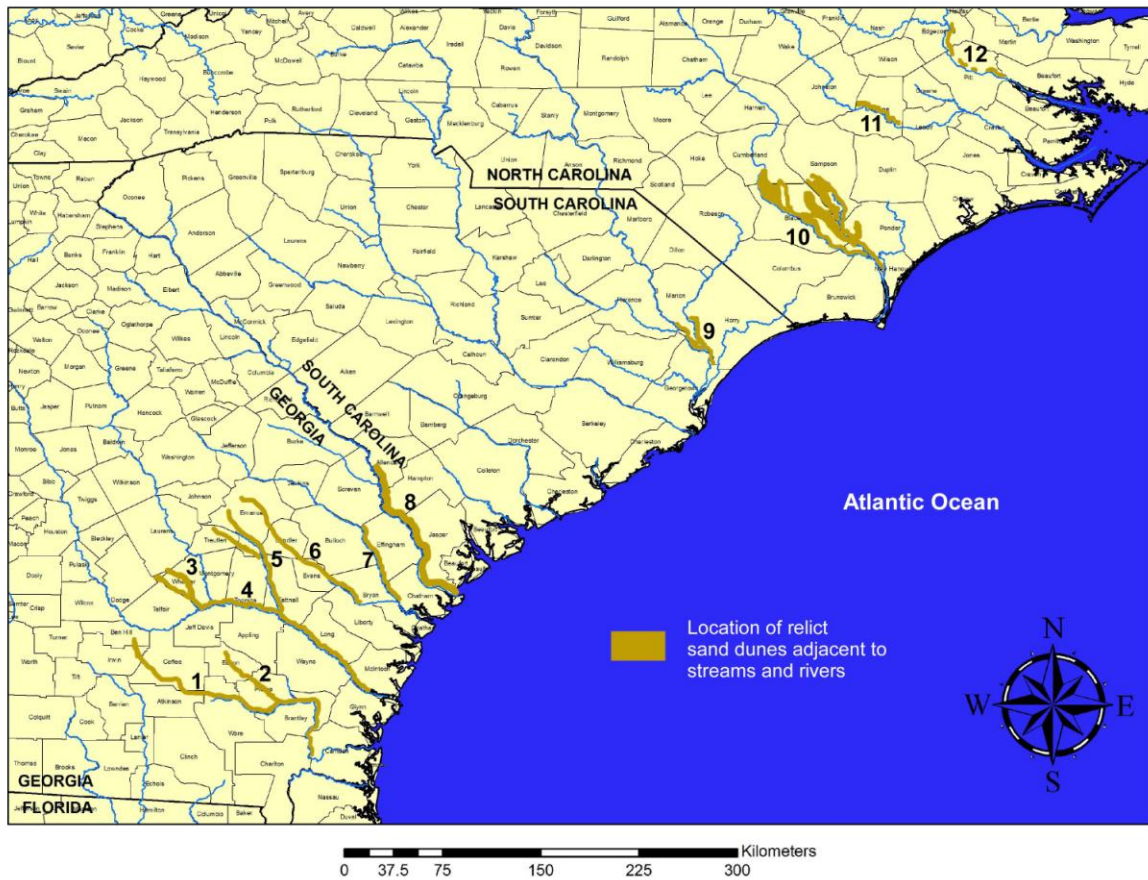


Figure 1-4. Known relict source-bordering dune regions along coastal rivers in Georgia, South Carolina, and North Carolina indicated on map are 1) Satilla River, 2) Alabaha River, 3) Little Ocmulgee River, 4) Altamaha River, 5) Ochopee and Little Ochopee Rivers and Pendleton Creek, 6) Canoochee River, 7) Ogeechee River, 8) Savannah River, 9) Great Pee Dee River, 10) Combined Cape Fear and Black Rivers, 11) Neuse River and 12) Tar River. (after Markewich and Markewich 1994:4)

Note: Areas along the Tar River with relict dunes have been added by the authors.

RESEARCH PROBLEMS

Geoarchaeological excavations at the Barber Creek Site (31Pt259) (Daniel 2002b; Daniel et al. 2008) and elsewhere along the Tar River (Moore 2009b) lead to the following general hypothesis: Landform aggradation and archaeological site burial along the Tar River resulted from localized and episodic aeolian deposition during cool/dry climatic events over the Holocene (ca. 11,450 CALYBP–present) [Note: All ^{14}C dates are reported in calendar years BP unless otherwise noted]. Some fluvial contributions from flood events are also evident—particularly for lower paleo-braidplain sites. This research suggests that stratified archaeological remains within these sediments preserve a record of both prehistoric human adaptations to local conditions and changes in depositional processes marking regional climatic change in the southeastern United States. In particular, work has focused on illuminating the stratified Archaic (11,450-3,200 CALYBP) and Woodland (3,200-1,000 CALYBP) period occupations along the Tar River and establishing the respective ages of those components. Understanding potential differences in the age and intensity of site use will allow the modeling of prehistoric hunter-gatherer settlement in the region in response to environmental change during the late Pleistocene to late Holocene.

Research conducted over the last few years has attempted to address specific questions concerning the archaeology and geomorphology of the Tar River Basin (discussed below). The objectives of this research include, 1) refining the existing cultural chronology, 2) assessing site integrity and site formation processes, 3) establishing a landform geochronology, and 4) providing a framework for understanding prehistoric technological change and settlement adaptations to climate change in the North Carolina Coastal Plain. In addition, this research has attempted to characterize the overall lithostratigraphic nature of shallow late Quaternary aeolian and fluvial deposits along the Tar River (Moore 2009b). This was done in order to understand landform geomorphology and site formation processes as they relate to changing fluvial and aeolian depositional environments. Understanding these processes is of critical importance to archaeological and paleoenvironmental studies in the region. Below are a series of research questions with testable implications derived from our hypothesis.

Research Problem 1: Geoarchaeological survey

A geoarchaeological survey was initiated as part of this project to enable the archaeological occupations at Barber Creek (31Pt259) (Daniel et al. 2008) to be placed in a broader environmental context. A transect along the Tar River was surveyed to address the following questions: *Do additional stratified sand ridges occur along the Tar River and where are they located? If other stratified sites are present, what archaeological components are present in them?*

Data collected for this study included extensive archaeological surveys of suspected relict aeolian/fluvial landforms selected from analyses of aerial imagery and high-resolution Light Detection and Ranging (LiDAR) elevation data produced by the North Carolina Floodplain Mapping Program. Suspected source-bordering dunes and landforms with potential for buried/stratified archaeological sites were selected based on the geology and terrace sequences of the Tar River. Final selection of sites for archaeological testing was based on results of archaeological surveys (i.e., shovel testing), distance of landforms from the active river channel or paleo-river channels, and the position of landforms along relict alluvial terraces of the river. Suspected sites containing buried archaeological sequences were sampled with test excavations

to examine buried cultural components and archaeostratigraphy, sampled for luminescence and radiocarbon dating, and cored for reconstruction of sedimentological lithofacies. Ground penetrating radar (GPR) was also used to evaluate landform thickness and stratigraphy, as well as to look for evidence of preserved sedimentary structures (e.g., aeolian cross-bedding) (Moore 2009b).

Research Problem 2: Geoarchaeology: site formation and chronology

Three interrelated questions are addressed with respect to geoarchaeology: *First, how were Barber Creek and the other Tar River sites formed and what is the chronology of site formation and prehistoric occupations at these sites? Second, what implications do the archaeological sequences present within buried sites along the Tar River have for understanding the fluvial history of the Tar River Basin? Third, to what degree does sedimentation vs. bioturbation contribute to site formation at Barber Creek and other sites along the Tar River?*

Geoarchaeological investigations thus far, suggest that the upper sand unit at Barber Creek (~1 meter) is a relict aeolian sand-sheet with minor contributions from fluvial deposition (Daniel et al. 2008; Moore 2009b). Further work was done to test this claim at other probable buried/stratified sites located along the Tar River. Sedimentological studies were also performed to evaluate site formation and site burial by aeolian or fluvial processes (e.g., Seramur and Cowan 2002; Daniel et al. 2008).

Cultural material recovered to date, suggests that Early Archaic through Early Woodland components are present at Barber Creek (Daniel 2002a; Daniel et al. 2008). Archaeological excavations were conducted at several other sites along the Tar River to sample their occupation sequences. Chronometric dates were also obtained from several sites to provide absolute dates for those occupations and to help determine the timing of site burial events.

With respect to the fluvial history of the Tar River, the presence of stratified archaeological remains in aeolian or fluvial sediments presumably preserves a record of both prehistoric human adaptations to local conditions and changes in depositional processes. Aeolian and fluvial deposits along coastal rivers may mark regional climatic change in the southeastern United States. The accumulation of wind-blown or aeolian deposits is usually associated with periods of cooler and dryer conditions (e.g., Markewich and Markewich 1994; Ivester et al. 2001; Ivester and Leigh 2003). And while it is not yet certain whether source-bordering aeolian accumulations along the Tar River were a response to overall dryer paleoclimatic conditions (e.g., drought) or periods of rapid climate change leading to ecosystem stress and increased fire (e.g. Marlon et al. 2009), conditions favoring riverine dune or aeolian sand-sheet formation in the Southeast likely included at least seasonal reductions in river discharge (Ivester and Leigh 2003). In addition, it appears likely that periodic and large-scale flood events may also be a contributing factor to site formation processes along the Tar River (e.g., braid-bars and levees).

The depositional events recorded at the Tar River sites and elsewhere in the Southeast (e.g., Zayac et al. 2001) are consistent with recent paleoclimate data indicating rapid climate change events that occur on millennial time-scales for the Holocene (e.g., Bond et al. 1997; Mayewski et al. 2004; O'Brien et al. 1995; Overpeck and Webb 2000; Springer et al. 2008; Steig 1999; Willard et al. 2005; Viau et al. 2002, 2006). Surely, such events—particularly significant droughts—influenced prehistoric use of the area. The timing and magnitude of these wet-dry cycles and their impact on prehistoric settlement along the Tar River can be evaluated by integrating sedimentological and archaeological data. These data can help to distinguish

depositional events and to define occupational horizons (e.g., Brooks and Sassaman 1990; Brooks et al. 1996; Leigh 2001).

With regard to our third question, existing archaeological data (e.g., artifact clusters, archaeological features, and stratigraphically correct chronometric dates) suggest that bioturbation (displacement and mixing of artifacts within the soil column) has not greatly compromised the stratigraphic sequence at Barber Creek (Daniel et al. 2008) or at other paleo-braidplain sites along the Tar River where buried sites have been located (Moore 2009b). Further work is needed to substantiate this interpretation since bioturbation can be a problem with respect to the burial and/or translocation of artifacts in some sandy sediments (e.g., Leigh 2001).

Although bioturbation has been offered as the primary mechanism of site burial for sandy coastal environments and upland interfluvies in the Southeast (Leigh 1998a, 1998b, 2001, 2004; Michie 1990), it is unclear if bioturbation is a significant factor in site formation in all sandy sites. For example, Michie's (1990) analysis of artifact frequency distributions (suggestive of bioturbation) relies heavily on assumptions of site formation processes but lacks quantitative sedimentological or chronometric data to support bioturbation claims. And while Leigh (1998b) makes a convincing case for bioturbation in upland sandy sites in the North Carolina Sandhills, more work is needed to determine if bioturbation is the principle mechanism of artifact burial for all upland sites, particularly in upland environments with relict dunes (e.g., Moore and Brooks 2011). Indeed, stratified sandy sites such as the Cactus Hill Site in Virginia (Wagner and McAvoy 2004) and Carolina Bay sand rims and relict dunes in South Carolina (Brooks et al. 1996) have demonstrated archaeological sequences in correct stratigraphic order, intact rock clusters and hearths (suggestive of intact occupation surfaces), and sedimentological profiles consistent with episodic depositional events throughout the Holocene (e.g., Brooks 1990; Brooks and Sassaman 1990; Brooks et al. 1996; Gunn and Foss 1992; Wagner and McAvoy 2004). In short, these works belie the notion that artifacts are significantly bioturbated in all sandy sites, and suggest that site integrity at sandy sites should be assessed on a case-by-case basis.

Space does not allow us to explicitly address the issue of bioturbation here. We will do that in a subsequent publication. Suffice it to say that while we acknowledge some stratigraphic mixing of archaeological deposits has occurred to varying degrees in the sites discussed here, we submit that the overall stratigraphic integrity of the sites in our study is relatively good. This inference is borne out by multiple lines of evidence including archaeostratigraphy, granulometry, ^{14}C dating, and geochronology of sediments derived from OSL dating (discussed below). Moreover, if episodic aeolian and/or fluvial sedimentation has occurred over the course of the Holocene (as indicated by these multiple data sets), then the potential exists that the remains of prehistoric occupations have been gradually buried and preserved. Thus, these geologic deposits represent a "time-capsule" for understanding the culture-history of the Tar River and serve as a proxy for understanding climate change and cultural adaptation.

METHODS

A geoarchaeological approach was used to address the questions posed by this research. The methods used include Geographic Information Systems (GIS) analysis, archaeological excavation, close-interval granulometry or grain size analysis, ground penetrating radar (GPR), detailed backplotting of piece-plotted artifacts, and chronometric dating using optically stimulated luminescence (OSL) and radiocarbon (^{14}C) dating of geological and archaeological

deposits. These methods were designed to (1) identify potential relict aeolian landforms along the Tar River using LiDAR data within a GIS database, (2) archaeologically test those landforms to determine if they contain buried archaeological remains, (3) analyze archaeological remains to determine the archaeological sequences they might contain, (4) develop a luminescence and radiocarbon geochronology of selected landforms and archaeological occupations, and 5) reconstruct site formation processes.

The recognition of possible relict aeolian dunes and/or fluvial sand ridges along the Tar River was made possible through the use of recently released very high-resolution laser altimetry data made in the wake of Hurricane Floyd to produce more accurate flood prediction maps. Also known as LiDAR (Light Detection and Ranging), these data allow 3D modeling of low elevation/low relief terrain. LiDAR data provide extremely high-resolution (+/- 25 cm) digital elevation models and have allowed the recognition of complex fluvial deposits including a stacked sequence of Pleistocene braided terraces, meander deposits, relict braid-bars, overbank levees, and numerous source-bordering dunes, aeolian sand-sheets, Carolina bays, and paleo-estuarine shorelines within the North Carolina Coastal Plain (e.g., Moore 2009b). Dunes along many southeastern rivers have distinct U-shaped parabolic, transverse, or irregular morphologies (e.g., Figure 1-3). LiDAR reveals these distinct landform signatures in ways not possible before.

An interpretation of the depositional environment(s) for sand ridges along the Tar River was achieved through the use of granulometry or grain size analysis (e.g. Friedman 1961, 1979; Leigh 1998a). Sediments from archaeological sites were compared with modern Tar River alluvium, overbank levee, and known dune sediments with the use of bivariate plots of sediment statistical parameters such as mean grain size, sorting, standard deviation, kurtosis, and coefficient of variation (cv). Detailed gravel, sand fraction, and percent fines (silt and clay) plots were also produced for all sites from the ground surface to just above unconformable boundaries with underlying marine/estuarine sandy clays (Moore 2009b). Although the details of the granulometry study are beyond the scope of this paper, publication of this work is forthcoming. Previous work at the Barber Creek Site (31Pt259) also indicated aeolian burial processes for sediments based on scanning-electron microscopy (SEM) analysis of individual sand grains (Seramur and Cowan 2002).

This research relies heavily on a dating technique known as luminescence or optically stimulated luminescence (OSL) dating (Huntley et al 1985; Murray and Roberts 1997). Generally speaking, OSL provides a measure of the amount of time sediments have been buried since last exposed to sunlight before deposition. During depositional events, exposure to light or heat resets any acquired luminescence signal. After burial, sand grains are exposed to naturally occurring background radiation, causing ionized electrons to become trapped within defects in the crystalline structure of the sand grains (The total amount of radiation received by the sediment since last burial is termed the equivalent dose). Equivalent dose is estimated in the lab by artificially irradiating the sample with a known dose to model the OSL sensitivity of that particular sample (Feathers 2003).

The goal of luminescence geochronology is to establish the timing of burial events (Aitken 1998). Problems with determining the timing of burial events may arise if depositional events occur at night or within water or have very short travel paths. Fluvial deposition of sediments may occur in very turbid conditions and cause attenuation of sunlight and thus incomplete resetting or “zeroing” of previously inherited luminescence. In these cases, partially bleached grains will contribute to age overestimations due to the inherited or residual luminescence signal carried over from a previous depositional site. In many cases, partially

bleached grains may be inferred from positively skewed dose distributions (Murray et al. 1995; Olley et al. 1998; Lepper et al. 2000; Lepper and McKeever 2002).

In spite of these problems, OSL dating is particularly well suited to address issues of cultural chronology and timing of depositional events for several reasons. First, OSL dating has demonstrated utility in the Southeast by providing reliable and accurate ages for dune chronologies (Leigh et al. 2004; Ivester et al. 2001). Secondly, OSL dates the actual sedimentary event that buried archaeological materials rather than associated carbon (which may or may not be linked with cultural deposits). Thirdly, close examination of single-aliquot or single-grain equivalent dose distribution data and radial plots can be used to interpret site integrity in ways not possible by traditional radiocarbon dating (Bateman et al. 2003; Boulter 2006; Feathers 2003; Frederick et al. 2002; Rhodes 2011).

Traditional single-aliquot OSL dating looks at small discs covered with several hundred to several thousand sand grains and calculates equivalent dose (D_e) age estimates based on an average of all grains. More recent developments in single-grain OSL dating (e.g., Bateman et al. 2003; Boulter et al. 2006; Feathers 2003, 2006b; Frederick et al. 2002) offer greater dating precision and the potential for more readily identifying the true time of burial. For example, single-grain dating is particularly appropriate for determining burial age from slightly mixed or bioturbated sediments, sediments with partially bleached grains, or in shallow and slowly accreting deposits, such as source-bordering dunes or fluvial braid-bar and overbank levee deposits (e.g., Feathers et al. 2006b) by clearly defining discrete populations of equivalent dose data.

Burial-age is evaluated based on an examination of equivalent dose distributions along with comparisons with archaeostratigraphy and correlation with radiocarbon dates (where available). Thus, the OSL chronology developed for each site is based on stratigraphic consistency between observed cultural horizons and/or radiocarbon dating along with examination of equivalent dose distributions. Either a central age model or a minimum age model are applied as appropriate based on individual luminescence age distributions for estimating true burial age (Feathers et al. 2006b; Galbraith et al. 1999). Moreover, temporally diagnostic artifacts, recovered from archaeological testing, should provide an independent age control or "ballpark" age range consistent with the OSL dates (e.g., Feathers et al. 2006a).

Use of the minimum age model in OSL dating should not be confused with the use of "minimum age" estimates derived from very old ^{14}C dating. In the latter case, the minimum age implies the potential for much greater antiquity, while the former (OSL minimum age model) is a method for extracting the true age of the desired or studied burial event in question. The minimum age model age estimate is derived from a subset population of sand grains from positively skewed or multimodal equivalent dose distributions in cases where partial-bleaching or bioturbation of 'older' grains into younger sediments is suspected or inferred from analysis of luminescence and or other proxy data (Galbraith et al. 1999). In the latter case, the archaeostratigraphy and corroborating ^{14}C dates become paramount to the application of various age models and the development of an OSL geochronology (e.g., Feathers et al. 2006).

DISCUSSION

Archaeological Survey

An approximate 80 km stretch of the Tar River from the confluence of Fishing Creek in northern Edgecombe County to Tranter's Creek in northeastern Pitt County was the focus of this survey (Figure 1-5). Shovel test survey and archaeological testing have identified numerous sites along the Tar River in Pitt and Edgecombe counties in North Carolina with potential for buried/stratified archaeological occupations. Test Unit excavations and geoarchaeological analysis of five of these sites (including the Barber Creek site) indicate site burial by primarily aeolian processes may be more common than once believed. In addition to ongoing archaeological investigations at the Barber Creek Site, Test Unit excavations were conducted at four sites identified during the shovel test survey. These sites are located along a stacked sequence of alluvial terrace formations, including a lower and upper paleo-braidplain and a more elevated upland alluvial terrace. Paleo-braidplain sites include Squires Ridge (31Ed365) and Owens Ridge (31Ed369), while the upland terrace sites include, Hart Ridge (31Pt606) and Taft Ridge (31Pt605). The Barber Creek Site (31Pt259) is located along the same lower paleo-braidplain terrace as Squires Ridge (31Ed365) but is ~40km south by way of the Tar River. Two (2x2 meter) Test Units were excavated at each site using standard archaeological procedures, including flat-shovel skimming of 10 cm arbitrary levels and piece-plotting. Diagnostic artifacts such as projectile points or pottery were piece-plotted *in-situ* when possible along with cobbles, cobble fragments, and obvious lithic tool fragments.

Although no definitive Paleoindian occupations were located, analysis of archaeological data from three of the five sites where Test Unit excavations were conducted revealed the presence of stratified Early Archaic through Woodland occupations (i.e., Barber Creek, Squires Ridge and Owens Ridge) (Figures 1-6, 1-7, and 1-8). While earlier occupations cannot be ruled out, one site produced diagnostic artifacts typical of Middle and Late Archaic occupations (i.e., Taft Ridge), while another produced shallow and generally non-diagnostic Woodland period lithics and ceramics (i.e., Hart Ridge) (Figure 1-8). Given the limited nature of Test Unit excavations conducted at these sites (only exception being the Barber Creek Site), it is likely that all five sites would produce additional components with more extensive testing. Interestingly, while Early Archaic components were identified for the lower paleo-braidplain sites (Barber Creek and Squires Ridge) and the upper paleo-braidplain site (Owens Ridge), no Early Archaic occupations were identified for either of the upper alluvial terrace sites (Hart and Taft Ridge) (see Figure 3-5 in Daniel and Moore, this volume). As stated above, a lack of additional components may simply be due to very limited Test Unit excavations. Based on the presence of undiagnostic cultural material at Taft Ridge below both Late and Middle Archaic occupations, the presence of earlier occupations at this site would not be unexpected with additional excavations.

Sedimentological and luminescence age data indicate that both Taft Ridge and Hart Ridge are relatively stable Pleistocene-age landforms, and, as such, remain potential candidates for late Pleistocene and early Holocene occupations. These landforms were of particular interest due to the fact that they are situated along an ancient alluvial terrace, overlooking relict Pleistocene braided river deposits and would not have been affected by late Pleistocene or Holocene fluvial scouring. Additionally these landforms were, at particular times during the late Pleistocene, immediately adjacent to active braided river channels. Thus, these landforms would

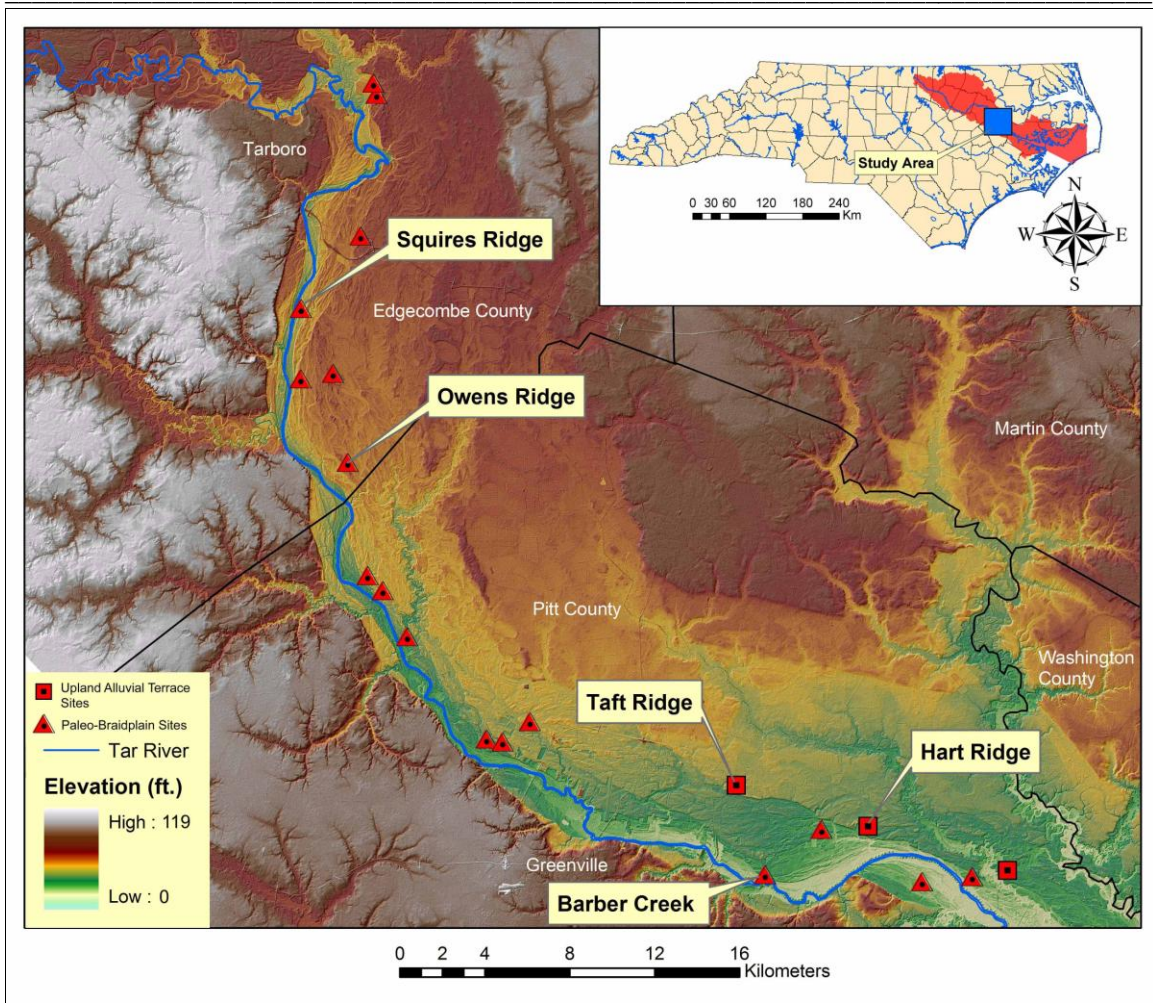


Figure 1-5. Locations of all archaeological sites identified during shovel test survey of selected sand ridges between Tranter's Creek (northeastern Pitt County) and Tarboro, North Carolina.

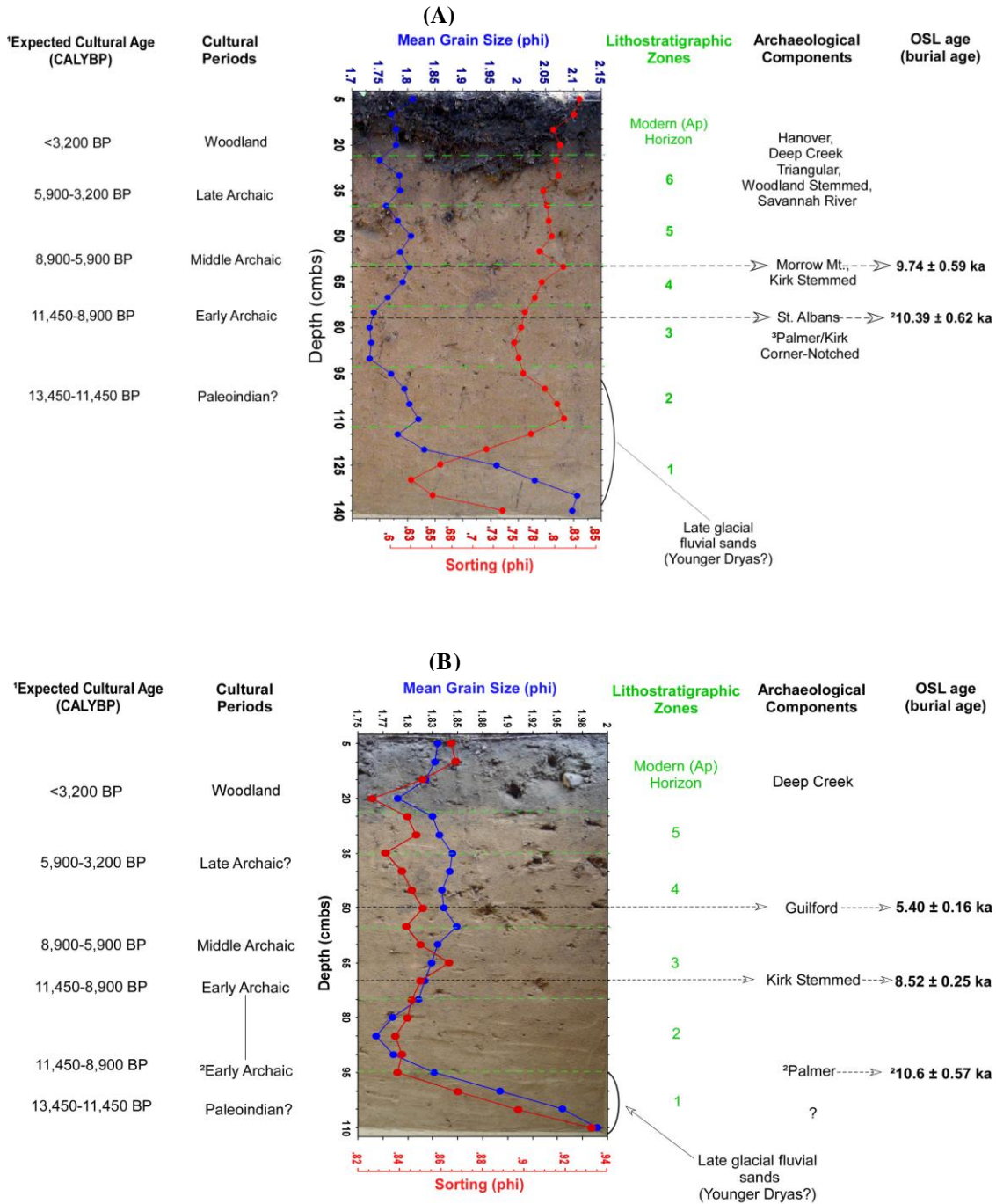


Figure 1-6. Archaeostratigraphy, interpreted lithostratigraphic zones, and luminescence (OSL) geochronology for the (A) Barber Creek Site (31Pt259) and (B) Squires Ridge (31Ed365). ¹Expected cultural age based on established (calendar year) time scale for Paleoindian and Archaic sub-periods (Anderson 2001). ²OSL samples calculated using minimum age model (Galbraith et al. 1999). See text for explanation. ³General stratigraphic position for Corner-Notched points at Barber Creek.

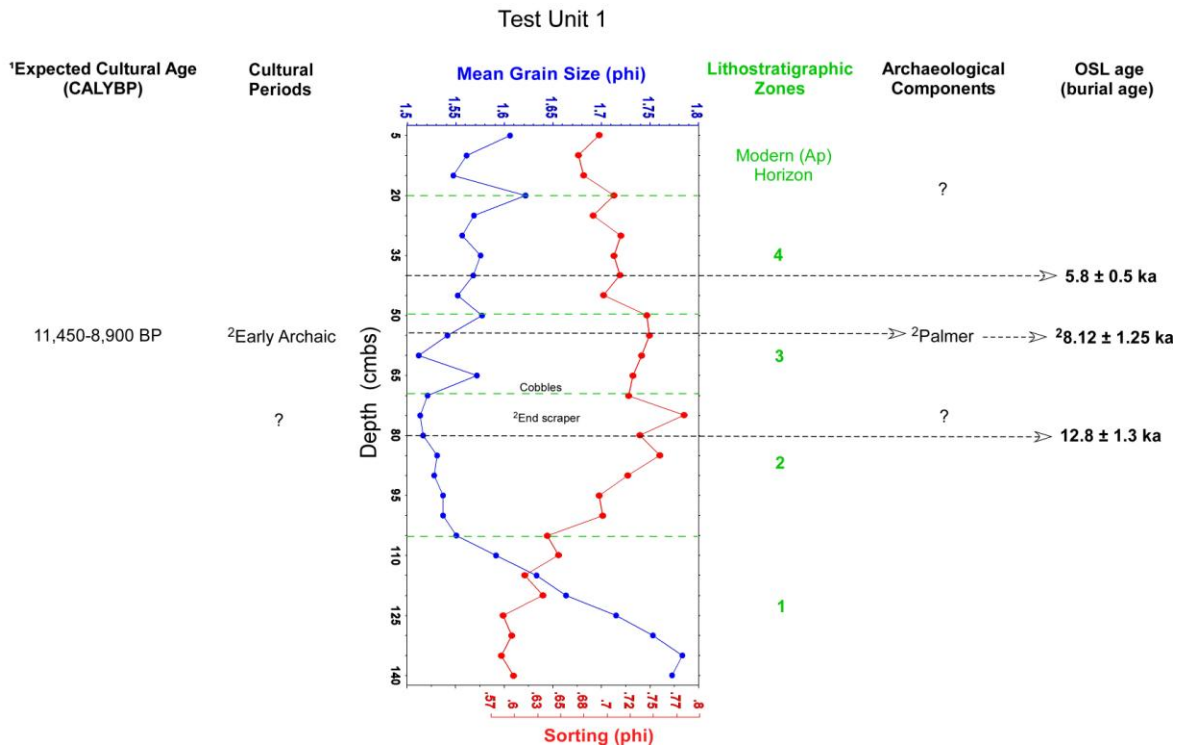


Figure 1-7. Archaeostratigraphy, interpreted lithostratigraphic zones, and luminescence (OSL) geochronology for the Owens Ridge Site (31Ed369). Note: Minimum age model used for all OSL age estimates for Owens Ridge (i.e., burial age) (Galbraith et al. 1999). See text for explanation. ¹Expected cultural age based on established (calendar year) time scale for Paleoindian and Archaic sub-periods (Anderson 2001). ²Palmer point and end scraper are from TU 2.

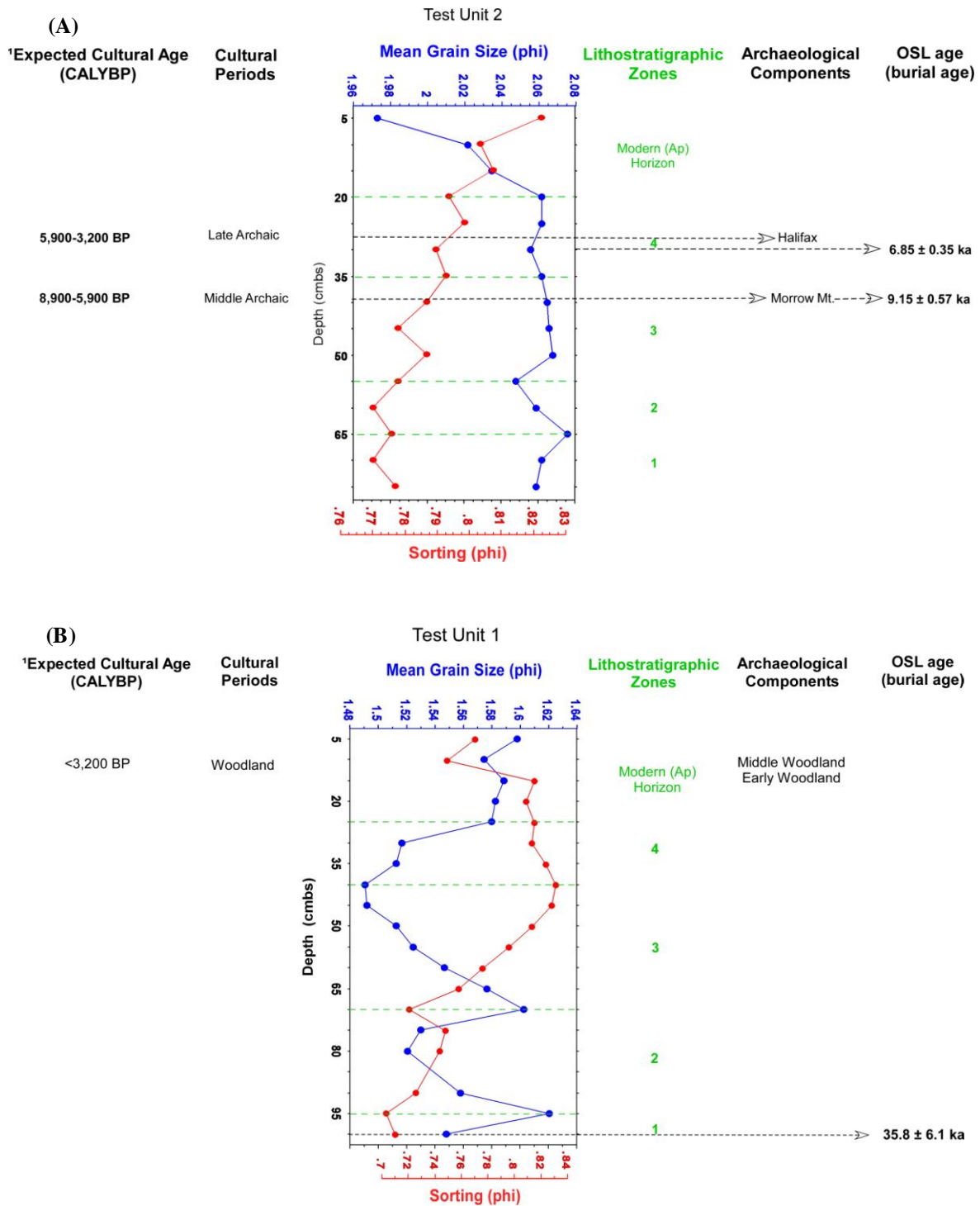


Figure 1-8. Archaeostratigraphy, interpreted lithostratigraphic zones, and luminescence (OSL) geochronology for (A) Taft Ridge (31Pt605) and (B) Hart Ridge (31Pt606). Note: Minimum age model used for both OSL age estimates at Taft Ridge (i.e., burial age) (Galbraith et al. 1999).

have been attractive for occupation by early Paleoindians encountering a very different fluvial landscape than later groups. Although initial Test Unit excavations at the Hart Ridge Site produced only low density and shallowly buried Woodland period artifacts, this landform has potential to contain deeply buried late Pleistocene or early Holocene occupations. This is particularly true given the position of Hart Ridge on the upland alluvial terrace and sedimentological data indicating a thick (>2 meter) aeolian or source-bordering dune sand unit at the site. Similarly, the Taft Ridge Site also has potential for buried early occupations, although site formation processes remain unresolved (see Daniel and Moore, this volume).

Woodland occupations were ubiquitous at most locations with almost all sites having at least some evidence of the Woodland Period, either in shovel tests or surface exposure of pottery sherds. Early Woodland (Deep Creek) pottery is the dominant pottery type at all sites with Woodland ceramics, while minor amounts of Middle Woodland Hanover and trace amounts of Mt. Pleasant were also recovered in some shovel tests. With rare exception, most pottery was confined to the upper 30 to 40 centimeters of soil with trace amounts found deeper, often a clear result of ground disturbance or possibly a result of leached out Woodland or Archaic Period storage pits or features. These leached features are often only identifiable through the careful excavation and recording of isolated concentrations of small charred nutshell and calcined bone fragments present through multiple excavation levels. In fact, it is the informed opinion of the authors that anthropogenic disturbances to site integrity (e.g., intrusive pits and features dug into earlier occupation floors) are probably at least as significant as other natural pedoturbation processes (e.g., roots, insects and tree throws).

Based on this research, archaeologically stratified aeolian dunes or mixed aeolian/fluvial sand-sheets (similar to the Barber Creek Site) appear to be present sporadically, if somewhat rarely, throughout the study area. In particular, small linear or coalescing parabolic aeolian landforms (similar to Owens Ridge) are clearly identifiable within the upper paleo-braidplain north and east of the current position of the Tar River in Edgecombe and Pitt counties (Figure 1-9). Many such landforms remain to be tested for buried archaeological sites. Lower paleo-braidplain sites were identified with the use of LiDAR elevation data as linear sand ridges immediately adjacent to the modern Tar River floodplain. These landforms lack classic aeolian or dune geomorphology but (based on sedimentology) have ~1 meter thick aeolian or mixed aeolian/fluvial caps overlying fluvial (fining-upward) braid bar or braid bar/fluvial levee type deposits (Moore 2009b). Thus, archaeologically stratified lower paleo-braidplain sites (e.g., Squires Ridge and Barber Creek) are perhaps better described as aeolian drapes or mixed aeolian/fluvial sand-sheets rather than true relict sand dunes (e.g., Owens Ridge and Hart Ridge). This suggests more complex site formation processes for lower paleo-braidplain sites as compared to upper paleo-braidplain and upland terrace sites. In fact, lower paleo-braidplain aeolian/fluvial deposits (although relatively shallow) may contain the most complete paleoenvironmental record of climate change (for landforms along the Tar River) during the late Pleistocene and Holocene. This is particularly true given that the upper meter of these deposits appears to have formed almost entirely over the last ca.13,000 calendar years.

Luminescence and ¹⁴C Geochronology

For this project, twelve single-aliquot and four single-grain OSL age estimates, along with one radiocarbon date were obtained from five different sites along the Tar River in Pitt and Edgecombe counties, North Carolina (Figures 1-10 and 1-11 and Table 1-1). With respect to

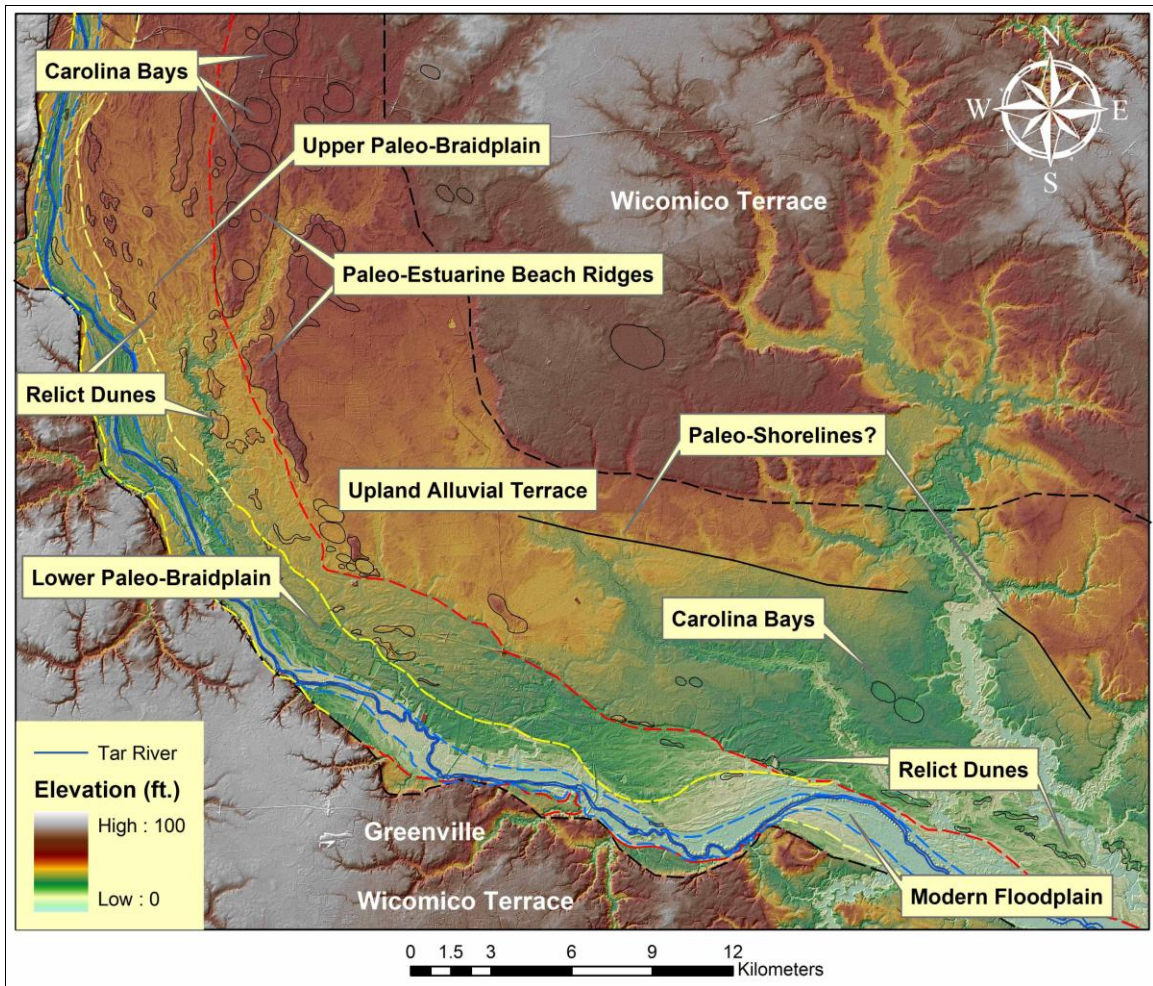


Figure 1-9. A generalized geomorphic map of the Tar River Basin between Tarboro, NC (northern Edgecombe County, NC) and Tranter's Creek (northeastern Pitt County, NC) based on analysis of LiDAR elevation data for the Tar River Basin produced by the NCDOT Floodplain Mapping Program. Riverine terrace sequences include: 1) upland alluvial terrace, 2) upper paleo-braidplain, 3) lower paleo-braidplain and 4) modern Tar River floodplain (see also Riggs, in review, 2009). Outlined features include likely relict aeolian dunes, braid-bars, paleo-estuarine beach ridges, and Carolina bays.

Note: The Wicomico terrace is a marine terrace with an elevation range between 14 and 29 meters amsl in the North Carolina Coastal Plain (Farrell et al. 2003).

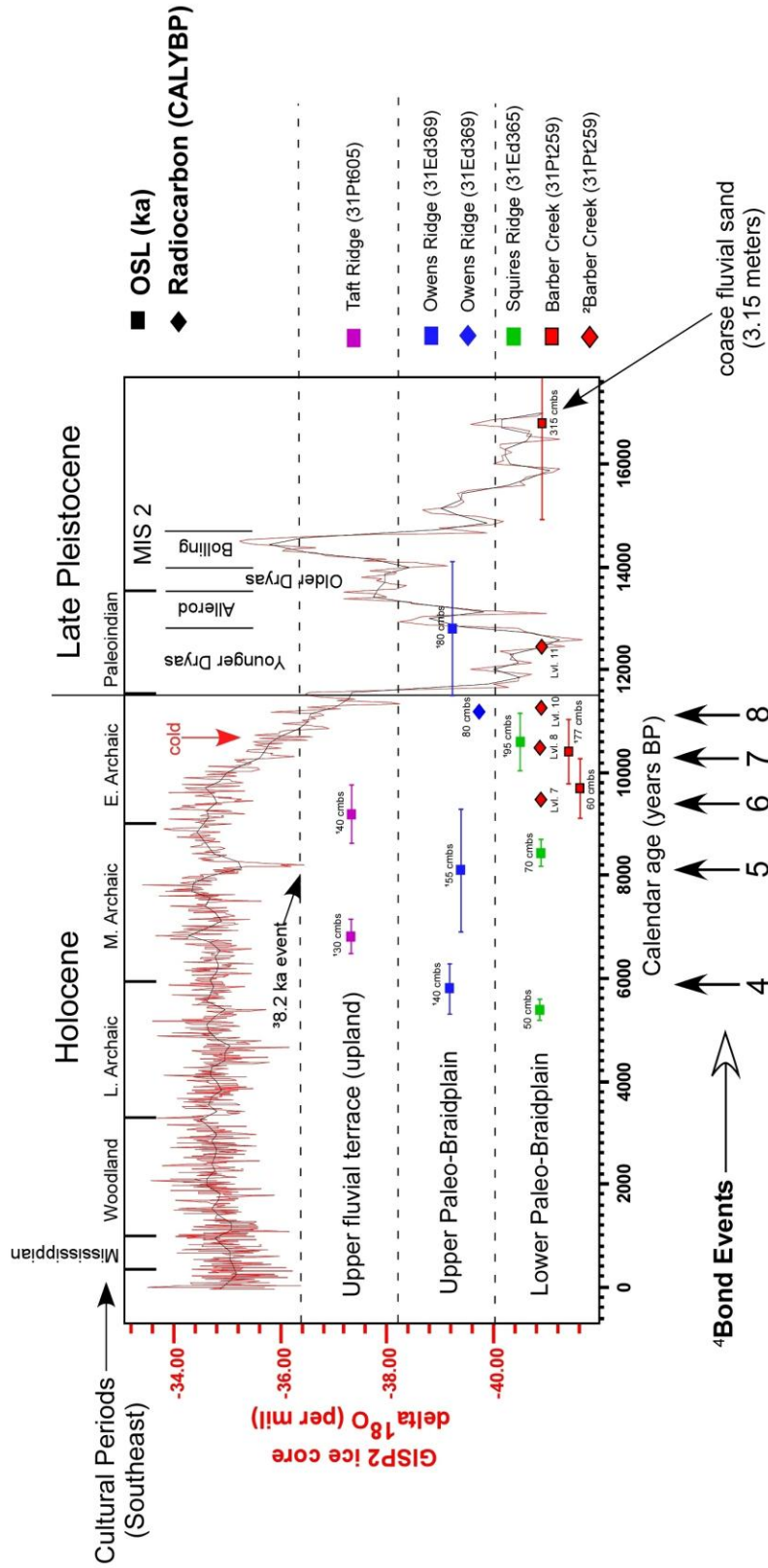


Figure 1-10. Single-aliquot luminescence and ^{14}C geochronology for buried archaeological sites along the Tar River plotted over the GISP2 Oxygen Isotope curve for the last 17 ka (Ice core data provided by the National Snow and Ice Data Center, University of Colorado, Boulder and the WDC-A for Paleoclimatology, National Geophysical Data Center, Boulder, Colorado). ¹Minimum age model used to determine burial age (all other OSL ages determined by central age model) Galbraith et al. 1999). See text for explanation. ²Barber Creek ^{14}C dates are from Daniel et al. 2008.

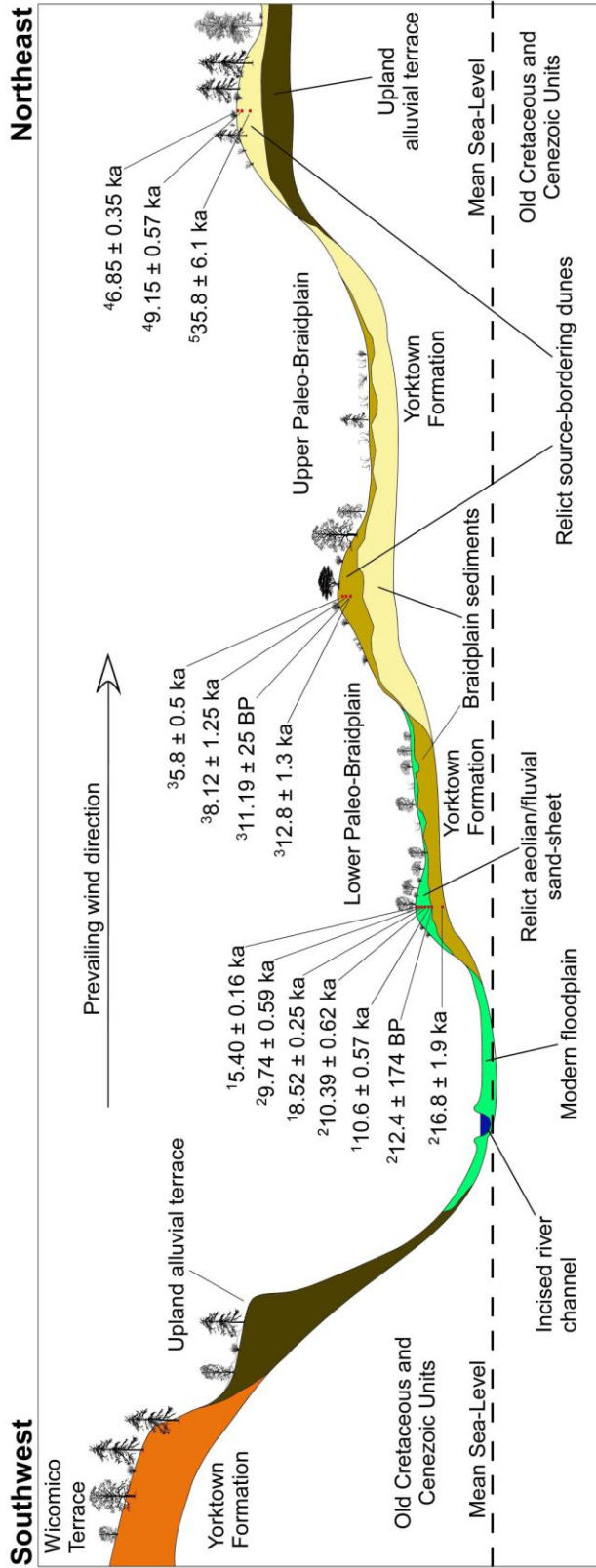


Figure 1-11. A Generalized topographic and geologic schematic of the Tar River Basin in the upper Coastal Plain of North Carolina showing relict sand ridges. (Map is not to scale). Barber Creek ^{14}C geochronology obtained for buried archaeological sites with relict sand ridges. (Map is not to scale). Barber Creek ^{14}C dates are from Daniel et al. 2008. 1 Squires Ridge (31Ed365), 2 Barber Creek (31Pt259), 3 Owens Ridge (31Ed369), 4 Taft Ridge (31Pt605), and 5 Hart Ridge (31Pt606).

TABLE 1-1. Dosimetry data and OSL ages for Tar River Survey, NC

Site Name/ FS #	County	Depth (cmbs)	% Water content ^a	K (%) ^b	Th (ppm) ^c	U (ppm) ^d	Cosmic dose ^e additions (Gy/ka)	Total Dose Rate (Gy/ka)	Mean De (Gy)	Minimum De (Gy)	n ^f	Mean Age (ka)	Minimum Age (ka)
Squires Ridge (31Ed365)													
FS #171	Edgecombe	50	3 (28)	1.31 ± 0.10	4.52 ± 0.17	1.34 ± 0.07	0.20 ± 0.02	1.88 ± 0.05	10.2 ± 0.09	7.84 ± 0.42	23 (24)	5.40 ± 0.16 ^g	4.17 ± 0.11 ^h
FS #172	Edgecombe	70	4 (27)	1.31 ± 0.10	4.52 ± 0.17	1.34 ± 0.07	0.19 ± 0.02	1.93 ± 0.05	16.4 ± 0.13	14.19 ± 0.83	26 (30)	8.52 ± 0.25 ⁱ	7.35 ± 0.23 ^h
FS #166	Edgecombe	95	4 (26)	1.31 ± 0.10	4.52 ± 0.17	1.34 ± 0.07	0.18 ± 0.02	1.97 ± 0.05	24.0 ± 0.60	20.92 ± 1.00	19 (24)	12.2 ± 0.46 ^g	10.6 ± 0.57 ^h
Owens Ridge (31Ed369)													
FS #179	Edgecombe	40	10% ± 5%	1.63	2.57 ± 0.65	1.2 ± 0.18	0.2047	2.0 ± 0.1	14.3 ± 2.23	11.87 ± 0.54	19	7.0 ± 1.2	5.8 ± 0.5
FS #169	Edgecombe	55	2 (30)	1.41 ± 0.15	4.57 ± 0.34	2.12 ± 0.08	0.19 ± 0.01	2.53 ± 0.09	23.6 ± 2.50	20.54 ± 1.12	24 (24)	9.31 ± 1.05 ^g	8.12 ± 1.25 ^h
FS #180	Edgecombe	80	10% ± 5%	1.57	1.1 ± 0.51	1.45 ± 0.14	0.1887	1.9 ± 0.1	32.1 ± 6.32	24.65 ± 1.9	19	16.6 ± 3.4	12.8 ± 1.3
Taft Ridge (31Pt605)													
FS #173	Pitt	30	5 (35)	1.71 ± 0.19	8.35 ± 0.62	1.28 ± 0.05	0.22 ± 0.01	2.11 ± 0.11	18.9 ± 0.66	14.46 ± 0.52	19 (20)	8.97 ± 0.57 ^g	6.85 ± 0.35 ^h
FS #174	Pitt	40	4 (24)	1.65 ± 0.19	7.60 ± 0.42	1.42 ± 0.05	0.20 ± 0.01	2.25 ± 0.09	26.3 ± 2.44	20.6 ± 0.84	23 (24)	11.7 ± 1.18 ^g	9.15 ± 0.57 ^h
Hart Ridge (31Pt606)													
FS#181	Pitt	100	10% ± 5%	1.28	4.24 ± 1.11	1.32 ± 0.32	0.1833	1.9 ± 0.2	66.3 ± 9.97	48.9 ± 4.34	16	35.8 ± 6.1	26.4 ± 3.2
Barber Creek (31Pt259)													
FS #2476	Pitt	60	2 (36)	1.36 ± 0.16	5.10 ± 0.26	1.41 ± 0.11	0.19 ± 0.01	1.97 ± 0.08	19.2 ± 0.88	13.7 ± 0.7	19 (20)	9.74 ± 0.59 ^g	6.95 ± 0.58 ^h
FS #2797	Pitt	77	1 (35)	1.27 ± 0.11	5.54 ± 0.22	1.33 ± 0.11	0.19 ± 0.01	1.91 ± 0.06	24.4 ± 1.11	19.84 ± 0.7	27 (30)	12.8 ± 0.71 ^g	10.39 ± 0.62 ^h
FS #2511	Pitt	315	10% ± 5%	1.37	7.3 ± 1.66	2.3 ± 0.49	0.15	2.3 ± 0.2	38.9 ± 2.66		19	16.8 ± 1.9	

^aMoisture value used in calculation of age (usually 55% of total saturation). Figures in parentheses indicate the complete sample saturation %.

^bAnalyses obtained using laboratory Gamma Spectrometry (low resolution NaI).

^cCosmic doses and attenuation with depth were calculated using the methods of Prescott and Stephens (1982) and Prescott and Hutton (1994). See text for details.

^dNumber of replicated equivalent dose (De) estimates used to calculate the mean. Figures in parentheses indicate total number of measurements made including failed runs with unusable data.

^eDose rate and age for fine-grained 250-180 um quartz sand. Linear fit used on age, errors to one sigma.

^fDose rate and age for fine-grained 250-180 um quartz sand. Exponential and linear fit used on age, errors to one sigma, weighed mean.

^gDose rate and age for fine-grained 150-90 um quartz sand. Exponential and linear fit used on age, errors to one sigma.

^hMinimum age model calculated using statistical model developed by Rex Galbraith. Errors to one sigma.

single-aliquot OSL dating, minimum age model age estimates (Galbraith et al. 1999) were considered better estimates of burial age in seven out of the twelve single-aliquot samples. This may be due to the presence of partially-bleached grains or grains with an inherited dose from a previous depositional environment. Partially bleached grains are common in many depositional environments; however, they are more common in fluvial or waterlaid deposits (Olley et al. 2004). In many cases, partially bleached grains may be inferred from positively skewed equivalent dose distributions (Murray et al. 1995; Olley et al. 1998; and Lepper et al. 2000). Many OSL age estimates from Tar River sites have positively skewed distributions (Moore 2009b) and may indicate the presence of fluvially deposited sediments or mixing with older sediments. In several cases, use of the minimum age model brought age estimates into close agreement with the known temporal range of associated projectile points and ^{14}C dates (e.g., Barber Creek and Squires Ridge). While this fact does little to refine the cultural chronology of the Coastal Plain, it does indicate that burial processes have been active during the Holocene.

Both OSL age estimates from the upper meter at the Barber Creek Site are in close agreement with the previously established radiocarbon dating sequence (Daniel et al. 2008) and may reflect periods of aeolian reactivation during Bond Events 6 and 7 respectively (see Figures 1-6A, 1-10, and 1-11). Bond Events are periods of rapid climate change during the Holocene and are associated with major ice-raftering events in the North Atlantic (Bond et al. 1997, 1999, 2001). In general, these events appear to represent the rapid onset of cooler and dryer conditions and occur on quasi-periodic (~1,500 year) cycles (Bond et al. 1997, 1999). Bond Events also appear correlated with regional records of rapid climate change in the mid-Atlantic (e.g., Willard et al. 2005) and globally by multiple proxy records of climate change (Mayewski et al. 2004). Implications for these rapid climate change events are discussed below.

Although the deeper OSL sample from Barber Creek (3.15 meters below surface) has two distinct population modes evident in its equivalent dose histogram, no minimum age was calculated for this sample given the closeness of equivalent dose values. This age (16.8 ± 1.9 ka) is consistent with those reported by Leigh (2006, 2008) for transitional braided to meandering river deposits; however, grain size analysis suggests that fluvial sedimentation continued to approximately 1 meter below surface. Further luminescence dating of fluvial sands between 1 and 3 meters below surface are needed in order to determine when braided river conditions transitioned to meandering and became vegetationally-bound along the Tar River.

At Squires Ridge, weighted mean or central age model age estimates were applied to the upper two samples (i.e., 50 and 70 cmbs), while a minimum age model estimate was deemed appropriate (based on analysis of equivalent dose) for the deeper sample (i.e., 95 cmbs) associated with an Early Archaic Palmer Corner-Notched projectile point (Moore 2009b). The upper two samples provided weighted mean age estimates in good agreement with both Guilford (5.4 ± 0.16 ka) and Kirk Stemmed/Serrated (8.52 ± 0.25 ka) occupations, while the deeper sample is consistent with the accepted temporal range for Palmer (10.6 ± 0.57 ka). OSL age estimates (see Figure 1-6B) probably reflect burial events during or immediately following occupation. The integrity of the stratified Guilford occupation suggests rapid burial. Interestingly, all three ages may reflect periods of aeolian deposition associated with rapid climate change during Bond Events 4, 5, and 7 (Bond et al. 1997, 1999) (see Figure 1-10).

Limited archaeological evidence in the form of diagnostic artifacts at Owens Ridge hampered efforts to link luminescence ages to cultural sequences; however, the minimum age model estimates provided a more satisfactory chronological sequence for site formation (see Figures 1-7 and 1-10). Two OSL age estimates from Owens Ridge (Test Unit 1) suggest burial

events during the Younger Dryas (12.8 ± 1.3 ka) and later during the mid Holocene (5.8 ± 0.5 ka) (possibly associated with Bond Event 4). A single luminescence age estimate for Test Unit 2, associated with an Early Archaic Palmer projectile point, returned a weighted mean age (9.31 ± 1.05 ka) consistent with late or terminal Early Archaic; however, examination of the equivalent dose distribution data suggests that a minimum age model is more appropriate for determination of true burial age. The 8.12 ± 1.25 ka minimum age model estimate more accurately reflects burial events and may be associated with Bond Event 5 (i.e., the 8.2 ka event). The 8.2 ka climate event is indicated by both Willard et al. (2005) pollen data and global climate proxies analyzed by Mayewski et al. (2004). In fact, this event is the most prominent climate event in the Holocene with approximately half the amplitude of the terminal Pleistocene Younger Dryas event (ca. 12,900-11,500 CALYBP (Alley 2000; Alley et al. 1997). Finally, a radiocarbon date obtained on wood charcoal from Level 8 (70-80 cmbs) in Test Unit 2 and associated with a Type I end scraper returned a early Holocene date (11,190 CALYBP) consistent with the observed archaeostratigraphy (see Figures 1-10 and 1-11) (Moore 2009b).

Weighted mean luminescence age estimates for Taft Ridge provided ages far older than suggested by the archaeology of the site. Recovered Halifax and Morrow Mountain projectile points indicate the presence of Middle and Late Archaic occupations. Examination of the equivalent dose histograms for Taft Ridge revealed bimodal and positively skewed distributions (Moore 2009b). Together, these suggested partially bleached grains with an inherited age. Reevaluation of these samples with the minimum age model provided ages closer to the expected age range but still significantly older than the known temporal range for Halifax or Morrow Mountain (see Figure 1-8A). These ages may reflect Morrow Mountain occupation of a long-term stable land surface, followed by site burial. This argument is particularly compelling given that the age of sand deposits immediately above (associated with Halifax) fall within the known range for Morrow Mountain (ca. 8,100-6,000 CALYBP).

While bioturbation may be a significant factor in site formation at Taft Ridge, the potential exists for relatively intact buried surfaces at 30 and 40 centimeters below surface. These surfaces may reflect limited reworking or deposition on an otherwise stable Pleistocene landform. Equivalent dose distribution data indicating the presence of partially bleached grains may also indicate more fluvial contributions to site formation than originally thought. This supports interpretations based on grain size analysis that indicate the potential for a non-aeolian origin for the landform.

Finally, a single luminescence date from the Hart Ridge Site (well below archaeological deposits) indicates a late Pleistocene origin for the landform. A weighted mean OSL age of 35.8 ± 6.1 ka is considered the best estimate of landform age based on a normally distributed equivalent dose histogram (see Table 1-1 and Figure 1-8B). A lack of evidence for partially bleached grains is further evidence for the purely aeolian nature of this landform and corroborates other lines of evidence gathered by analysis of landform geomorphology, geophysics, and grain size data (Moore 2009b).

Together, OSL and radiocarbon age estimates from Hart Ridge and Taft Ridge (upland), Owens Ridge (upper paleo-braidplain) and Squires Ridge and Barber Creek (lower paleo-braidplain), constrain the timing of depositional events and indirectly track changes in the fluvial evolution of the Tar River between three distinct alluvial terraces (see Figure 1-11). Thus, with each subsequent incision and reduction in braidplain width, the primary sand source for one set of source-bordering dunes was cut off and another activated within the fluvial environment immediately adjacent to remnant braidplain scarps.

Based on the OSL age estimate for Hart Ridge, the laterally extensive upper paleo-braidplain was weakly incised and shut-down as an active sand source sometime during late MIS 3 (ca. 35 ka), with only limited reworking of dune crests and site burial during the Holocene. This is consistent with OSL ages from Taft Ridge that produced early and middle Holocene ages for shallow archaeological deposits within the upper 40 centimeters.

Although basal dates for Owens Ridge (upper paleo-braidplain) are lacking, OSL and ^{14}C ages from the upper meter of sand indicate that the most significant period of dune emplacement had already occurred prior to the Holocene. That said, several periods of dune reactivation are indicated, and appear to have buried terminal Pleistocene and early Holocene cultural occupations within the upper 80 centimeters of sand. This may be due to the proximity of the Owens Ridge Site to the modern Tar River floodplain and/or periodic Holocene reactivation of several paleo-stream channels immediately adjacent to the landform (Moore 2009a, 2009b).

OSL and radiocarbon age estimates for basal aeolian deposits at lower paleo-braidplain sites (Barber Creek and Squires Ridge) indicate aeolian sand-sheet deposition beginning just before or during the Younger Dryas stadial event (ca. 12,900-11,500 CALYBP) (Daniel et al. 2008; Moore 2009b). An OSL age estimate was obtained from Barber Creek (ca. 16.8 ka) within coarse fluvial braidbar deposits (3.15 meters below surface) and well below the fluvial to aeolian transition (~1 meter below surface). Thus, incision of the lower paleo-braidplain and formation of the modern Tar River floodplain must have occurred sometime between ~17 ka and the onset of the Younger Dryas (*cf.* Leigh 2006, 2008; Leigh et al. 2004). In any case, aeolian deposition along the lower paleo-braidplain is unlikely to have begun until after this final incision event.

Four single-grain (as opposed to single-aliquot) OSL age estimates (Table 1-2 and Figure 1-12) from the Barber Creek Site support earlier conclusions (based on single-aliquot OSL data and ^{14}C). In particular, a single-grain OSL age estimate from 100 cmbs supports previous data already discussed and links the timing of a major transition in the lower paleo-braidplain to the Younger Dryas stadial event (i.e., the transition from predominantly fluvial to mixed aeolian/fluvial deposition within the upper 1 meter of sand at Barber Creek). In addition, the reevaluation of a single-aliquot date (FS# 2797 from Table 1-1) using the single-grain technique suggests that in some cases, even the minimum age model estimates for single-aliquot dating may overestimate burial age. This may be due to the presence of partially bleached grains or the inherent problems of using single-aliquot dating to accurately distinguish depositional age from slightly mixed or bioturbated sediments (Boulter et al. 2006).

In any event, the addition of single-grain OSL age estimates provide ages generally consistent with those already obtained through single-aliquot dating and bolster claims for an entirely Holocene origin for much of the upper meter of sand at the Barber Creek Site and at other sites along the Tar River. Multiple lines of evidence, including the archaeostratigraphy, chronometric dating (^{14}C and OSL), and granulometry all support this inference. Thus, a hypothesis of extreme bioturbation for stratifying archaeological deposits through biomantle formation of artifact 'stone zones' within old/stable Pleistocene landforms, as proposed by Johnson (1990) and others (e.g., Leigh 1998a, 1998b) is rejected. In this case, bioturbation is more accurately conceived as an "overprint" of the shallow archaeostratigraphy of many of the relict sand ridges along the Tar River rather than as the primary mechanism of artifact burial. This fact may have important implications for Cultural Resources Management (CRM) in the Coastal Plain—particularly in regard to assessments of site significance. The picture emerging from research along the Tar River suggests that burial and shallow stratification of

Table 1-2. Dosimetry data and single-grain OSL ages for Barber Creek (31Pt259).

Sample	FS#	Depth (m)	^{238}U (ppm)	^{232}Th (ppm)	K (%)	H_2O %	Beta dose rate (Gy/ka)		Total dose rate (Gy/ka)	Central age D_e (Gy)	Age (ka)	% error
							β -counting	α -counting/flame photometry				
UW1907	^a 3315	0.8	1.64±0.13	5.22±0.91	1.39±0.03	6 ± 3	1.28±0.11	1.47±0.04	2.01±0.08	18.5 ± 0.9	9.2 ± 0.7	7.1
UW1908	^a 3316	1	1.53±0.12	3.74±0.76	1.28±0.04	6 ± 3	1.35±0.11	1.32±0.04	1.91±0.08	23.1 ± 0.8	12.1 ± 0.7	6.2
UW1909	^a 3319	1.4	0.31±0.07	3.73±0.74	1.36±0.03	6 ± 3	1.13±0.10	1.21±0.03	1.72±0.07	24.8 ± 1.3	14.5 ± 1.0	7.1
UW1963	^b 2797	0.77	1.33±0.11	5.54±0.22	1.27±0.11	6 ± 3	n/a	n/a	1.99±0.10	18.0±0.8	9.1 ± 0.7	7.3

^aN445, E430

^bThis sample was also dated using the single-aliquot technique (see Table 1-1).

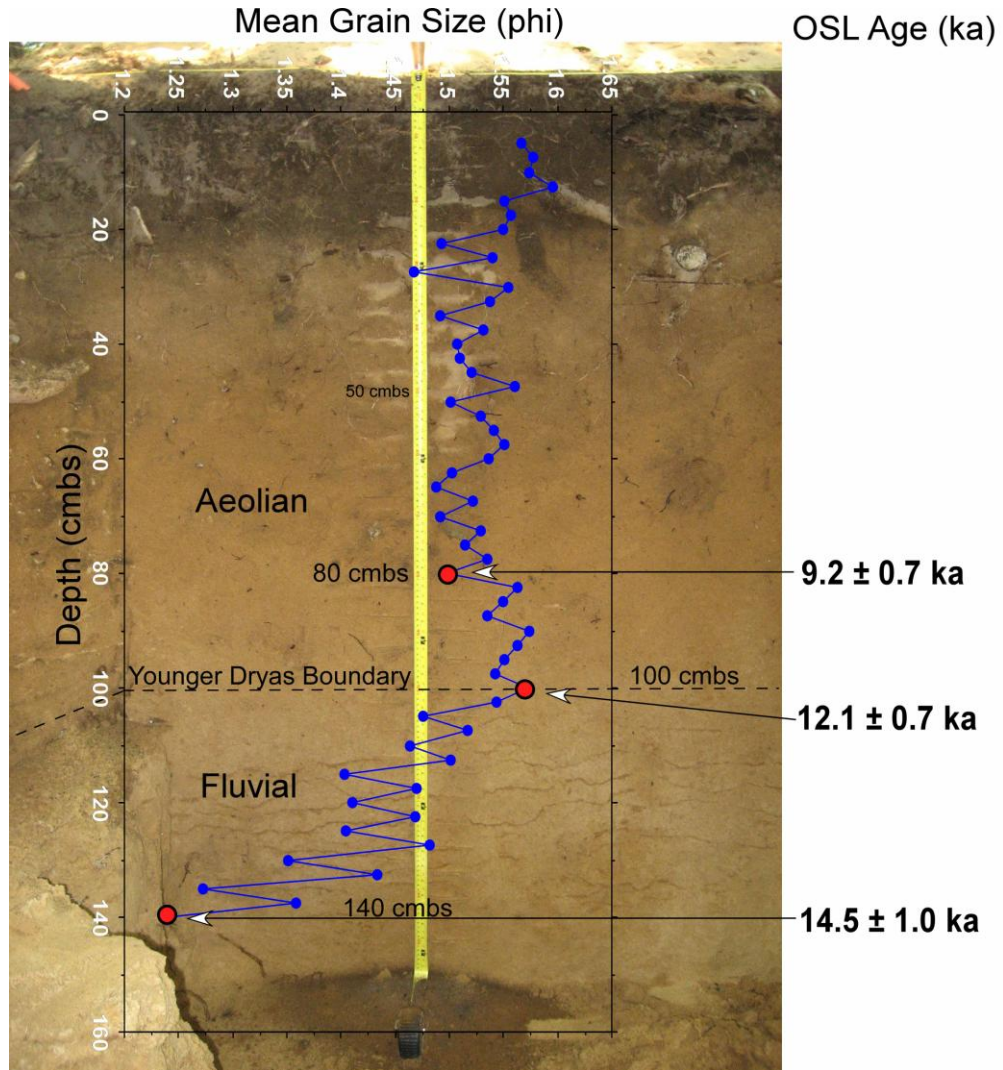


Figure 1-12. Single-grain luminescence (OSL) age estimates for the Barber Creek Site (N445, E430) showing a lithostratigraphic boundary between underlying fluvial or flood-deposited sediments (note fining-upward sediment lenses defined by granulometry and overprinted by pedogenic lamellae) and predominantly aeolian sediments (upper meter of sand). The Younger Dryas Boundary (YDB) is indicated by OSL dating at this transition. Note: Close-interval grain size data are from McFadden (2009).

archaeological occupations may be more common than once thought in the North Carolina Coastal Plain. This is all the more likely within riverine environments where source-bordering accumulations of wind-blown sand and flood deposits are a possibility. In any case, it suggests sites need to be accessed for significance based on sound geoarchaeological evidence.

CONCLUSIONS

Investigations of relict “source-bordering” dunes and/or relict aeolian/fluvial sand ridges identified along the Tar River in Pitt and Edgecombe counties, North Carolina have produced a wealth of archaeological and paleoenvironmental data (e.g., Choate 2011; Daniel 2002a, 2002b; Daniel et al. 2008; McFadden 2009; Moore 2009a, 2009b; Seramur and Cowan 2002). Combined archaeological and sedimentological analyses along with luminescence (OSL) and ¹⁴C dating suggest that direct burial of cultural remains occurred throughout the late Pleistocene and Holocene by wind-blown sand as well as by flood deposits (Moore 2009a, 2009b). Geophysical, stratigraphic, chronometric, and grain size data collected from these sites indicate multiple phases of aeolian/fluvial accretion with varying rates of deposition. Close-interval grain size data and chronometric dating, along with temporally stratified artifact assemblages (typically within the upper meter of sand) suggest five or six periods of small-scale accretion at lower paleo-braidplain sites followed by periods of stability or erosion (see Figure 1-6). Based on the archaeostratigraphy of piece-plotted artifacts, three major periods of landform stability and occupation are evident at Barber Creek with shallowly stratified early, middle, and late Holocene archaeological components (see also McFadden 2009 and Choate 2011).

Upper paleo-braidplain sites, such as Owens Ridge, are large source-bordering aeolian dunes with much deeper surficial (i.e., upper sand unit) deposits than lower paleo-braidplain sites. While the majority of these landforms are likely late Pleistocene in age, periodic reactivation of the Owens Ridge Site during the Holocene is responsible for site burial and stratification of archaeological components to a depth of 80-90 cmbs. Grain size data suggest at least four periods of aeolian or fluvial accretion since the late Pleistocene (See Figure 1-7). Archaeological and chronometric data from Owens Ridge suggest this site has great potential for buried Paleoindian occupations. This may be due in part to the stratigraphic position and age of upper paleo-braidplain landforms compared with lower paleo-braidplain sites. Other large source-bordering dunes are located just north of Owens Ridge, immediately to the east of the Town Creek confluence, and should be investigated for their potential to produce evidence of the early Paleoindian occupation of the Tar River Valley.

Upland relict dunes along the Tar River are late Pleistocene in age and formed during periods of extensive braided river conditions during terminal marine isotope stage (MIS) 3 (60-30 ka). Relict landforms such as Hart Ridge are large dunes with nearly 2 meters of aeolian deposits. These sands were likely reactivated during Holocene climate events; however, depositional events may have been limited to reworking of dune crests (e.g., Ivester et al. 2001). Limited Holocene deposition at these sites may be due to the fact that, by the late Pleistocene, the sand source in the upper paleo-braidplain had been shut-down.

On a more speculative note, burial events along the Tar River may reflect Holocene millennial-scale climatic cyclicity (e.g., Bond et al. 1997) and its related effects on the fluvial system—providing a source of sand for aeolian or in some cases overbank flood transport onto adjacent braidplain scarps (Moore 2009b; Moore and Daniel 2010). Similarly, recent geoarchaeological research on the Savannah River has demonstrated that the late Quaternary

sedimentological record, "...appears to be linked to and coupled with abrupt climate and vegetation changes" (Waters et al. 2009). These events likely influenced both hunter-gatherer adaptation and site preservation along the Tar River and elsewhere in the Southeast. Luminescence and radiocarbon dates from stratified sand ridges along the Tar River correspond closely to Bond Events 4 through 8. While more work is needed to test this hypothesis, chronometric data presented here indicate a pervasive and episodic signature of climate change over the last 11,500 CALYBP (see Figures 1-10 and 1-11). Three chronometric dates (two OSL and one ^{14}C [Daniel et al. 2008]) also indicate depositional events associated with the Younger Dryas stadial event. These dates are associated with a lithologic break based on grain size data and indicate a shift in depositional environment in some cases (i.e., fluvial to aeolian)—particularly for lower paleo-braidplain sites.

At the Barber Creek and Squires Ridge sites, artifacts diagnostic of the Early Holocene were recovered near the base of dune deposits and above fluvial braidplain sediments. Although evidence for earlier Paleoindian occupations may yet be found (ca. 13,500-11,500 CALYBP), the presence of buried Early Holocene-age (i.e., Early Archaic) and the lack of Paleoindian artifacts immediately above or within the fluvial to aeolian transition at lower paleo-braidplain sites indicate braided river conditions may have continued as late as ca. 13,000 CALYBP (*cf.* Leigh 2006, 2008, Leigh et al. 2004). In other words, active braided river conditions may have prevented occupation of the Barber Creek Site by early Paleoindian foragers. Further work is needed to test this hypothesis.

OSL and ^{14}C ages collected near the base of mixed aeolian/fluvial and cultural deposits also indicate major fluvial channel sedimentation on the lower paleo-braidplain ceased around the time of the Younger Dryas stadial (ca. 12,900-11,500 CALY BP). This was followed by initiation of primarily aeolian accretion and cultural occupation along the lower paleo-braidplain alluvial terrace that continued episodically through much of the Holocene. Evidence for dune building during the Younger Dryas has also been found for relict aeolian dunes along the North Carolina Coast (Mallinson et al. 2008).

Thus, the absence of Paleoindian occupations at lower paleo-braidplain sites, such as Barber Creek, may be due to a late transition from active braiding conditions to the modern Tar River meandering floodplain during or post Younger Dryas. Alternatively, Pleistocene-age archaeological sites may have been scoured from the lower paleo-braidplain during early Holocene meandering. On the other hand, LiDAR imagery lack evidence of large-scale paleo-meander channels within the study area, but do reveal significant preservation of former braided terraces east and north of the river. Instead, the Tar River is characterized by slight down-cutting and incision—transitioning directly from relict braided terraces to a very weakly meandering and incised or vegetationally-bound fluvial system (e.g., Riggs, in review, 2009) (see Figures 1-1 and 1-2). Conversely, just slightly upstream of the study area, LiDAR data reveal a lack of relict braided river terraces (i.e., from Tarboro to the west) and are instead characterized by large-scale paleochannels and scrollwork indicative of former meandering channels. A similar pattern has been reported for fluvial terraces of the Lower Little River (see Suther et al. 2011). Source-bordering dunes or aeolian/fluvial sand-sheets overlying relict levee and braid-bar deposits are common along the scarps separating individual upland, braidplain, and meandering river terraces. These sand ridges track changes in the fluvial system since the late Pleistocene. Additional luminescence dating of transitional braided river to aeolian sediments and basal alluvium in the modern floodplain are needed to address the timing of this transition.

To anticipate criticism that we have failed to adequately consider bioturbation processes for explaining the observed stratified sequences for Tar River sites (e.g., Johnson 1990; Leigh 2001), we want to briefly address the issue here. To start with, we are not suggesting that sand ridges along the Tar River lack evidence of bioturbation, rather that this process appears to have had limited and spatially variable impact to the overall archaeostratigraphic character of these sites. We base this inference on multiple lines of evidence including the archaeostratigraphy (detailed piece-plotting and analysis of artifact backplots) from numerous sites, close-interval sedimentology (indicating breaks in lithostratigraphy), and numerous ^{14}C and OSL age estimates gathered through a detailed study of sand ridges along the Tar River with obvious evidence of stratified archaeological remains (Moore 2009b). While occasional stratigraphic inversions of temporally diagnostic artifacts and vertically displaced refits occur, the presence of discrete occupation floors or zones is clear upon examination of piece-plot data for large excavation blocks or trenches (e.g. Choate 2011). The vertical mixing of smaller artifacts (both above and below occupation zones) through trampling and other forms of anthropogenic disturbance (e.g., hearths and pit features), erosion, burrowing animals, tree throws, and other pedoturbation processes are not unexpected. These processes act to blur the lines between occupations—particularly for shallowly buried sandy sites in the Coastal Plain.

The inherently shallow nature of these sites and likely centimeter-scale burial events between multiple occupations have also resulted in nearly continuous vertical distributions of small artifacts (e.g., debitage). This is particularly true when our analytical units for analysis consist of arbitrary 10 centimeter excavation levels—levels that likely cross-cut multiple archaeostratigraphic boundaries. Continuous vertical distributions of small artifacts are also the likely result of small-scale bioturbation and anthropogenic disturbance of active and long-term stable to erosional occupation surfaces followed by episodic accretion during periods of climatic or environmental instability (e.g., floods, drought and/or fire, and anthropogenic disturbance to the local environment). Larger artifacts, on the other hand, appear to be more stable vertically and can be used to infer occupation surfaces or zones—particularly when combined with detailed granulometry. In most cases, careful piece-plotting in large excavation blocks may be necessary to distinguish stratigraphic occupation zones or zones of long-term stability or erosion. Recent work at Barber Creek (31Pt259) by Choate (2011) and three seasons of fieldwork at the Squires Ridge Site (31Ed365) have revealed the clearest evidence to date for vertical stratigraphy in these shallow sand ridges.

We submit that the methods utilized in this research address the issue of equifinality for distinguishing site burial through bioturbation as opposed to direct burial by sedimentation processes. In particular, we believe the combination of detailed archaeostratigraphic and single-grain OSL age data reveal clear and irrefutable evidence for direct burial of archaeological occupations over the last ca. 11,000 calendar years along the Tar River. Although stated previously, we contend that bioturbation is more accurately conceived as an overprint of the relatively intact archaeostratigraphy than as the principle mechanism for site burial. As we have done here, sites must be evaluated individually and with careful collection and scrutiny of archaeological, geological, and chronometric data before similar conclusions may be made for other sites or even for all areas of the sites we examine here. The correct evaluation of buried sandy sites for the relative influences of pedoturbation verses sedimentation is crucial for paleoenvironmental determinations and behavioral inferences (Leigh 2001). While we don't expect this long-standing debate to be settled by this paper—which we will address in more detail in a later paper—we do think we have an obligation to move on and utilize these sites to

address broad paleoenvironmental issues including the effects of rapid climate change on fluvial and aeolian depositional environments, riverine paleoecology, and cultural adaptation in the upper Coastal Plain of North Carolina.

Future work should focus on identifying and preserving other relict landforms within the paleo-braidplains of the Tar River and other Piedmont draining rivers in North Carolina. Many of these sand bodies are actively mined or are potentially threatened by future sand mining activities along the Tar River. Development is also actively destroying many of these sites with homes preferentially built along elevated and well-drained relict dunes and sand ridges close to the river. Given the fact that the vast majority of these sites are located on private lands, it is all the more imperative that archaeologists work with local land-owners and conservationists to provide protection for imperiled watersheds, ecologically sensitive areas, and cultural resources. When possible, conservation easements or land buyouts should be offered—particularly when significant archaeological sites overlap with important floodplains, watersheds, and biologically diverse communities along the Tar River. While this research has identified several important archaeological sites along the Tar River, none of these sites are currently protected from mining or development and many more have likely already been lost.

Archaeologically, future research should focus on additional excavations of stratified sites, primarily within the upper and lower paleo-braidplain. Additional close-interval grain size analysis (i.e., 2.5 cm or less) along with the application of close-interval, single-grain OSL dating using small-diameter sampling tubes should be applied to address site-formation questions raised by this research. In addition, soil chemistry analyses such as total phosphorous, organic carbon, phytolith extraction (e.g., Ivester et al. 2011; Leigh 2004) micromorphology studies (e.g., McPhail and McAvoy 2008) and application of other geophysical techniques (e.g., magnetic susceptibility, magnetometry, gradiometry, and electrical resistivity) may provide additional evidence for buried surfaces and/or cultural activities associated with occupations (e.g., hearths or cultural features). Together, these techniques will allow archaeologists to begin to address the substantive issues of cultural chronology and typology for the North Carolina Coastal Plain and provide archaeological correlates for understanding climate variability and the influence of environmental change on hunter-gatherer settlement and adaptation.

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