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Geoarchaeological investigations at the Topper and Big Pine Tree sites, Allendale County, South Carolina

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ABSTRACT

The Topper and Big Pine Tree sites are located along the central Savannah River in South Carolina. Both sites contain significant Clovis horizons and the Topper site is reported to contain a pre-Clovis assemblage characterized by a smashed core and microlithic industry. The stratigraphic position of the early assemblage at Topper is indeed below Clovis and radiocarbon and luminescence ages support its pre-Clovis age. However, the human origin of the proposed artifacts has not been conclusively proven. The late Quaternary stratigraphic sequence developed for this segment of the Savannah River provides support for a regional pattern of river metamorphosis over the last 50,000 years in southeastern U.S. streams.

1. Introduction

Stratified Paleoamerican sites are rare in the southeastern United States. In this paper, we present the results of geoarchaeological studies at two Paleoamerican sites, Topper (38AL23) and Big Pine Tree (38AL143), which are located along the central Savannah River near Allendale, South Carolina. The objectives of this paper are to present the stratigraphic and geochronologic contexts for the Topper and Big Pine Tree sites, discuss the geological position and estimated age of the archaeological components of these sites, and place the geological history of this portion of the Savannah River into the regional framework of late Quaternary stream behavior and response to climate and vegetation change.

2. The Allendale study area

The Topper and Big Pine Tree sites are located in the Upper Atlantic Coastal Plain along the Savannah River about 80 km from the coast (Fig. 1). In the study area, the Savannah River is a meandering stream that is incised into Tertiary-age formations of unconsolidated clastic sediments (Stevenson, 1976; Leeth and Nagle, 1996; Fallaw and Price, 1992).

A floodplain and two terraces flank the Savannah River (Fig. 2). The first terrace (T-1) lies about 99 m above sea level (asl) and within the sandy alluvium of this terrace fill is the Big Pine Tree site. The second terrace (T-2) is situated about 101.5 m asl and colluvium covers most of the terrace tread. The archaeological components at the Topper site are buried within the fill of this terrace and in the overlying colluvium. Above the terraces, the landscape slopes gently upward and is covered by late Quaternary colluvium and eolian sediments.

3. History of research

Archaeological investigations have been conducted at the Topper and Big Pine Tree sites for almost 20 years by Goodyear (1999, 2005a). Big Pine Tree is a stratified site with multiple occupation horizons dating from Clovis to the Late Prehistoric. Topper also has a stratified sequence and evidence of human occupations dating from the Late Prehistoric to Clovis, with potential pre-Clovis components.

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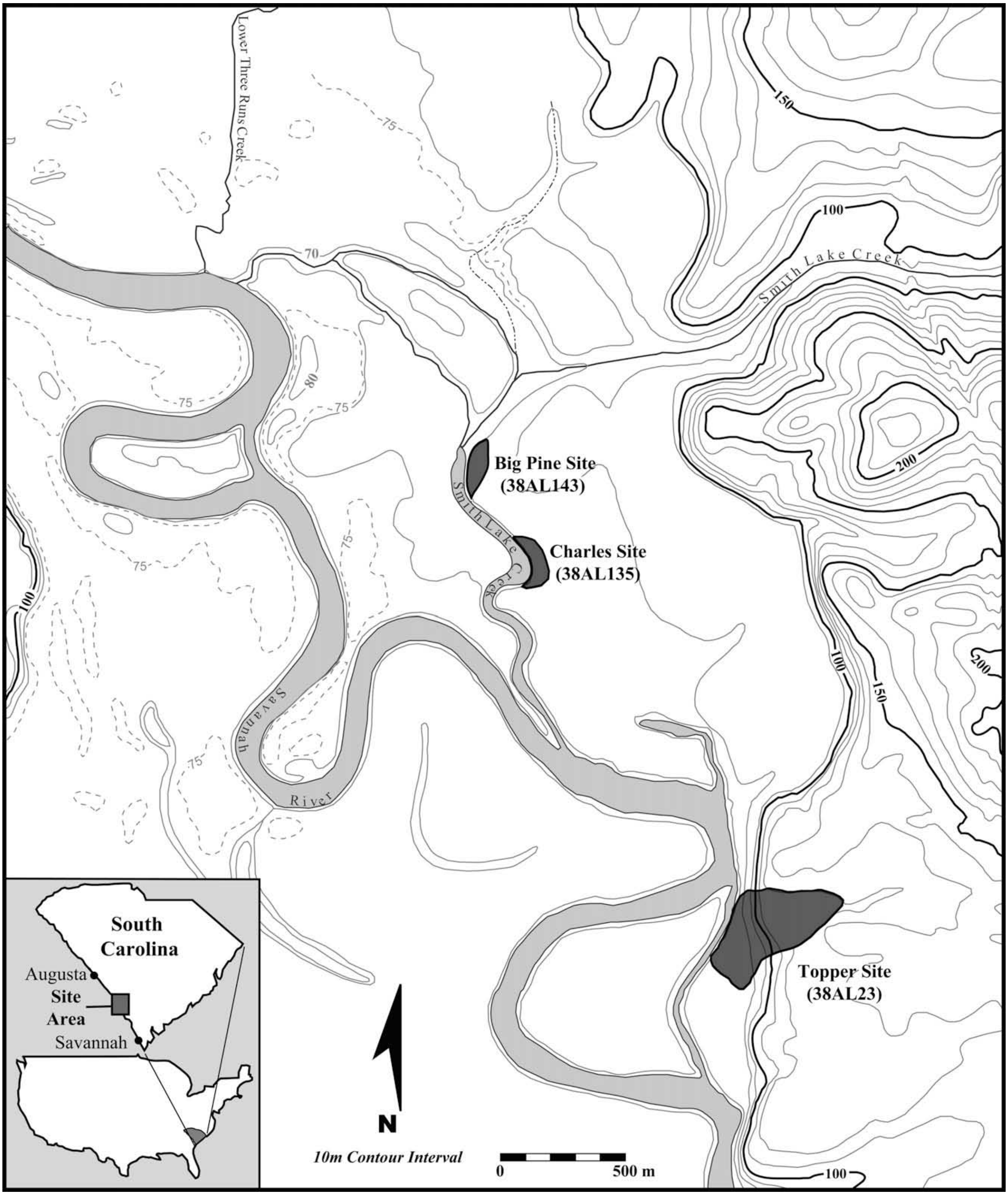

Fig. 1. Map of the Allendale study area, South Carolina showing the location of the Topper and Big Pine Tree sites.

Previous geological studies at these sites were undertaken by Foss (Goodyear and Foss, 1993; Goodyear, 1999) who described the stratigraphy of each site and provided detailed pedologic descriptions. Our study was undertaken starting in 1999 to define the stratigraphy at Topper and date the possible early component at the site using the radiocarbon and luminescence techniques. The stratigraphy of Big Pine Tree was also investigated to develop a more complete understanding of the alluvial history of the region.

Backhoe trenches were excavated at the Topper (Fig. 3) and Big Pine Tree sites to expose the alluvial and colluvial stratigraphy. At the Topper site, a series of trenches and excavation areas are correlated to provide an east-to-west transect across the site (Figs. 3 and 4). Additional profiles were recorded for Trench 7 (Fig. 5b),

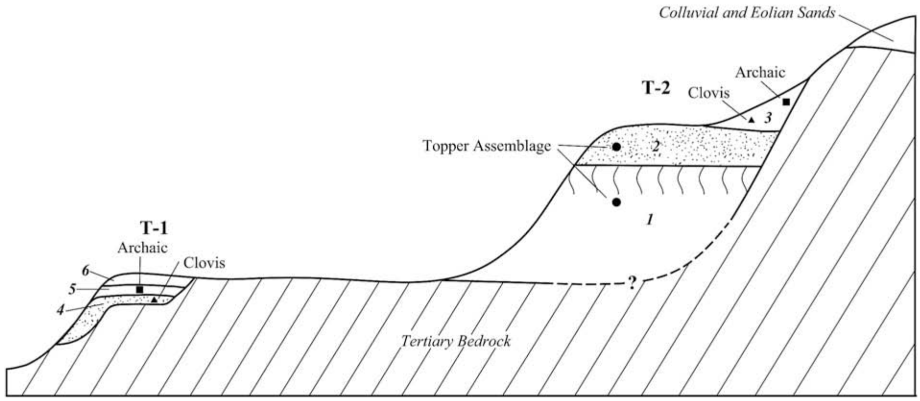

Fig. 2. Generalized cross-section showing the alluvial terraces along the Savanna River. The Topper site is located on T-2 and the Big Pine Tree site on T-1. Numbers indicate the major late Quaternary stratigraphic units discussed in the text. The location of archaeological components is indicated on the cross-section.

Trench 15 (Fig. 6), and an excavation area at the north end of the site (Fig. 5d). At these localities a number of stratigraphic units were distinguished and correlated to the site archaeology. Samples for radiocarbon and luminescence dating were collected from these profiles to provide age estimates for the geological deposits.

4. Late Quaternary stratigraphy of the Topper site

Topper is located on the second terrace (T-2) of the Savannah River (Fig. 2). At Topper, late Quaternary deposits include both alluvium and colluvium, which are divided into three major units,

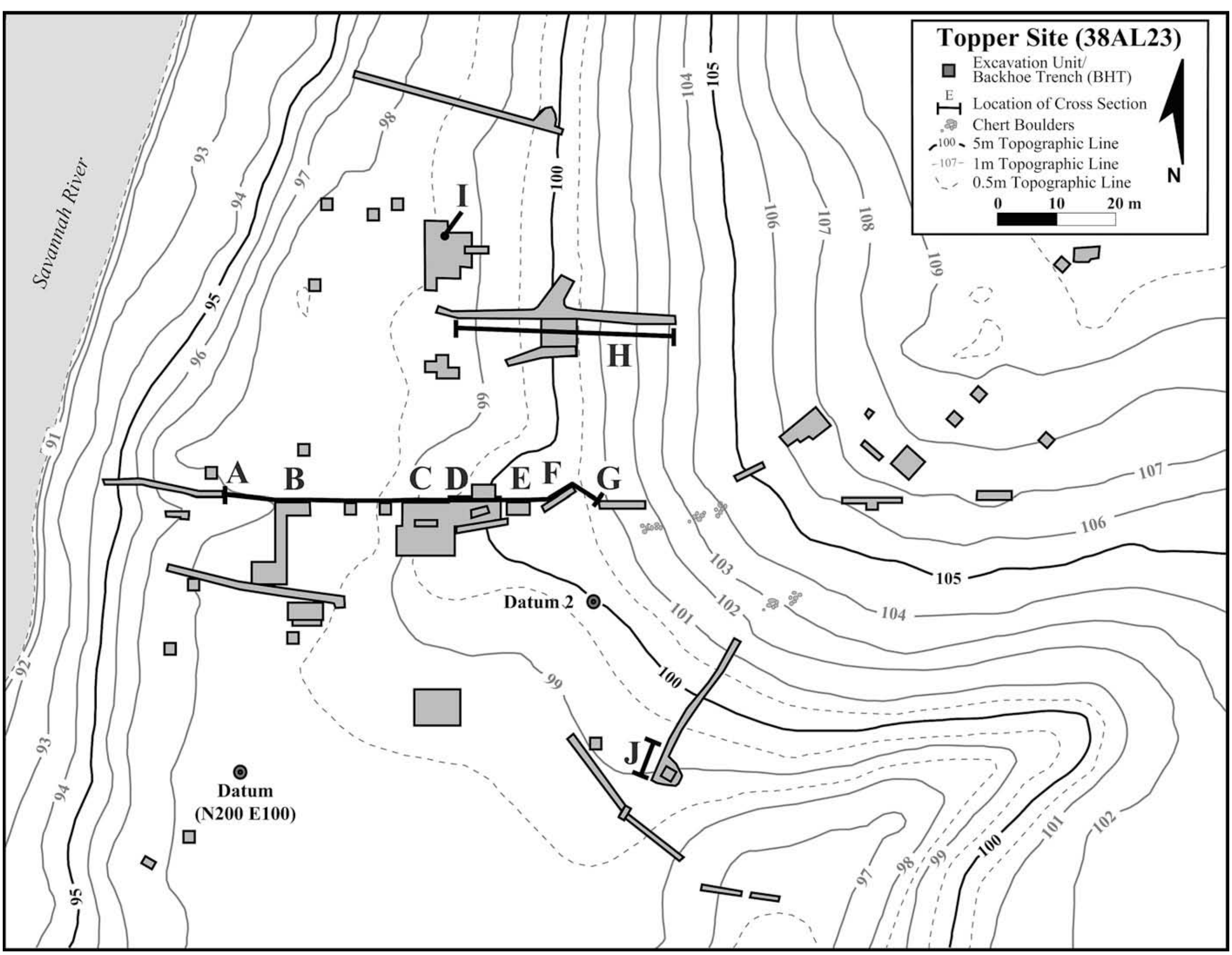

Fig. 3. Map of the Topper site showing the location of excavated areas and trenches. Letters A–J designate the location of specific cross-sections shown in Figs. 4 and 5.

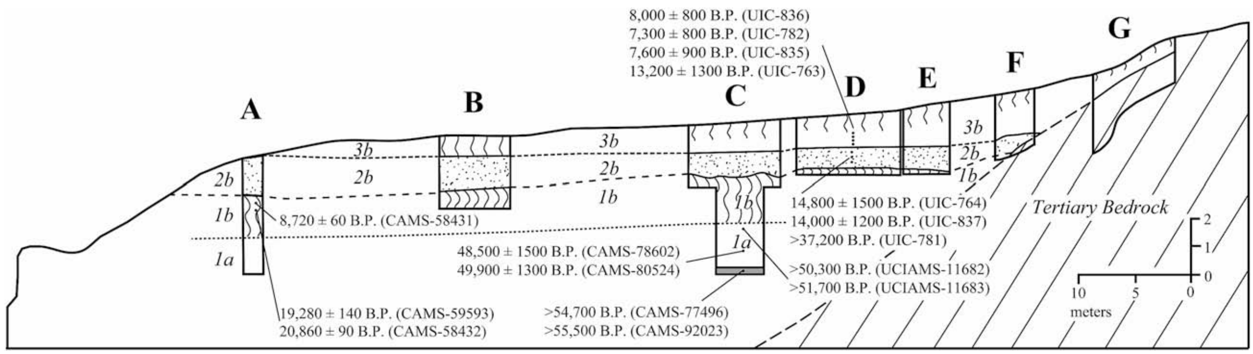

Fig. 4. Cross-section of the late Quaternary stratigraphy of the Topper site along a west to east transect. See line A–G in Fig. 3.

designated 1 through 3, from oldest to youngest. All units are subdivided into smaller subunits that are designated with lower case letters. A generalized profile of the Topper site stratigraphy showing all the defined stratigraphic units is provided in Fig. 7.

All late Quaternary sediments at the Topper site rest unconformably against an eroded scarp of Tertiary-age bedrock (Figs. 2, 4, and 6). This bedrock consists of weathered, red colored deposits of sand, silt, and clay that appear to be the Miocene Altamaha Formation. This formation occurs stratigraphically above the late Eocene Tobacco Road Formation (Fallaw and Price, 1992). The bedrock is capped unconformably by late Quaternary eolian sands and colluvium that contain Clovis and later period artifacts (Fig. 2).

Inset onto the eroded surface of the bedrock is unit 1, which is divided into two subunits (Figs. 2, 4, 6–8). The lower part of this unit is composed of sand (unit 1a) and is conformably overlain by gray silty clayey sand (unit 1b). Unit 1 represents a fining-upward sequence of sediments deposited by a meandering prehistoric Savannah River. Unit 1a reflects deposition within the channel and point bar and unit 1b reflects deposition by overbank processes on a floodplain. Pedogenic processes have altered the upper portion of unit 1 creating a weak Bt, which was later truncated by erosion. Goodyear (2005a,b) has recovered chert pieces that he identifies as pre-Clovis artifacts and a charcoal concentration (feature 91) that had the appearance of a possible hearth in unit 1. An organic-rich clay lens, below the pre-Clovis levels within 1a yielded wood and other plant macrofossils.

Unit 2 consists of sediments deposited by both colluvial (unit 2a) and fluvial (units 2b and 2c) processes (Figs. 2, 4, 6–8). Unit 2a consists of gravels and sands (Figs. 6 and 7) that accumulated along the edge of the erosional scarp and in some cases interfinger with the fluvial deposits of unit 2b. Isolated gravels occur on the eroded scarp and in one case have accumulated at the base of the scarp as weathered chert pebbles and cobbles that apparently rolled down the side of the slope that formed the edge of the channel (Fig. 6).

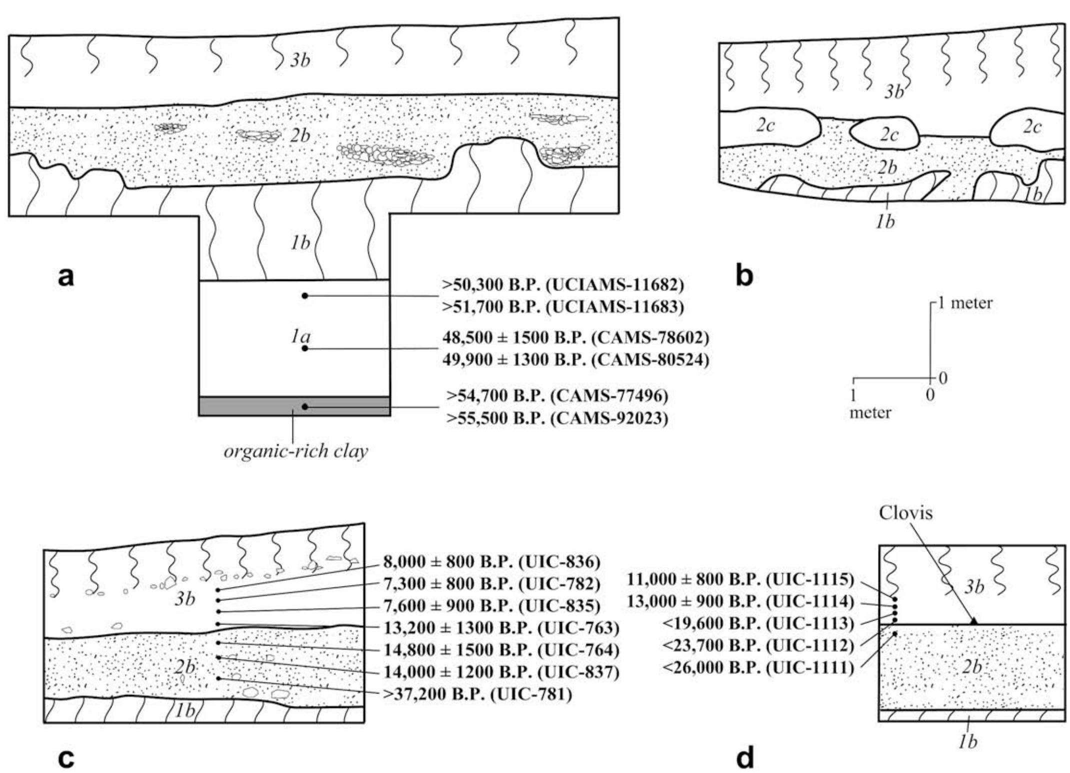

Fig. 5. Detailed cross-sections showing the stratigraphy and dates obtained at specific locations along the cross-section line A–G (Fig. 3) and of two other localities. a. Area C (Figs. 3 and 4); b. Area J (Fig. 3); c. Area D (Figs. 3 and 4); d. Area I (Fig. 3).

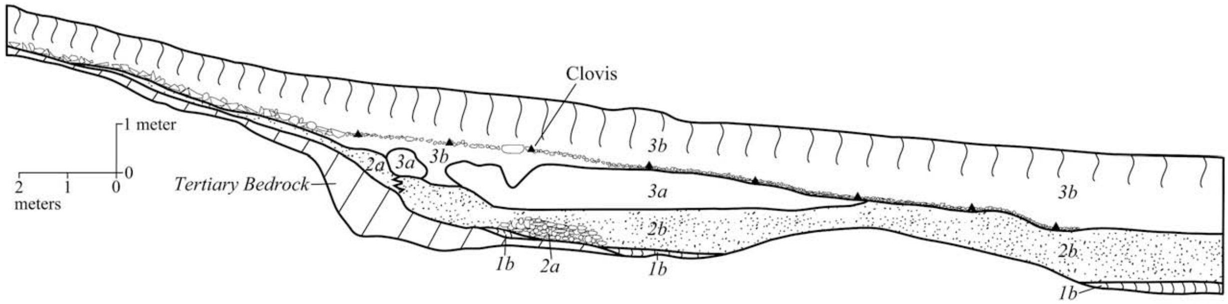

Fig. 6. Detailed cross-section of the stratigraphy along section line H (Fig. 3).

Unit 2b overlies the eroded surfaces of the Tertiary bedrock and unit 1b. This unit is composed primarily of sand with some lenticular lenses of gravel (Figs. 4 and 5a). The gravels fill small channels (50–140 cm wide; 5–30 cm deep) that occur throughout unit 2b. In some places, large chute channels (3–5 m wide; 0.5–0.8 m deep) occur within this unit. These sediments were deposited in a fluvial environment that had multiple shallow channels, possibly part of a braided fluvial system. The north–south orientation of the channel thalwegs indicates paleo-river flow parallel to the present Savannah River. Close to the erosional scarp, secondary clay–iron lamellae are present within this unit. These lamellae quickly disappear away from the eroded channel edge. Goodyear (2005a) identifies pre-Clovis chert artifacts (the "Topper assemblage") within the sands of unit 2b.

Immediately overlying this sandy alluvium is unit 2c (Figs. 5b and 7). This unit is composed of gray sandy silty clay that forms discontinuous lenticular masses ranging from 1 to 2 m long and approximately 0.5 m thick. These sediment bodies were either overbank flood deposits that once formed a continuous floodplain deposit that was later disturbed by tree-throw or were isolated pockets of fine-grained sediments that accumulated in channels and depressions that existed on the sandy surface. Micromorphological examination of unit 2c indicates that the upper 30 cm were altered by pedogenic processes creating a weak subangular blocky structure with clay bridging occurring between sand grains. This unit represents the last time that fluvial deposition occurred at the site.

Overlying the fluvial sediments is unit 3 which was emplaced by colluvial processes as sediments were shed from the adjacent hillslopes onto the abandoned terrace tread (Figs. 2, 4–8). This unit is divided into two subunits. The oldest unit, 3a, disconformably overlies the sands of unit 2b (Figs. 6 and 7). Unit 3a is a brown silty sand with clear evidence of soil development as indicated by a 70 cm thick, brown soil horizon that has weak structure with faint clay films on the ped faces. This unit occurs in two locations at the site and represents localized deposition on the terrace tread. This is overlain by unit 3b (Figs. 2, 4–6) which is ubiquitous across the site. This unit consists primarily of silty sand with occasional angular gravels that become more abundant toward the slope. In some places, the angular gravels close to the slope become 10 cm thick and grade downslope into a stone line (Fig. 6). The upper 60 cm of unit 3b is pedogenically altered into a weak Bw horizon with a 15–20 cm thick A or AP horizon. Unit 3b immediately overlies units 3a and 2b. The contact between units 3b and 2b is sometimes difficult to clearly identify due to their similar textures. Clovis artifacts occur at the base of unit 3b. Above the Clovis horizon is a stratigraphically coherent cultural sequence that ranges from early, middle, and late Archaic to Woodland near the top (Goodyear, 2001).

5. Radiocarbon dating at the Topper site

Charcoal and wood are rare at the Topper site. Wood and plant macrofossils were either recently introduced by plant bioturbation into older sediments, or were *in situ* lignified plant remains that were preserved in rare reducing environments that escaped oxidation by the vertically fluctuating water table. Another source of dateable organic carbon were humic acids within flood basin sediments and paleosols.

Samples were processed for radiocarbon dating by using either standard pretreatment methods or modified techniques that

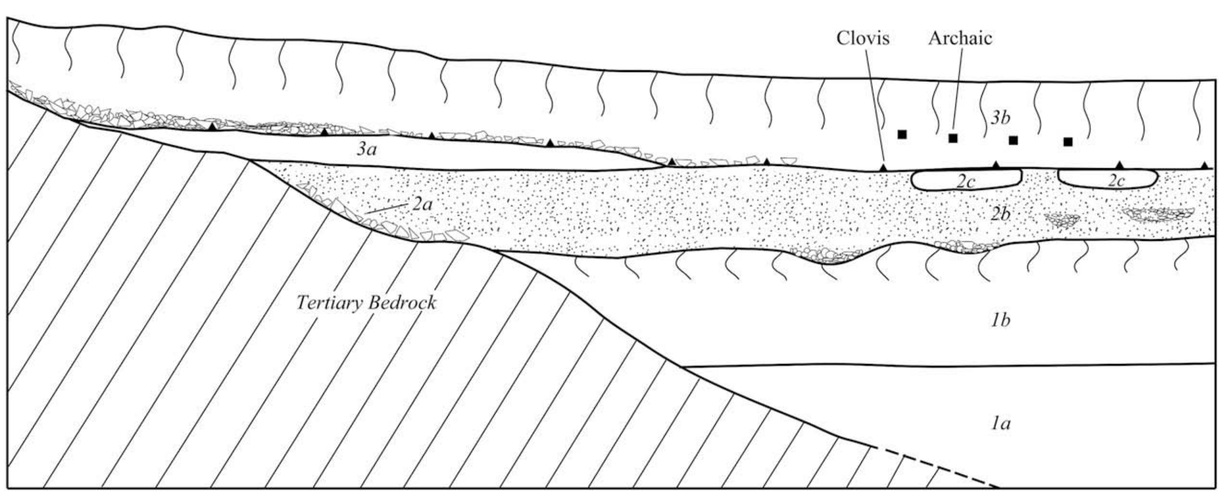

Fig. 7. Generalized stratigraphy of the Topper site showing the position of artifacts.

Fig. 8. Photograph of an excavation area at the Topper site showing the superposition of units 1b, 2b, and 3b. Unit 3b extends from the surface to the ledge. Unit 2b extends from the ledge to the contact with the dark layer. Unit 1b is the dark layer at the base of the section.

evaluated diagenesis. HCl removed carbonates and iron that were soil or groundwater-derived. Alkali treatment with NaOH or KOH removed humates that were secondary contaminants derived either from active pedogenesis or enclosing sediments, and occasionally from groundwaters flowing through the sediments.

Charcoal, wood and plant macrofossils were treated with 0.5 N HCl, washed to neutrality and treated with alternating cycles of 0.2 wt% KOH, DI water, 0.05 N HCl, and DI water until solutions were clear and colorless. Before freeze drying, the samples were washed with 0.05 N HCl. Samples purified by the preceding methods are denoted as acid–base–acid (ABA) treated charcoal, wood or macrofossil.

The organic matter in paleosols and flood basin sediments ranges from low molecular weight fulvic acids, to humic acids, and the highest molecular weight compounds that are humins. These organic molecules originate during pedogenesis or are from primary biological activity in the flood basin environments. Dating these humic compounds provides average-age time estimates for soil horizons and can provide absolute ages for fluvial depositional events.

From 2 to 50 g of $<$1 mm size sediment were freeze dried and soaked in DI water to disperse the sediments by removing water-soluble ions. The sediment slurry was passed through a 47 μm screen and the $<$47 μm fraction was saved for chemical extraction. The sieving removes coarse silt and larger clastics from the silt and clay fraction, which is used for humate extraction. The fine screening also removes fine rootlets and other modern plant detritus that could contribute geologically younger carbon.

After freeze drying, several grams of the $<$47 μm fraction were decalcified in 0.5 N HCl at RT and the supernatant discarded. After washing to neutrality with DI water, 0.2 wt% KOH at RT was added to the sediment and reacted for 6 h. The supernatant was separated from clays by centrifugation. The supernatant was filtered through 0.45 μm Millipore Durapore filters. Humic acids were precipitated by adding 6 N HCl until pH 1 was attained. Humic acid precipitation was either instantaneous or it occurred over several hours. Centrifugation concentrates the humic acids and yields either a clear and colorless supernatant or a light yellow to yellowish brown solution containing fulvic acids. KCl formed during neutralization of KOH solutions with HCl was removed by repeatedly washing the humic acid in 0.05 N HCl. Humic acids were freeze dried and yields per gram of dry $<$47 μm sediment calculated. These chemical methods were modified depending on sample type and the material's behavior in KOH, and to assess the degree of foreign-carbon overprinting in paleosols and fluvial sediments.

An important variation on the prescribed chemical purification procedures is deleting the KOH step or dating sequential aliquots of humates extracted by repetitive KOH treatment. Conventionally, plant fossils and charcoal should be treated with repetitive HCl–KOH–HCl cycles until the KOH solution remains colorless – a visual assessment that humates have been removed. However, organic matter burned at low temperature (partial pyrolysis) or plant remains preserved in reducing (anaerobic) environments commonly dissolve 100% during the KOH extraction. Visually, it is impossible to distinguish between humates being removed and the endogenous sample being dissolved. Frequently, the first KOH extraction may remove all exogenous humates, while subsequent KOH treatments dissolve original, but weakly carbonized original sample material. To test if partially combusted or weakly reduced plant remains are dating accurately, plant material treated only with HCl, and sequential extractions of "humates" are radiocarbon dated when customary hydroxide extraction would dissolve 100% of the sample. This technique was used on a sample of organic matter from unit 1a. The "humic acids" isolated from the first extraction from this sample yielded dates of 44,300 ± 1700 ^{14}C yr B.P. (CAMS-77496) and 45,800 ± 1000 ^{14}C yr B.P. (CAMS-78601). The second humic acid extraction was discarded and not dated. Humates from the third extraction yielded dates of 48,700 ± 1500 ^{14}C yr B.P. (CAMS-78602) and 49,900 ± 1300 ^{14}C yr B.P. (CAMS-80534). These dates are evidence that negligible younger humate contamination existed in the samples. However, the dates from the third extractions yield more reliable ages. Regardless, these dates are all minimum ages because the dates are at the maximum limits of the radiocarbon method.

The AMS radiocarbon measurements from the Topper site are summarized in Table 1. One sample (CAMS-66110) consisting of a small piece of charcoal comes from a feature in the early Archaic or Paleoindian levels of unit 3b. This charcoal yielded an age of 2170 ± 40 ^{14}C yr B.P. This sample is significantly younger than its stratigraphic position and represents modern plant material that was moved downward by bioturbation.

Humates derived from two sediment samples from the alluvial deposits of units 1b and 2c yielded dates that are significantly younger than their geologic age because endogenous humates were contaminated with younger humates derived from modern deciduous forest vegetation and to a lesser extent from dissolved organic matter in groundwaters. These samples which yielded ages of 6670 ± 70 ^{14}C yr B.P. (CAMS-58430) and 8270 ± 60 ^{14}C yr B.P. (CAMS-58431) are from strata (Fig. 4) underlying unit 3b that contains *in situ* Clovis artifacts, which provides a typologically based age of 11,000–10,800 ^{14}C yr B.P. (Waters and Stafford, 2007).

Two humate samples of floodplain alluvium of unit 1b yielded ages of 19,280 ± 40 ^{14}C yr B.P. (CAMS-59593) and 20,860 ± 90 ^{14}C yr B.P. (CAMS-58432; Fig. 4). These represent minimum dates for these deposits.

Six samples of wood, nutshell, and humic acids were dated from unit 1a (Figs. 4 and 5). These dates represent minimum ages for unit 1a and indicate that this unit dates in excess of 50,000 ^{14}C yr B.P. A date of $>$54,700 ^{14}C yr B.P. (CAMS-79022) was obtained on a Hickory (*Carya*) nutshell and a date of $>$55,500 ^{14}C yr B.P. (CAMS-19023) on a piece of fir wood (*Abies*) from an organic horizon within unit 1a underlying the reported oldest cultural horizon at the Topper site. The lens containing the *Carya*, *Abies*, and other plant species is interpreted to be woody plant material that accumulated naturally in a shallow swale in the streambed. Two dates, $>$50,300 ^{14}C yr B.P. (UCIAMS-11682) and $>$51,700 ^{14}C yr B.P. (UCIAMS-11683) were obtained on reduced woody plant remains from a low-relief, thin, lenticular accumulation of physically well-

Table 1
AMS radiocarbon measurements from the Topper site.

Stratigraphic horizon	^{14}C yr B.P. ± 1 sd	AMS lab number	Material dated	Comments	Depth below datum (m)	Depth below surface (m)
Unit 3b	2170 ± 40	CAMS-66110	Charcoal	Rejected	98.15	1.25
Unit 2c	6670 ± 70	CAMS-58430	Humic acids	Minimum age—modern C contamination	97.70	0.70
Unit 1b	8270 ± 60	CAMS-58431	Humic acids	Minimum age—modern C contamination	96.25	1.75
Unit 1b	20,860 ± 90	CAMS-58432	Humic acids	Minimum age—modern C contamination	95.75	1.5
Unit 1b	19,280 ± 140	CAMS-59593	Humic acids	Minimum age—modern C contamination	94.25	1.0
Unit 1a	44,300 ± 1700	CAMS-77496	Humic acids (2001TS-180)	Minimum age	94.55	4.2
Unit 1a	45,800 ± 1000	CAMS-78601	Humic acids—1st KOH extraction (2001TS-181)	Minimum age	94.55	4.2
Unit 1a	48,700 ± 1500	CAMS-78602	Humic acids—3rd KOH extraction (2001TS-181)	Minimum age	94.55	4.2
Unit 1a	49,900 ± 1300	CAMS-80534	Humic acids—3rd KOH extraction (2001TS-181) remeasurement	Minimum age	94.55	4.2
Unit 1a	>54,700	CAMS-79022	Hickory (*Carya* sp.) nutshell	Minimum age—naturally accumulated plant remains	93.60	4.95
Unit 1a	>55,500	CAMS-79023	cf. *Abies* wood	Minimum age—naturally accumulated plant remains	93.60	4.95
Unit 1a	>50,300	UCIAMS-11682	Reduced woody plant macroflora	Minimum age feature 91	95.54	3.45
Unit 1a	>51,700	UCIAMS-11683	Reduced woody plant macroflora	Minimum age feature 91	95.54	3.45

preserved plant material within the fluvial sands of unit 1. Goodyear defined this as feature 91 and suggested that this may represent a hearth-like feature (Goodyear, 2005b). Although the plant remains were black, there is no evidence the plant material had been combusted or that the plant fossils had been emplaced secondarily into the fluvial sands. The organic carbon rich lens was lithologically conformable vertically and horizontally with enclosing stream channel sands, there was no evidence of heat-caused oxidation (hematite development) in sand immediately below the organic matter, and the plant remains were soft, retained excellent cellular structure, and reacted immediately and strongly with weak KOH used during the radiocarbon pretreatment process.

6. Luminescence dating at the Topper site

Eighteen luminescence ages were obtained from the sediments at the Topper site (Table 2; Fig. 5). Luminescence geochronology is based on the time-dependent dosimetric properties of silicate minerals, predominately feldspar and quartz (Aitken, 1985, 1998). The technique has been used to date <200 ka old sediments that received sunlight exposure prior to deposition (e.g., Berger et al., 2002; Duller, 2004; Murray and Olley, 2002; Forman et al., 2000). For OSL (optically stimulated luminescence) dating, exposing sediment to sunlight for ca. 10–60 min (e.g., Godfrey-Smith et al., 1988) eliminates most of the previously acquired luminescence in mineral grains. After the sediment is buried and shielded from further ionizing light, radiation from the decay of naturally occurring radioisotopes of U, Th, and K produces free electrons that are subsequently trapped in crystallographic charge defects in silicate minerals. Excitation of these minerals by light recombines the stored charge and yields luminescence emissions. The intensity of the luminescence is calibrated in the laboratory to yield an equivalent dose (D_e), which is divided by an estimate of the radioactivity that the sample received during burial (dose rate, D_r) to render a luminescence age.

Luminescence dating at the Topper site concentrated on the predominately colluvial–fluvial units 2 and 3, whose sediment received adequate sunlight to reset grain luminescence during deposition. Both the fine-grained polymineral (4–11 μm) and coarse-grained (100–150 μm) quartz fractions were dated by OSL as an internal check for chronologic consistency. Infrared-stimulated luminescence (IRSL) values are determined on the fine-grained (4–11 μm) polymineral fraction by multiple aliquot additive dose (MAAD) methods, similar to those of Forman and Pierson (2002). The coarse-grained quartz fraction was also isolated and dated by single aliquot regeneration (SAR) protocols (Murray and Wintle, 2000, 2003) and multiple aliquot regeneration (MAR) dose procedures, using the component-specific dose normalization (CSDN) method (Jain et al., 2003). The quartz fraction is isolated by density separations using Na-polytungstate followed by 40-min of etching with HF. The HF etches the grain's outer 10+ μm that is affected by alpha radiation from enclosing sediments (Mejdahl and Christiansen, 1994). The mineralogical purity of the quartz separate was evaluated by petrographic inspection and point counting of a representative aliquot. Samples that contained >1% non-quartz minerals were retreated with HF and checked again petrographically. Because sands from the Topper site often contain >90% quartz, isolating a pure quartz fraction is easily achieved.

Optical stimulation of sediments for the MAAD analyses was accomplished by using an automated Daybreak 1100 reader with infrared emission (880 ± 80 nm) from a ring of 30 diodes that deliver 17 mW/cm^2 to the sample. MAR analyses are completed under green light (514 ± 20 nm) excitation. A filtered halogen light source in the Daybreak reader delivers a total power of 7.4 mW/cm^2. The resultant blue emissions were measured at room temperature (~25 °C) by a Thorn EMI 9635 Q photomultiplier tube coupled with one 3-mm thick Schott BG-39 glass filters and one 3-mm thick Corning 7-59 glass filter, which combined, block >90% luminescence emitted below 390 nm and above 490 nm. Blue-dominated emissions were chosen for measurement because previous studies indicate blue-light's greater suitability as a chronometer than ultraviolet wavelengths (e.g., Balescu and Lamothe, 1992, 1994; Berger et al., 1994; Lang and Wagner, 1996; Lang et al., 2003). The background count rate for measuring blue emissions was low (<80 counts/s), with a signal-to-noise ratio of >20. Samples were excited for 90 s, and the resulting IRSL signal was recorded in 1 s increments.

An Automated Riso TL/OSL reader (Bøtter-Jensen et al., 2000) is used for SAR analyses. Blue light excitation (470 ± 30 nm) is from an array of 30 light-emitting diodes that delivers ~15 mW/cm^2 to

Table 2
Optically stimulated luminescence ages for sediments from the Topper site, South Carolina.

Field number	OSL lab number	Unit/sediment type	SAR[a] D_e (Gy)	MAR[b] D_e (Gy)	MAAD-IR[c] D_e (Gy)	U[d] (ppm)	Th[d] (ppm)	$K_2$0[d] (%)	SAR age[e] (ka)	MAR age[e] (ka)	MAAD-IR age[e] (ka)	Concluded age (ka)	Depth below datum (m)	Depth below surface (m)
TP99-03	UIC695	2/Alluvium		Saturated	49.40 ± 2.06	1.9 ± 0.3	4.9 ± 0.7	0.32 ± 0.02		Uncalculable	37.2 ± 3.3	<37.2		
TP99-03	UIC695	2/Alluvium		Saturated		1.4 ± 0.2	4.6 ± 0.6	0.43 ± 0.02		Uncalculable				
TS0-01	UIC763	3b/Colluvium	20.34 ± 1.74	18.96 ± 0.09	24.18 ± 0.04	2.4 ± 0.4	6.5 ± 0.8	0.32 ± 0.02	13.4 ± 1.6	13.2 ± 1.1	13.0 ± 1.2	13.2 ± 1.3	98.21	1.19
TS0-02	UIC835	3b/Colluvium	8.39 ± 0.47	12.43 ± 0.11	18.97 ± 0.07	3.2 ± 0.4	7.7 ± 1.1	0.34 ± 0.02	4.7 ± 0.6	7.2 ± 0.7	7.8 ± 0.9	7.6 ± 0.9	98.40	1.00
TS0-02	UIC835b	3b/Colluvium			18.42 ± 0.44	3.2 ± 0.4	7.7 ± 1.1	0.34 ± 0.02			7.9 ± 0.9	7.9 ± 0.9	98.40	1.00
TS0-04	UIC836	3b/Colluvuim	8.01 ± 0.46	14.21 ± 0.03	18.75 ± 0.06	2.9 ± 0.3	8.4 ± 1.0	0.34 ± 0.02	4.5 ± 0.6	8.2 ± 0.6	7.6 ± 0.8	8.0 ± 0.8	98.68	0.72
TS0-03	UIC782	3b/Colluvium	10.07 ± 0.39	11.08 ± 0.19		2.3 ± 0.3	5.2 ± 0.7	0.40 ± 0.02	7.1 ± 0.8	7.5 ± 0.8		7.3 ± 0.8	98.51	0.89
TS0-05	UIC764	2b/Alluvuim	31.30 ± 2.27		30.93 ± 0.09	2.3 ± 0.4	7.0 ± 1.0	0.38 ± 0.02	14.2 ± 1.5		15.2 ± 1.5	14.8 ± 1.5	98.00	1.40
TS0-06	UIC837	2b/Alluvium	11.56 ± 0.47	18.77 ± 0.19	27.05 ± 0.07	2.4 ± 0.3	7.0 ± 0.8	0.31 ± 0.02	8.1 ± 0.9	13.3 ± 1.1	14.8 ± 1.3	14.0 ± 1.2	97.73	1.67
TS0-07	UIC781	2b/Alluvium	Saturated	Saturated	Saturated	2.6 ± 0.5	11.1 ± 1.4	0.39 ± 0.02	Uncalculable	Uncalculable	Uncalculable	Uncalculable	97.45	1.95
TS0-010	UIC762	Modern soil	0.84 ± 0.10			3.6 ± 0.4	5.8 ± 1.0	0.40 ± 0.02	0.42 ± 0.10			<0.4	99.40	0.00
TL-54	UIC1115	3b/Colluvium		8.49 ± 0.06	11.16 ± 0.04	0.76 ± 0.1	2.4 ± 0.1	0.31 ± 0.02		11.0 ± 0.7	11.0 ± 0.8	11.0 ± 0.8	98.13	0.70
TL-53	UIC1114	3b/Colluvium	6.34 ± 0.30	9.08 ± 0.11	11.80 ± 0.06	0.73 ± 0.1	2.4 ± 0.1	0.25 ± 0.02	9.0 ± 0.7	13.0 ± 0.9	13.0 ± 0.9	13.0 ± 0.9	98.03	0.80
TL-52	UIC1113	3b/Colluvium	10.92 ± 0.62		13.55 ± 0.06	0.57 ± 0.1	2.0 ± 0.1	0.11 ± 0.02	22.5 ± 2.1		19.6 ± 1.6	<19.6	97.93	0.90
TL-51	UIC1112	3b/Colluvium	12.37 ± 0.56	19.42 ± 0.10	17.20 ± 0.07	0.53 ± 0.1	1.9 ± 0.1	0.22 ± 0.02		34.0 ± 2.3	23.7 ± 1.7	<23.7	97.81	1.00
TL-50	UIC1111	2b//Alluvium		23.34 ± 0.66	21.83 ± 0.15	0.66 ± 0.1	1.9 ± 0.1	0.25 ± 0.02		37.6 ± 2.6	26.0 ± 1.9	<26.0	97.68	1.15
TS03-01	UIC1229	3b/Colluvium		3.95 ± 0.03		1.06 ± 0.1	3.0 ± 0.1	0.26 ± 0.02		4.3 ± 0.3		4.3 ± 0.3		
TS03-02	UIC1228	3b/Colluvium	6.60 ± 0.26	5.90 ± 0.06		1.04 ± 0.1	3.2 ± 0.1	0.19 ± 0.02	8.5 ± 0.6	7.6 ± 0.5		8.0 ±.5		

[a] Single aliquot regeneration method of Murray and Wintle (2000, 2003) on 150–200 μm quartz grains on 16 or more aliquots.
[b] Multiple aliquot regeneration method of Jain et al. (2003) on 150–200 μm quartz grains.
[c] Multiple aliquot additive dose method from Singhvi et al. (1982) and Forman and Pierson (2002) on 4–11 μm polymineral fraction.
[d] U, Th and $K_2$0 determined by ICP-MS, except for U and Th content by thick source alpha counting for UIC762–764, 781, 782 and 835–837.
[e] Ages included a cosmic ray dose rate component between 0.14 and 0.20 mGy/yr from Prescott and Hutton (1994) and an assumed burial moisture content of 10 ± 3%.

the sample at 90% power. Photon emissions are measured with a Thorn EMI 9235 QA photomultiplier tube coupled with three 3-mm thick Hoya U-340 detection filters that transmit from 290 and 370 nm. Laboratory irradiations used a calibrated $^{90}Sr/^{90}Y$ beta source coupled with the Riso reader; the experimental sequences were executed using Riso TL/OSL software for Windows (version 4.0). All emissions are integrated over the first 0.8 s of stimulation out of 500 s of measurement, with background based on emissions for the last 90- to 100-s interval. Before the application of SAR protocols a series of experiments evaluated the effect of preheating at 180 °C, 200 °C, 220 °C, and 240 °C on the regenerative signal (cf. Murray and Wintle, 2000, 2003). Because experiments showed that 200 °C preheat temperatures yielded the highest and most consistent equivalent doses, aliquots were preheated at this temperature for 10 s for the SAR protocols. Tests for dose recovery were also performed and for all samples the last dose coincides well with the initial dose (at one sigma errors).

A critical analysis for luminescence dating is the dose rate, which is used to calculate how much ionizing radiation the sediment received during burial (Table 2). Most ionizing radiation in sediments is from U and Th isotope decay-chains, and the radioactive potassium isotope ^{40}K. The sediments' U and Th contents, assuming secular equilibrium in the decay series, are determined either by alpha counting or inductively coupled plasma-mass spectrometry (ICP-MS) at Activation Laboratory Ltd., Ontario, Canada. The sediments' ^{40}K component is determined from the ICP-MS assayed K_2O content of the sediment. The beta and gamma dose was adjusted according to grain diameter to compensate for mass attenuation (cf. Fain et al., 1999). A small cosmic ray component, between 0.15 and 0.20 ± 0.01 mGy/yr, is included in the estimated dose rate and follows calculations of Prescott and Hutton (1994). The sediments' assumed $10 \pm 3\%$ moisture content is the field capacity for sandy soils (Brady, 1974, 191–192). All OSL ages are reported in years prior to A.D. 2000.

Three different optically stimulated luminescence date techniques, SAR, MAR and MAAD were used to constrain the age of sediment deposition of units 2 and 3 (Table 2). In all samples but three (TSO-04), the respective age determinations overlap at two standard deviations, and thus are statistically indistinguishable. We use the "concluded" ages shown in Table 2 that are the mean of the three methods used, weighted for the MAR method on quartz grains, which yielded the stratigraphically consistent values. Luminescence samples were collected from several different locations at the site. A suite of seven samples in stratigraphic order were collected from units 2b and 3b in area D (Fig. 5c) and five samples from units 2b and 3b in area I (Fig. 5d). Three additional samples were collected from other portions of the site. In area D, two finite ages $14,000 \pm 1200$ (UIC837) and $14,800 \pm 1500$ yr B.P. (UIC764) were obtained from the uppermost portion of unit 2. Two other samples from unit 2 (UIC695 and UIC781) yielded a saturated response to laboratory dose and thus ages could not be calculated. The most reliable series of ages were obtained from the colluvium (unit 3). A total of four finite ages were produced and ranged from $13,200 \pm 1300$ (UIC763) to 7300 ± 800 yr B.P. (UIC782). In area I, samples yielded absolute ages, but all ages were older than the associated diagnostic artifacts (Fig. 5d). This indicates that the sediments had been mixed by bioturbation, which was not evident in the field when the samples were collected. The samples from this area do not accurately date the site. Two additional samples were collected from the upper part of unit 3 (UIC1228 and UIC1229) and yielded corresponding ages of 8000 ± 500 yr and 4300 ± 300 yr.

7. Late Quaternary history of the Topper site

The physical stratigraphy, coupled with chronological control provided by radiocarbon and luminescence ages, and diagnostic artifacts document a complex sequence of alluvial and colluvial deposition and erosion (Figs. 2 and 7). The Savannah River, sometime in the late Pleistocene, flowed through the area of the Topper site and deposited alluvium against the valley's Tertiary bedrock walls. This included channel, point bar, and overbank sediments (unit 1) deposited within a meandering stream. The age of the deposition is unknown, but the infinite radiocarbon ages from this unit indicate that deposition occurred before 55,000 yr B.P. A period of floodplain stability and soil formation followed the deposition of fine-grained overbank deposits (unit 1b). This was followed by a period of fluvial scouring when the soil developed on unit 1b was truncated. Sometime after this erosional period, colluvium (unit 2a) accumulated locally next to the channel edge and the alluvial sands were deposited (unit 2b) across most of the site. These sediments appear to have been deposited in arcuate channels, potentially part of a braided stream system. Swales at the top of this unit are filled with fine-grained overbank deposits (unit 2c) and represent the last episode of fluvial deposition at the site. Luminescence dating suggests that fluvial deposition ceased around 15,000 yr B.P. At this point, the river downcut and abandoned the floodplain, creating Terrace 2. A period of stability is indicated by the development of a modest Bw horizon in unit 2c reflecting <2000 years of pedogenesis. Unit 2c was then eroded in places. Following this weathering and erosion, colluvial deposition (unit 3) began and dominated the subsequent history of the site. Unit 3a was deposited as colluvium was shed from the adjacent slope. This was followed by stability and pedogenesis. Colluvial deposition continued during the late Pleistocene and Holocene as sediments shed from the slopes created unit 3b. Luminescence ages from unit 3 and the presence of Clovis artifacts at the base of unit 3b indicate that colluvial deposition began around 13,000 yr B.P. Diagnostic Archaic and younger period artifacts, and luminescence ages show that colluvial deposition (unit 3b) continued into the Holocene. Later historic agriculture and other activities disturbed the upper layers of the colluvium.

8. Geological context and site formation processes of the archaeological components at Topper

Clovis artifacts occur at the base of unit 3b (Fig. 7). These artifacts occur in place or were moved slightly downslope. Clovis artifacts also occur within the colluvium on the hillside slopes above T-2. Early Archaic Taylor and the later prehistoric components (Kirk, Morrow Mountain, and early–middle Woodland) are consistent with the stratigraphic succession and luminescence ages of unit 3b. These artifacts appear to have been buried with minimal disturbance by slow continuous deposition of colluvial sand and silt from the slopes.

Below the Clovis horizon, Goodyear (2005a) reports the presence of what he believes are pre-Clovis artifacts. This "Topper assemblage" is buried within units 2b and 1. The stratigraphic position of the "Topper assemblage" indicates an antiquity older than Clovis, but how much older remains unresolved. Stratigraphic relationships show that a moderately well-developed paleosol (Bw horizon) formed in colluvial deposits (unit 3a) that lie between the Clovis horizon and the "Topper assemblage" that reflect a few hundreds to a few thousands of years of deposition and pedogenesis. Two OSL ages, $14,400 \pm 1200$ yr B.P. (UIC763) and $15,200 \pm 1500$ yr B.P. (UIC764), are from the top of unit 2b and provide a provisional minimum age for the proposed pre-Clovis material. The base of this sand remains undated. Even older "Topper assemblage" material has been reported in the older unit 1a and 1b sediments and are associated with dates of >50,000 ^{14}C yr B.P. (Table 1).

The "Topper assemblage", consisting of a smashed core and microlithic industry (Goodyear, 2005a), is typologically and technologically unique among New World archaeological sites. Goodyear (2005a) believes that spalls and flakes were modified into small unifacial tools and bend-break tools that were used to work wood and other organic materials. The human origin of the "Topper assemblage" has not yet been unequivocally demonstrated. Alternatively, the pieces making up the "Topper assemblage" could have been produced naturally as a result of thermal fracturing (forest fires and freeze-thaw cycles) or physical fracturing during stream transport. Finally, the "Topper assemblage" is highly diachronous, occurring in sediments ranging in age from >50,000 to 15,000 yr B.P. It is unusual that there was no lithic technological change for ca. 35,000 years.

9. Late Quaternary stratigraphy and geochronology of the Big Pine Tree site

Big Pine Tree is situated on the first terrace (T-1) adjacent to Smith Creek, a flood channel of the Savannah River (Fig. 2). The late Quaternary stratigraphy at Big Pine Tree is separated into three major units, labeled 4, 5, and 6, from oldest to youngest (Figs. 9 and 10). No radiocarbon or luminescence ages were obtained from this site. Chronological control is provided by diagnostic artifacts found within the different stratigraphic units.

Terrace 1 is primarily a cut terrace composed of unconsolidated Tertiary bedrock that is covered by a thin veneer of late Quaternary alluvium. The bedrock consists of a fining-upward sequence of what appear to be alluvial deposits. At the base is loose, coarse-to-medium sand, conformably overlain by massive fine sand, silt, and clay. This unit is pedogenically altered and characterized by abundant, strong brown and yellowish red mottles.

The late Quaternary sediments occupy a channel cut into the bedrock and also form a thin floodplain veneer over the truncated bedrock. The channel is filled with loose, very coarse to fine sand that fines upward to very fine silty sand (unit 4). Within the channel, clay lamellae extend from the bedrock into the sand of the channel. Clovis artifacts are found in the silty sand overlying the eroded bedrock surface, but have not been found within the channel fill.

Unit 4 is unconformably overlain by unit 5. Scouring of unit 4 is evident by the small incised channels and undulatory upper contact. Unit 5 is massive and ranges from silty sand to sandy silt and contains late Paleoindian Dalton, early Archaic Taylor and Kirk, and late Archaic Allendale projectile points. This unit represents overbank deposition from the Savannah River probably during the early to the middle Holocene.

Another period of erosion is evident by the scouring of the upper contact of unit 5. Overlying this unconformable surface is unit 6, which is a massive sandy silt to silt. This unit was laid down by the Savannah River during floods. The upper portion has been pedogenically altered into a Bw horizon. Within this unit Woodland and Mississippian artifacts are found, indicating deposition during the late Holocene.

10. Summary of the alluvial stratigraphy of the central Savannah River

The stratigraphy of Topper and Big Pine Tree sites provides an understanding of the late Quaternary alluvial history of the central Savannah River (Fig. 2).

Sometime during the late Pleistocene, before 55,000 yr B.P., the Savannah River began to aggrade and deposited unit 1. The Savannah River at this time appears to have been a meandering stream. Sometime during the late Pleistocene, aggradation ceased and soil formation altered the upper portion of unit 1. This is followed by a period of scouring, which in turn is followed by renewed fluvial deposition (unit 2). The Savannah River at this time appears to have had a sandy, multiple, arcuate channel morphology potentially reflecting a braided river system. Sometime before 15,000 yr B.P. the Savannah River abandoned this surface and downcut, creating Terrace 2 (T-2). The river downcut at least 2.5 m in the study area stabilized around 13,000–14,000 yr B.P. and established a meandering pattern. Deposition occurred in a channel (unit 5) and buried Clovis artifacts on the T-1 floodplain. This was followed by continued floodplain aggradation on T-1 during the Holocene. Channels associated with the vertical accretion deposits on T-1 appear to be located within the active floodplain of the Savannah River.

Penecontemporaneous with the last period of downcutting and fluvial deposition on Terrace 1, was colluvial deposition over Terrace 2. Colluvial deposition occurred on T-2 from ca. 13,000 yr B.P. and buried Clovis, Archaic, and Late Prehistoric period artifacts.

11. Interpretation of the major changes observed in the late Quaternary stratigraphy

Several major changes are observed within the late Quaternary sequence of the central Savannah River in the study area. The first pattern observed in the stratigraphic record of the Savannah River is the switch from a single channel, meandering pattern, to a multiple, arcuate channel pattern that was potentially part of a braided system, followed by channel downcutting and

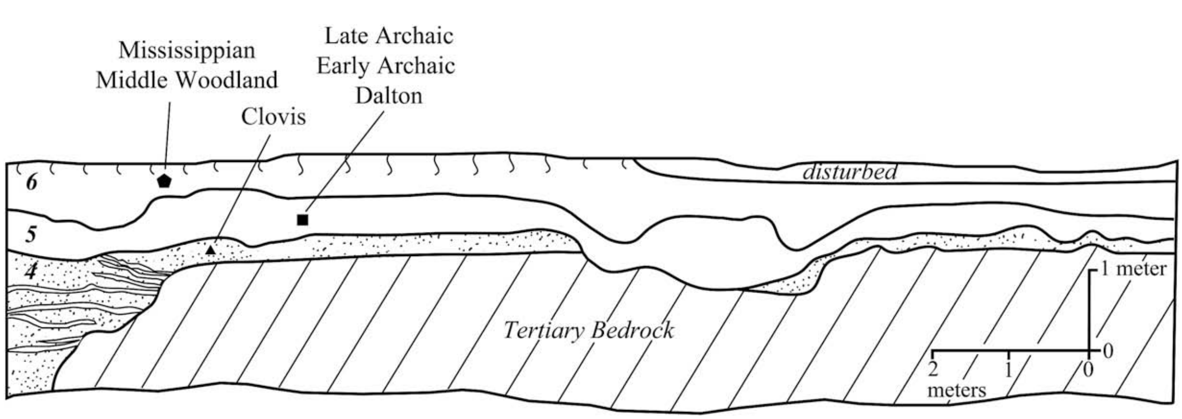

Fig. 9. Late Quaternary stratigraphy of the Big Pine Tree site.

Fig. 10. Photograph of the late Quaternary stratigraphy of the Big Pine Tree site as shown in Fig. 9.

reestablishment of a meandering pattern. This sequence of events has been reported from several other streams in North Carolina, South Carolina, and Georgia (Leigh et al., 2004; Leigh, 2008). This pattern of channel metamorphosis and downcutting appears to have occurred across the southeastern United States during the late Quaternary. Along the central Savannah River, little chronological information is available on the timing of these changes. The timing of the first change from meandering to braided is unknown, with only dates in excess of 50,000 yr B.P. being reported from the upper portion of the deposits of the first meandering stream package. This study of the terraces at the Topper site yielded similar minimum limiting ages (>55,000 yr B.P.) for the initial meander period. Leigh et al. (2004) have suggested that the shift from meandering to a braided stream regime occurred in other streams in the Southeast possibly as early as 70,000 yr B.P. and as late as 30,000 yr B.P., though this age span may reflect precision limits on radiocarbon dating.

The timing of the end of braiding, followed by channel downcutting and a return to a meandering pattern is better documented along the central Savannah. These events appear to have occurred between 15,000 and 13,000 yr B.P. based on the luminescence ages and the position of Clovis artifacts overlying the alluvial–colluvial contact. This age estimate correlates well with other streams in the southeastern United States that have a similar history. The Oconee–Altamaha River (Georgia), Pee Dee River and its tributaries (South Carolina), and Cape Fear River (North Carolina) changed from a braided to a meandering form sometime between 16,000 and 14,000 yr B.P. (Leigh et al., 2004; Leigh, 2008). A meandering pattern has characterized the Savannah River and other southeast streams from 14,000–16,000 B.P. to present.

The changes observed in the late Quaternary history of the Savannah River were probably independent of changes in sea level because of the distance from the coast and the complex responses of fluvial systems (cf. Leigh et al., 2004; Leigh, 2008). Instead, changes on the central Savannah River and elsewhere appear to be linked, regional, and coupled to vegetation and climate.

The period of braiding along the central Savannah River and elsewhere in the southeastern United States, corresponds to the period when Boreal forests covered the region. South Carolina had an open landscape characterized by a mosaic of spruce and pine forests with prairies and vegetation-covered sand dunes (Watts, 1980; Jackson et al., 2000). The climate was much drier than today and had up to 50% less precipitation and cooler temperatures. Drier conditions are also indicated by the presence of abundant sand grains within pollen cores and the fact that some water bodies had become desiccated. The resultant drier climates, more open vegetation, and less dense vegetation cover during the late Pleistocene would have increased sediment yield in drainage basins (Leigh et al., 2004; Leigh, 2006, 2008). Drier environments during the late Pleistocene also reduced riparian vegetation and increased bank erodablility. The increased bed load and channel bank instability led to braided river morphologies.

The period of downcutting and return to meandering conditions is linked with another abrupt vegetation and climate change along the central Savannah River at about 16,000 yr B.P. (Leigh, 2008). The previous boreal vegetation was rapidly replaced with a temperate-wet forest of mixed deciduous trees and a climate that was warmer and wetter than the previous climate and that of today (Watts, 1980; Jackson et al., 2000). This switch to mesic and warmer conditions and concomitant vegetation change resulted in lower sediment yields and lower, more uniform stream discharge that favored meandering stream environments (Leigh et al., 2004; Leigh, 2006, 2008).

Coupled with vegetational and climatic changes is a regional pattern of channel change and downcutting across the southeastern United States. The initiation of colluvial deposition on T-2 also appears to be related to the vegetation and climate shifts described above. Colluvial deposition on T-2 commenced with downcutting of the Savannah River and the transition from a cold-dry open landscape to a temperate-mesic forest environment ca. 16,000 yr B.P. The rate of accumulation of colluvial sediments remained relatively low ($\sim$12 mm/100 yr), until ca. 8.5 ka, when it accelerated to >40 mm/100 yr, with a subsequent decrease ca. 6 ka. This early Holocene interval of rapid accumulation of colluvial sediments is coincident with wetter conditions inferred from proxy river discharge records for the Southeast U.S. (Gorman and Leigh, 2004; Leigh and Feeney, 1995; Leigh, 2008).

12. Conclusions

The Topper and Big Pine Tree sites are important Paleoamerican sites that contain Clovis through Late Prehistoric archaeological components. Hypothesized pre-Clovis artifacts derive from several stratigraphic units below the Clovis horizon at Topper. However, the anthropogenic origin of the "Topper assemblage" has yet to be adequately demonstrated and it may be natural in origin. Unlike the changing cultural assemblages of the late Pleistocene and Holocene components of the Topper site, the "Topper assemblage" is highly diachronous, spanning between >50,000 and 15,000 yr B.P. with no change in technology. Further studies are needed to resolve the origin of the "Topper assemblage".

The major sedimentological and stratigraphic changes observed in the late Quaternary record of the central Savannah River appear to be linked to and coupled with abrupt climate and vegetation changes. The morpho-dynamics of the Savannah River has varied significantly during the late Quaternary, providing a changing riparian environment for exploitation by humans. A meander river system existed >55,000 year ago. The Savannah River aggraded and was dominated by multiple-arcuate channels, probably part of a braided system sometime between ca. 55,000 and 15,000 yr B.P. The Savannah River commenced downcutting at the transition from a cold-dry open landscape to a temperate-mesic forest environment ca. 16,000 yr B.P., with ensuing colluvial deposition.

Finally, the Topper and Big Pine Tree sites provide evidence that stratified Paleoamerican sites exist in the southeastern United States. The stratigraphic and geochronological framework of these sites along with the fluvial landscape model of Leigh (2008) provides a model that can be used to prospect for early sites in other areas of the Savannah River and along other streams in the

Southeast. Geoarchaeological methods should be used to find early sites in the southeastern United States.

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