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Geomorphology 78 (2006) 161–177

GEOMORPHOLOGY

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Holocene erosion, sedimentation, and stratigraphy at Raven Fork, Southern Blue Ridge Mountains, USA

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Received 1 May 2005; received in revised form 30 September 2005; accepted 17 January 2006
Available online 21 February 2006

Abstract

Holocene colluvial and alluvial stratigraphy and a radiocarbon chronology are presented for the valley of the lower three kilometers of Raven Fork, a mountain stream draining 194 km^2 of high relief (1.3 km) terrain of the Southern Blue Ridge Mountains in western North Carolina, USA, which is in a region that lacks good chronological data. Lower hillslopes, alluvial/colluvial fans, alluvial bottomlands (first terrace and floodplain), and the modern stream channel are landforms described with respect to soils, stratigraphy, and sedimentary structures. Standard methods for subsurface investigations (core holes, excavation units, exposures) are used in conjunction with extensive archeological excavations and cultural chronologies. Radiocarbon ages from each landform are used to calculate long-term-average rates of sedimentation. Results indicate that the first half of the Holocene experienced somewhat more rapid rates of hillslope sedimentation (0.3 to 1.1 mm/yr) than the last half of the Holocene (0.1–0.2 mm/yr) on footslopes, toeslopes, and alluvial/colluvial fans prior to historic time. We suggest that these subtle differences in the rates of sedimentation were driven by changes in global paleoclimate that favored a high frequency of heavy rainfall, including tropical storms and/or severe thunderstorms and more (and possibly larger) floods during the first half of the Holocene. Prehistoric rates of vertical accretion on the first terrace (T1) ranged from 0.1 to 0.8 mm/yr between about 10,000 and 3000 calendar years ago, and incision below T1 formed the late Holocene floodplain beginning at about 6000 years ago. We suggest that this incision is linked to a reduction in the supply of sediment and a reduction in the magnitude of floods. Historical rates of sedimentation on all parts of the depositional landscape (2.0–2.7 mm/yr on hillslopes and fans and 5.8–6.5 mm/yr on floodplains) were about an order of magnitude greater than prehistoric rates. We attribute these rates to human impacts, such as timber harvest and land clearing, which caused accelerated erosion. We attribute the abundance of fine-grained sediment in streams of the Southern Blue Ridge province, which is atypical in many mountain streams around the world, to the regionally widespread mantle of saprolite as a source of sediment to the fluvial system. Holocene sedimentation on all depositional landforms in the valley led to sedimentary burial of archeological materials, which highlights the need to consider site burial on lower hillslopes and terraces for evaluation of the cultural resources in the Southern Blue Ridge Mountains. These findings show that the entrenched condition of the Raven Fork channel was inherited from the middle Holocene and can be considered a "natural" state for this mountain stream, casting doubt on the negative connotation that is often assigned to entrenched channels.

Keywords: Appalachian; Sediment; Colluvium; Hillslope; Terrace; Entrenched; Channel; Archeology

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doi:10.1016/j.geomorph.2006.01.023

1. Introduction

Stratigraphic records of Holocene erosion and sedimentation have been the focus of numerous geomorphic studies around the world and provide important information about variations in climate, human impact on the landscape, and geomorphic processes (e.g., Knox, 1984; Meade et al., 1990; Gregory et al., 1995; Walling and Webb, 1996; Knighton, 1998; Wohl, 2000). The Southern Blue Ridge Mountains in the southeastern United States (the highest relief province of the Southern Appalachian Highlands), however, have received relatively little study regarding Holocene colluvial and alluvial chronologies. For example, only one of eight studies referenced by Mills (2005) in his database for the chronologies of stream terraces in the Appalachians was from the Southern Blue Ridge province. As a consequence of this lack of chronological data, geomorphic responses to climate change and human impacts in these mountains are not well understood.

Lack of good chronological data prompted Mills and Delcourt (1991) to indicate "major needs" for studies involving numerical ages, stratigraphy, and sedimentology of surficial deposits in the Appalachian Highlands. A small number of studies throughout the region of the southern and central Appalachian Highlands have published numerical ages for late Quaternary sediments (Kochel, 1987; Shafer, 1988; Jacobson et al., 1989; Engel et al., 1996; Leigh, 1996; Kite et al., 1997; Eaton et al., 2003a,b; Delcourt and Delcourt, 2004), but only two of these (Shafer, 1988; Leigh, 1996) are from the Southern Blue Ridge province. Other studies simply have relied on estimates of relative ages (Hack and Goodlett, 1960; Mills, 1981, 1982, 1988; Kochel and Simmons, 1986; Whittecar and Ryter, 1992; Mills and Allison, 1995a,b; Liebens and Schaetzl, 1997; Mills, 2005).

Here we present Holocene colluvial and alluvial stratigraphy for the lower valley of Raven Fork, which is a typical mountain stream that drains 194 km^2 of high relief (1.3 km) terrain in the core of the Southern Blue Ridge Mountains in western North Carolina, USA (Fig. 1). We provide a chronology that spans from 11,000 calendar years ago (11 ka) to present, based on 16 radiocarbon samples from hillslopes, alluvial/colluvial fans, terraces, and floodplains. These findings provide baseline data with respect to morphology and sedimentation of the stream valley that facilitate evaluation of climate change and human impact on erosion, sedimentation, channel morphology, and processes of evolution for terraces and floodplains. Also, these findings have

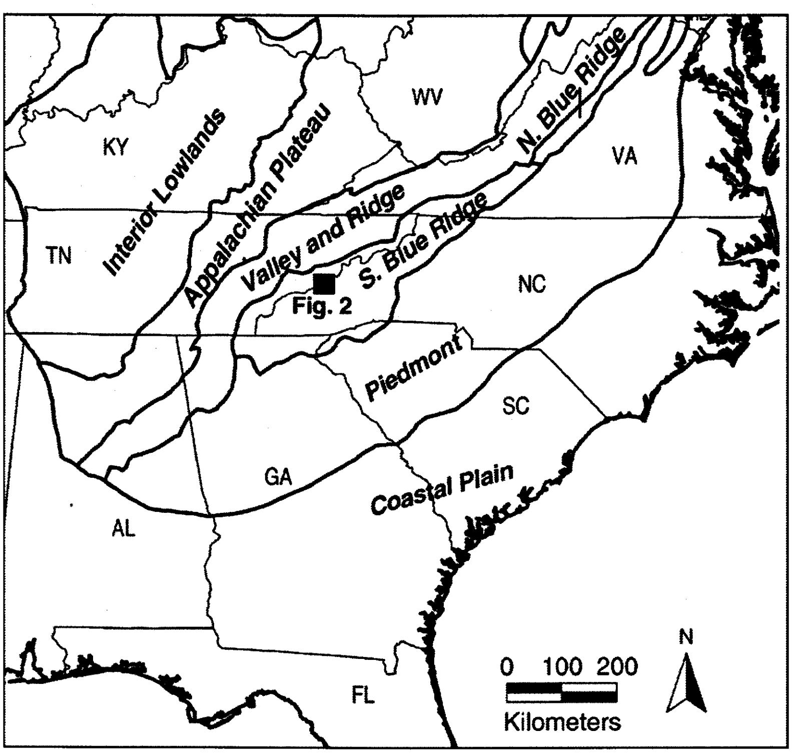

Fig. 1. Location of the study area (Fig. 2 rectangle) in the southeastern United States showing the Southern Blue Ridge and surrounding physiographic provinces.

important implications about the potential for burial of prehistoric archaeological sites in the southern Appalachian Highlands, as well as for perspectives on the "natural" condition of entrenched stream channels and stream restoration.

1.1. Study area

The study area includes three kilometers of the lower Raven Fork valley near its confluence with the Oconaluftee River on property now owned by the Eastern Band of Cherokee Indians and adjacent land within Great Smoky Mountains National Park in the heart of the Southern Blue Ridge Mountains (Figs. 1 and 2). This region of the southern Appalachian Mountains was tectonically uplifted by convergence that terminated at about 300 ma (Alleganian orogeny) when the initial high relief topography of these mountains may have been comparable to the present-day Andes. The present-day moderate relief (1.3 km) is the product of long-term weathering, erosion, and exhumation throughout the tectonically stable late Cenozoic (Spotila et al., 2004). These mountains are underlain by metamorphic and igneous rocks of Paleozoic to Precambrian age and they have not been glaciated. A somewhat unique aspect of the Southern Blue Ridge Mountains is the presence of a relatively thick (up to 30 m) weathering mantle of saprolite (Southworth et al., 2003), which provides an abundant source of fine sediment to the drainage network. The watershed of Raven Fork encompasses 194 km^2, and the combined watershed of Oconaluftee River and Raven Fork at the confluence is 329 km^2. Valley bottoms are at about 600 masl and mountain peaks reach 1900 masl. Bedrock in the watersheds primarily consists of metagraywacke, granitic biotite gneiss, and metasiltstone, although some quartzite deposits are present in the immediate study area (Hadley and Goldsmith, 1963; North Carolina Geological Survey, 1985; Robinson et al., 1992). A fault, mapped along the east side of the valley, separates metasedimentary rocks on the east from biotite gneiss on the west. The surficial deposits in the uplands include patches of saprolite, colluvium, and bedrock, and the valleys contain colluvium and alluvium that drape saprolite and bedrock. Matrix supported bouldery diamicton (colluvium), resulting from ubiquitous debris flows and landslides, fills most of the smaller tributary valleys further upstream in the watershed; however, the study area is far enough downstream to be dominated by relatively well sorted alluvium with colluvial deposits only on the margins of the valley (Southworth et al., 2003).

The channel of Raven Fork is about 20–30 m wide, has an average stream gradient of 0.0075, with gravel, cobbles, and boulders comprising most of the channel bed. The morphology of the channel bed is characterized by rapids, riffles, and runs, with only a few pools interspersed in the studied reach. Small outcrops of bedrock are exposed in many places along the channel. Riverbanks range from one to four meters high, depending on whether the river channel has developed a floodplain or whether it is incised into a terrace. Alluvial floodplains and terraces are well represented in the study area (Fig. 2), but most of the study reach of the Raven Fork channel is entrenched beneath the first alluvial terrace (T1), leading to stream banks that are three to four meters high. A second alluvial terrace occurs in the vicinity, but was not found in the study area. The alluvial valley in the study area is about 100–450 m wide with colluvial deposits covering the sides of the valley (Fig. 2).

Soils on the terrace and floodplain typically consist of a normally graded, massive, light brown, sandy silt loam top-stratum that abruptly overlies the bottom-stratum of stratified and imbricated sand, gravel, and boulders found at depths of one to two meters. Soils on the terrace are slightly weathered Inceptisols (A, Bw, C profiles) that typically exhibit cambic Bw horizons in the subsoil. Soils on the floodplain are Entisols (A, C profiles) that exhibit little to no weathering or horizonation. Soils on the alluvial/colluvial hillslopes typically are Inceptisols (A, Bw, C profiles) consisting of light brown sandy loam to silt loam that is interstratified with lenses of angular cobbles, but older Ultisols (A, Bt, C profiles) and younger Entisols (A, C profiles) also occur on colluvial hillslopes.

Vegetation in the watershed primarily consists of deciduous forests and mixed forests that change to montane fir and spruce forests at the highest elevations (e.g.,1750–1900 masl). Small pastures presently occur on the valley bottoms. Paleoenvironmental reconstructions for the region (Delcourt and Delcourt, 1985, 2004; Kneller and Peteet, 1999) indicate that natural forest communities changed somewhat during the Holocene, but the basin has been almost completely forested throughout the terminal Pleistocene and Holocene. The main feature of vegetation change during the terminal Pleistocene through the Holocene was the ascent of an evergreen/deciduous ecotone (Delcourt and Delcourt, 2004). Patches of erosive clearings periodically have opened amidst the pristine forest cover because of fires, storm damage, mass movement, and limited Native American agriculture.

Large parts of the Appalachian forest experienced clear-cutting and rapid erosion during the 1800s and

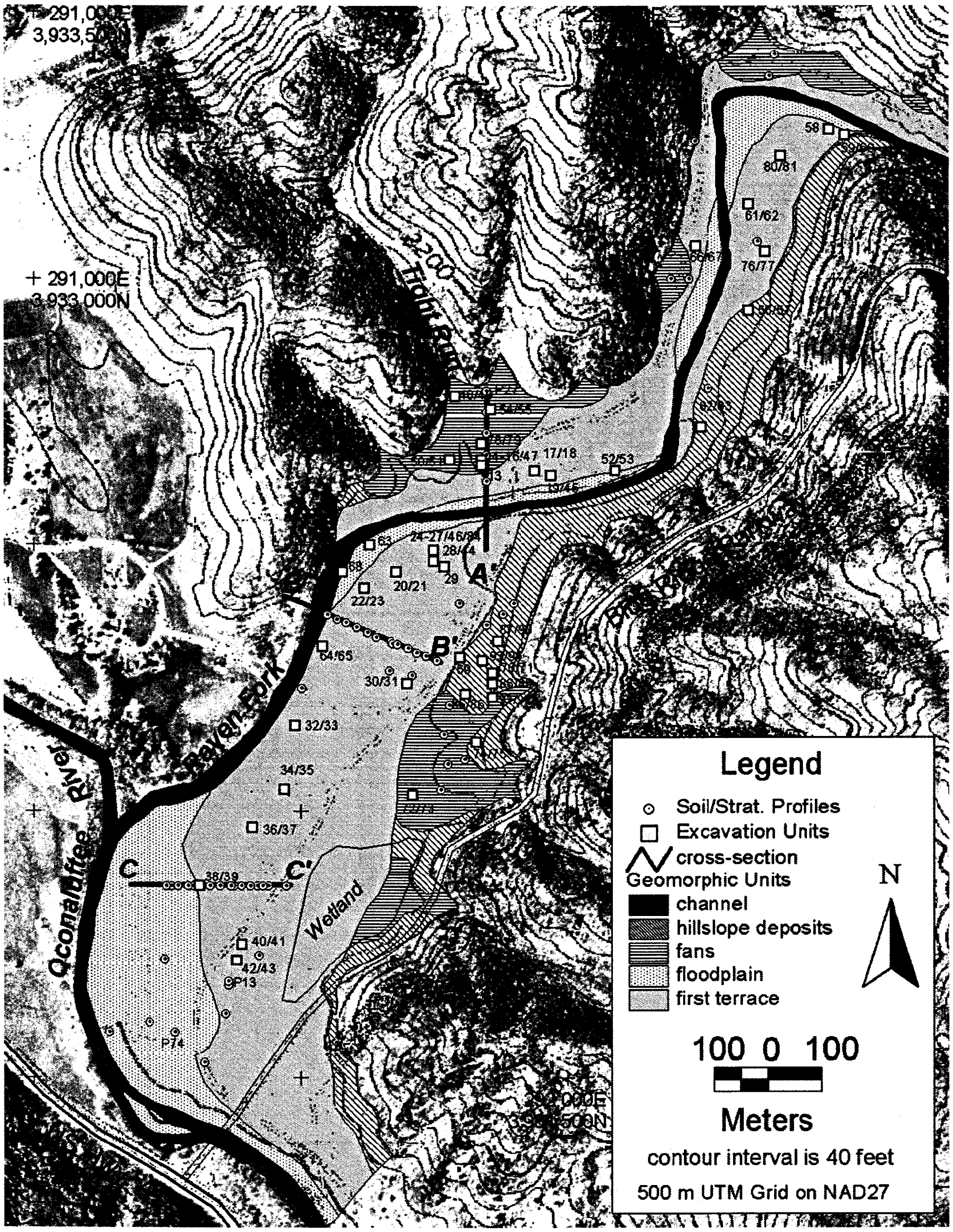

Fig. 2. Geomorphic map of the lower Raven Fork stream valley at its confluence with the Oconaluftee River, including topographic lines from the Smokemont, 7.5-min USGS quadrangle. The north and west side of Raven Fork is part of the Great Smoky Mountains National Park and the south and east side includes the Qualla Cherokee Reservation as well as additional park land.

early 1900s, because of logging and limited clearing for agriculture (Roosevelt, 1902; Ayres and Ashe, 1905; Glenn, 1911). Only about four percent of the Raven Fork catchment was mapped, however, as having been clear-cut by 1904 (Ayres and Ashe, 1905), which mostly included cutting of valley bottoms and low-elevation hillslopes. Glenn (1911) describes most of the Oconaluftee basin as forested, with little to no "damage" to streams from logging activities. Glenn contrasts the unaltered conditions of streams in the Oconaluftee basin (including Raven Fork) with those of a nearby watershed, the Soco River basin, which experienced pronounced changes in sedimentation and morphology because of erosion and sediment yield from clear-cut hillslopes. Subsequent studies (Holmes, 1911; Lambert, 1961; Pierce, 2000) indicate that the Raven Fork basin has been a relatively pristine forest, whereas the Oconaluftee basin experienced some erosional impacts from tree harvest shortly prior to the creation of the Great Smoky Mountains National Park in 1934. Much of the Raven Fork catchment is mapped as "virgin" forest by the National Park Service.

The local climate is characterized by a mean annual temperature of about 12 °C and mean annual rainfall of about 1200 mm, according to the most comparable long-term climate station nearby at Waynesville, North Carolina. Annual snowfall is typically 100–500 mm. Paleoclimate was characterized by periglacial conditions during the last glacial maximum (circa 15–20 ka) that changed to temperate forest conditions by about 15 ka (Delcourt and Delcourt, 1985; Kneller, 1996; Kneller and Peteet, 1999). Since about 15 ka, the climate has been characterized by humid temperate conditions.

2. Methods

Much of the geomorphic work for this research was done in association with extensive archeological testing (Webb, 2002) at the "Ravensford Land Exchange" tract, a bottomland parcel that was exchanged from the National Park Service to the Eastern Band of Cherokee Indians and comprises most of the valley on the south and east side of Raven Fork (Fig. 2). Soil and stratigraphic profiles were observed in archaeological test units, river cutbanks, cores retrieved with a Giddings hydraulic soil probe, and by samples from a bucket auger. A total of 104 soil/stratigraphic profiles were observed in the study area and recorded on the Universal Transverse Mercator (UTM) grid system referenced to the 1927 North American Datum (Webb, 2002). Profiles were described according to the U.S. Department of Agriculture (USDA) Soil Survey Manual (U.S. Division of Soil Survey, 1993) using moist Munsell colors. Geomorphic mapping was accomplished by field survey augmented by U.S. Geological Survey (USGS) topographic maps, USGS aerial photographs, and USDA soil maps (Perkins and Gettys, 1947).

Simulations of floods were made with version 2.2 of the HEC-RAS River Analysis System program (U.S. Army Corps of Engineers, 1998). Discharges for selected flood recurrence intervals were calculated by the regional frequency equations for floods in the Southern Blue Ridge province of North Carolina that are based on drainage area (Pope and Tasker, 1999). Channel cross-sections and stratigraphic cross-sections were surveyed with a Topcon GTS 311 electronic total station.

Archaeological survey was conducted by shovel testing to a depth of 70 cm or to cobbles on a 10 m grid throughout the entire study area. Shovel testing was followed by excavation of 41 rectangular (1 × 2 or 1 × 1 m) test units (TUs) located on sites that were discovered by the shovel testing. The test units were excavated in 10 cm levels down to culturally sterile sediments or to the water table. Identification and age assessment of diagnostic artifacts is provided by Webb (2002).

Radiocarbon (^{14}C) ages were determined by the University of Georgia Center for Applied Isotope Studies using a National Electrostatics Corporation Model 1.5SDH-1 500 kV accelerator mass spectrometer (AMS). Geomorphic samples for radiocarbon dating were obtained directly from exposed excavations within an undisturbed sediment matrix. A few radiocarbon samples were collected from archaeological features by flotation of sample material to date the associated cultural strata around the feature. All radiocarbon samples were pretreated with a standard acid–alkali–acid bath (HCl–NaOH–HCl), rinsed with distilled water, and oven-dried prior to combustion into CO_2 gas and transformation into graphite targets for AMS analysis. Calendar year conversions were made with CALIB 4.3 (Stuiver and Reimer, 1993) using a five sample (50 year) smoothing function. Rates of sedimentation were calculated as depth/age functions based on the intercept values for the estimates of calendar years. Thus, the rates of sedimentation represent average long-term rates that aggregate individual pulses of discontinuous events of sedimentation. Although it is possible that charcoal dated in some profiles was redeposited long after it was initially burned, thus producing erroneously old ages for the sediment, temporally diagnostic artifacts and independent radiocarbon ages on uncarbonized materials associated with nearby charcoal ages indicate that such error is relatively insignificant for our samples.

3. Results

The valley contains five depositional units: (1) hillslope deposits; (2) alluvial/colluvial fans; (3) first terrace; (4) floodplain; and (5) the river channel (Fig. 2). The steep slopes above the valley bottom were not mapped, but they consist of bedrock covered with patchy residuum, as well as colluvium within tributary valleys. The morphology, sedimentology, stratigraphy, soils, and age of each unit are described below. Radiocarbon ages associated with these units are provided in Table 1 and rates of sedimentation are provided in Table 2.

3.1. Hillslope deposits

3.1.1. Hillslope morphology

Depositional components of the hillslopes include lower backslopes, footslopes, and toeslopes where the slope angle is less than 30%. Middle and upper backslopes comprise higher and steeper (>30%) erosional elements of the slopes that lack significant thickness (>30 cm) of unconsolidated sediments. The eastern side of the valley exhibits widespread hillslope deposits, whereas hillslope deposits are virtually absent on the western side of the valley (Fig. 2). Gneiss on the west may be less favorable for production of hillslope sediments than the metasedimentary rocks on the east. Also, the slope on the west side is generally steeper, which may favor sediment transport instead of deposition.

3.1.2. Hillslope sedimentology, stratigraphy, and soils

Most hillslope deposits consist of silt loam and fine sandy loam that includes lenses of matrix-supported angular cobbles and gravels (Fig. 3). These cobbles and gravels are interpreted as debris flow and landslide deposits that have been somewhat reworked by slopewash and soil creep subsequent to the initial deposition further upslope. Sedimentary structures in the silty and sandy strata include massive and thinly stratified to laminated beds. The thickness of hillslope sediment exceeded five meters in an auger hole drilled beneath TU 85/86. The total thickness was impossible to determine because the auger encountered cobbles. Most of the footslope and toeslope deposits consist of massive and well sorted silt loam and fine sandy loam, which indicates transport and deposition by fluvial sheetflow (similar to the alluvial/colluvial fans). In contrast, gravelly and bouldery mass-movement facies are more

Table 1
Radiocarbon ages

Lab number	Provenience[a] unit or profile number, and depth	Material	C-12/C-13 corrected age (^{14}C yr BP)	C-12/C-13 corrected 2-σ range (^{14}C yr BP)	Calibrated intercepts (cal yr BP)	Calibrated 2-σ range (cal yr BP)
Floodplain south of Raven Fork						
UGA-9922	N1585 E1265 (Profile 74); 160 cm	Hemlock cones	70±40	Modern	0–274	0–274 BP
Terrace 1						
UGA-9838	N1680 E1365 (Profile 13); 250 cm	Uncarb. wood	4830±50	4730–4930	5589	5469–5642
UGA-9840	N1720 E1380 (TU 42/43); 75 cm	Wood charcoal	1630±40	1550–1710	1531	1411–1611
UGA-9923	N1860 E1310 (TU 38/39); 138 cm	Wood charcoal	5710±40	5630–5790	6482	6404–6622
UGA-9924	N2640 E2090 (TU 52/53); 68 cm	Wood charcoal	5400±40	5320–5480	6198	6048–6289
Hillslope deposits east side of Raven Fork Valley						
UGA-10085	N2214 E1860 (TU 92), 90 cm	Wood charcoal	7880±40	7800–7960	8632	8575–8964
UGA-10079	N2240 E1860 (TU 89), 60 cm	Wood charcoal	6940±40	6860–7020	7748	7674–7846
UGA-10086	N2240 E1860 (TU 89), 130 cm	Wood charcoal	8200±40	8120–8280	9133	9024–9296
UGA-10216	N2259 E1861 (TU 71), 90–100 cm	Wood charcoal	9340±100	9140–9540	10,556	10,243–10,747
Alluvial/colluvial fan (Tight Run fan) north of Raven Fork						
UGA-9839	N2755 E1857 (Profile 10); 120–140 cm	Wood charcoal	8560±170	8220–8900	9533	9153–10,131
UGA-9920	N2790 E1850 (Profile 27); 550 cm	Uncarb. leaf stem	9630±40	9550–9710	11,092	11,166–10,737
UGA-9921	N2755 E1857 (TU 54/55); 166 cm	Wood charcoal	9010±40	8930–9090	10,195	10,147–10,231
UGA-9984	N2690 E1840 (TU 78/79); 48 cm	Wood charcoal	5310±40	5230–5390	6064	5952–6195
UGA-10221	N2660 E1779 (TU 50), 66–76 cm	Wood charcoal	1130±50	1030–1230	1047	942–1169
UGA-10218	N2659 E1838 (TU 16), 104–115 cm	Wood charcoal	8750±40	8670–8830	9721	9564–9914
UGA-10633	N2790 E1850 (Profile 27); 115 cm	Wood charcoal	4760±40	4680–4840	5528	5333–5592

[a] North (N) and east (E) refers to meters north and east of 3,930,000 m north and 290,000 m east on the UTM NAD 27 grid.

Table 2
Rates of sedimentation

Unit	Location	Lower age (cal yr BP)	Upper age (cal yr BP)	Lower depth (mm)	Upper depth (mm)	Sed. rate (mm/yr)	Time range (ka)
Hillslope[1]	TU 71	10,556	8250	1250	570	0.29	10.6–8.2
Hillslope	TU 89	9133	7748	1300	600	0.51	9.1–7.7
Hillslope	TU92	8632	8500	900	750	1.14	8.6–8.5
Hillslope	TU 92	8632	150	900	300	0.07	8.6–0.0
Hillslope	TU 89	7748	150	600	430	0.02	7.7–0.0
Hillslope[2]	TU 92	150	0	300	0	2.00	0.15–0.0
Hillslope[2]	TU 89	150	0	430	0	2.87	0.15–0.0
Alluvial/colluvial fan	TU 54/55 and P 10	10,195	9533	1660	1300	0.54	10.2–9.5
Alluvial/colluvial fan	Profile 27	11,092	5528	5500	1150	0.78	11.1–5.5
Alluvial/colluvial fan	Profile 10	9533	0	1300	0	0.14	9.5–0.0
Alluvial/colluvial fan	TU 16	9271	1942	1100	330	0.11	9.3–0.0
Alluvial/colluvial fan	TU 78/79	6064	0	480	0	0.08	6.1–0.0
Alluvial/colluvial fan	Profile 27	5528	0	1150	0	0.21	5.5–0.0
Alluvial/colluvial fan[3]	TU 50	1047	0	710	0	0.68	1.0–0.0
Alluvial/colluvial fan	TU 48/49	150	0	400	0	2.67	0.15–0.0
Terrace 1	TU 38/39	6482	2500	1380	150	0.31	6.5–2.5
Terrace 1	TU 52/53	6198	2500	680	150	0.14	6.2–2.5
Terrace 1	Profile 13	5589	2500	2500	150	0.76	5.6–2.5
Terrace 1 (swale)	TU 42/43	1531	0	750	0	0.49	1.5–0.0
Terrace 1 (plow zone)	Many TUs	2500	0	150	0	0.06	2.5–0.0
Floodplain[4]	Profile 74	274	0	1600	0	5.84	0.3–0.0
Floodplain[2]	Profile 57	77	0	500	0	6.49	0.1–0.0

[1]Upper age is estimated from diagnostic artifact association.
[2]Based on stratigraphic delineation of historical stratum and assumes base of historical sediment to be A.D. 1850.
[3]Represents period of prehistoric corn cultivation.
[4]Minimum estimate of sedimentation rate based on oldest end of 2-σ radiocarbon age.

common on the higher and steeper parts of the lower backslope and upper footslope.

Three laterally and vertically separated soil-stratigraphic units are recognized on the hillslopes, including upper (historical), middle, and lower units. The upper unit is historical sediment, which is composed of laminated and thinly stratified brownish-yellow (10YR 6/6) sandy loam and silt loam that exhibits little to no development of the soil profile (A over C horizons) and contains historical artifacts. The distribution of the historical upper unit is restricted to zero-order swales and first-order drainages. The middle unit, the most widespread on hillslopes, consists of micaceous brown to yellowish brown (10YR 4/3 to 10YR 5/6) silt loam to sandy loam that exhibits cambic Bw horizons and weakly-expressed buried A horizons in its upper part (Fig. 3). The lower unit consists of strong brown (7.5YR 5/6 to 7.5YR 5/8), non-micaceous, heavy silt loam to silty clay loam that exhibits argillic horizon (Bt) development.

3.1.3. Hillslope age and rates of sedimentation

The upper soil-stratigraphic unit is clearly historical in age, as indicated by lack of pedogenic development and historical artifacts. Three radiocarbon ages from the middle unit on the east side of the valley (Table 1) indicate that at least the top meter is Holocene in age. The two oldest radiocarbon ages (9133 cal yr BP, UGA-10086; 8632 cal yr BP, UGA-10085) are conformably underlain by at least one more meter of similar sediment without intervening paleosols, which indicates sedimentation was active in the middle unit prior to 9 ka. Assemblages of artifacts corroborate the radiocarbon ages, because TU 70/71 recovered a diagnostic Middle Archaic projectile point (Stanly type, ca. 8–8.5 ka) from 0.5–0.6 m depth, along with a chert core indicative of the Early Archaic period (ca. 9.0–11.5 ka) from 1.0–1.1 m depth in the same level that produced a radiocarbon age of 10,556 cal yr BP (UGA-10216) from a flotation sample of charcoal in the associated sediment matrix. In addition, a serrated fragment of an early Archaic projectile point (ca. 8.5–10.0 ka) was recovered at about 15 cm above the radiocarbon age of 8632 cal yr BP (UGA-10085) in TU 92. No radiocarbon ages were available for the lower soil-stratigraphic unit, but relative age traits related to weathering (soil color, texture, low mica content) confirm that it predates the middle unit, which is at least early Holocene in age. The

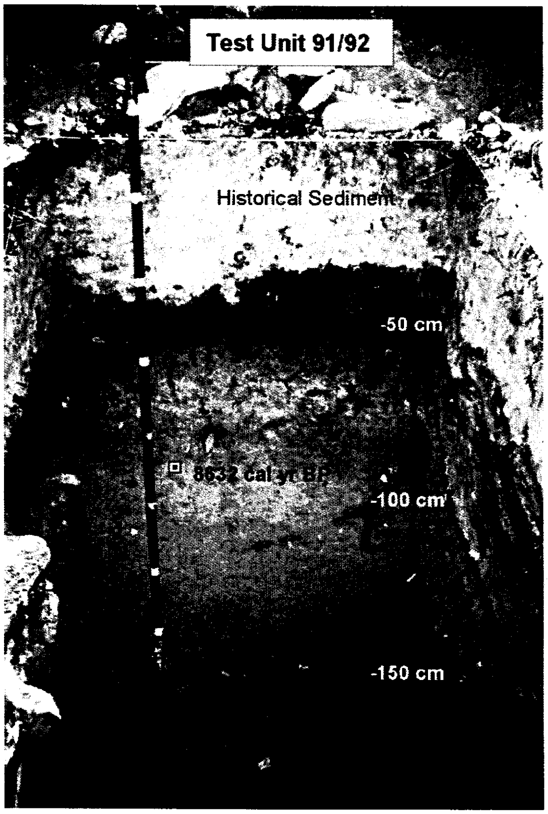

Fig. 3. Photograph of typical footslope deposits from test unit 91/92 on the eastern side of Raven Fork valley showing a distinct stratum of historical sediment in the top 30–40 cm of the profile.

lower hillslope soil-stratigraphic unit probably predates 13–15 ka as indicated by the absence of artifacts from the subsoil and argillic horizon development, along with the fact that >9 ka sediment lies conformably beneath the middle unit.

The dated sections indicate somewhat more rapid hillslope sedimentation (via slopewash and creep) during the early Holocene (0.3–1.1 mm/yr) than during the middle and prehistoric late Holocene (<0.1 mm/yr) (Table 2). The low number of radiocarbon samples, however, may not be sufficient to accurately resolve differences in the rates of sedimentation within separate time intervals of the Holocene. The historical part of the late Holocene period (last 150 years) registers the most rapid rates of sedimentation (2.0–2.9 mm/yr).

3.2. Alluvial/colluvial fans

3.2.1. Fan morphology

The alluvial/colluvial fans primarily are composed of alluvium, but contain moderate amounts of colluvium, including debris flow deposits. The fans range from 12 m thick at the apex to less than one meter thick where they interfinger with fluvial sediment on the first terrace (Fig. 4). Gradients on the fan surfaces range from one to ten percent on large fans and from one to 20% on small fans. The large fans are saturated with water most of the year, as indicated by water tables found within one meter of the ground surface observed during September and October 2001, which was considered a dry year. Also, waterlogged fan sediments are indicated by unoxidized sediment beneath the apex of the Tight Run fan and by gleyed sediment within the medial and lower parts of the large fan on the eastern side of the valley (Fig. 2).

3.2.2. Sedimentology, stratigraphy, and soils on fans

Large fans mostly contain sheetflow facies of well sorted silt loam and sandy loam textures that are interbedded with occasional thin discontinuous beds of stream gravels. The small fans contain relatively large amounts of angular cobbles and boulders in a silty matrix (debris flow facies), which are interstratified and juxtaposed with well sorted fine sediment derived from sheetflow and overbank facies.

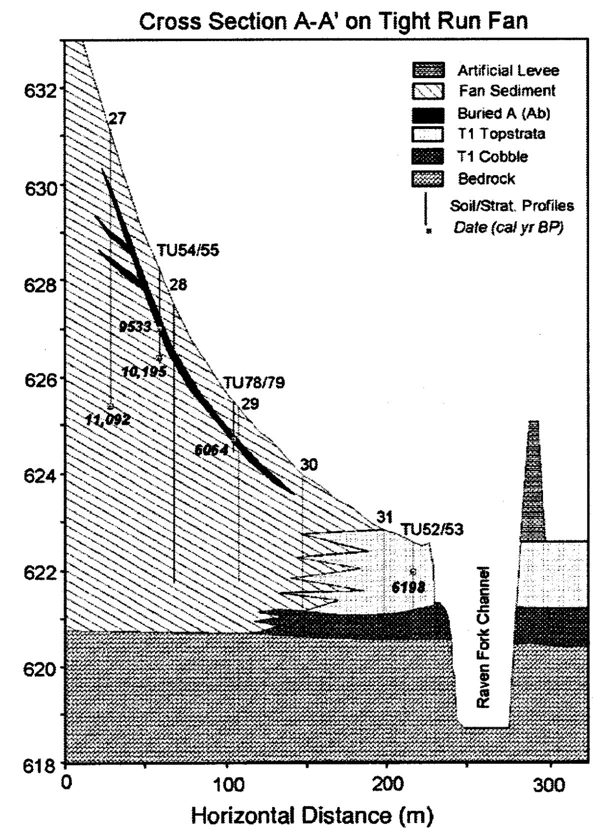

Fig. 4. Longitudinal stratigraphic cross-section through the Tight Run alluvial fan (A–A′ on Fig. 2).

Large alluvial/colluvial fan deposits, exemplified by the Tight Run fan (Fig. 4), generally consist of an upper stratum of massive, yellowish-brown (10YR 5/6) silt loam that is about one to two meters thick and contains multiple buried Ab and Bw horizons (Fig. 5). The upper stratum overlies a lower stratum of mottled grayish brown to light olive brown (2.5Y 5/2 to 2.5Y 5/6) pebbly heavy silt loam to silty clay loam that typically is found at or below the water table and exhibits little development in the soil profile, with Bw and C horizons being the most common. The deepest buried A horizon (Ab) is the approximate dividing line between the upper and lower strata in the Tight Run fan (Fig. 4). The lower stratum in the Tight Run fan resembles upland saprolite. The poorly sorted saprolite-like sediments in the lower stratum probably are debris flow facies. The sedimentary and pedologic structures of the upper fan typically are massive to subangular blocky, and the sedimentology is generally indicative of sheetflow facies. Gravel lenses are scattered throughout the fan, however, and indicate episodic channelized flow. Historical sediment has a limited and patchy distribution on the surface of fans. It typically consists of light yellowish-brown (2.5Y 6/4 to 2.5Y 6/5) silty and fine sandy sediment that is commonly laminated and contains historical artifacts.

3.2.3. Fan age and rates of sedimentation

Radiocarbon ages from Tight Run fan indicate that much of the fan is Holocene in age (Fig. 4; Table 1). An 11,092 cal yr BP age (UGA-9920) on an uncarbonized leaf stem from 5.5 m beneath the apex of the Tight Run fan suggests that the upper half is Holocene in age and that the lower half is Pleistocene in age. Alternatively, some Pleistocene deposits may be juxtaposed with Holocene deposits in the fan because of Holocene cut-and-fill deposits situated along infilled paleochannels or gullies on the fan.

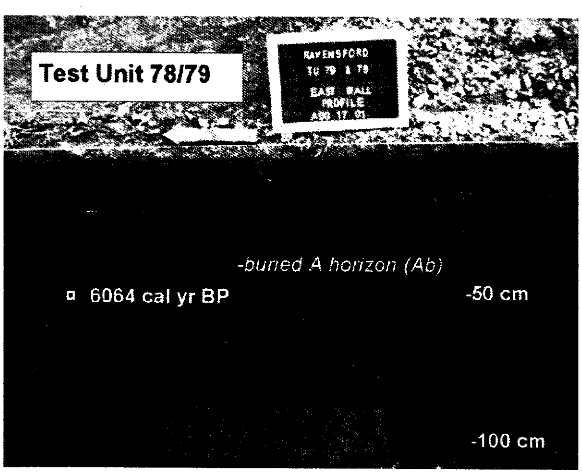

Fig. 5. Photograph of typical alluvial/colluvial fan deposits.

The chronology from Tight Run fan indicates relatively rapid sedimentation on the fan from the terminal Pleistocene until the middle Holocene (ca. 11–6 ka; Table 2). Rates of sedimentation range from about 0.5–0.8 mm/yr from 11 ka until 6 ka, as opposed to 0.1–0.2 mm/yr during the middle Holocene through the late Holocene. One profile, (TU50) dated at 1047 cal yr BP (UGA-10221), suggests that rates of sedimentation may have locally increased, perhaps in response to cultivation on the fan during the Mississippian and Cherokee cultural periods (<1 ka), which is a time when charred pieces of maize cupules occur in the archeological record from Tight Run fan (Webb, 2002). Relatively rapid sedimentation on the fan at circa 11–6 ka is corroborated by a lack of buried soils in the lower stratum as opposed to many buried soils in the upper stratum that indicate periodic cessation of sedimentation. Debris flow facies in the lower fan sediments versus sheetflow facies in the upper fan provide another stratigraphic trait consistent with most rapid sedimentation at 11–6 ka. The radiocarbon chronology is supported by diagnostic artifacts that include only terminal Archaic and younger artifacts (<4 ka) within the upper 50 cm of soil. Historical sedimentation, though spatially isolated in swales and lobes on the lower fan, was rapid (2.7 mm/yr) compared to the prehistoric rates.

3.3. First terrace (T1)

3.3.1. T1 morphology

The first terrace (T1), the most prominent fluvial surface in the valley (Fig. 2), stands at about three to four meters above the bed of the Raven Fork channel (Fig. 6a). The terrace surface is relatively flat and featureless, but contains some slight depressions that represent paleochannels and back-channel chutes that, when compared to the prevailing tread of the terrace, have been filled with more deposits from recent vertical accretion. The soils on T1 are moderately well drained, except for a wetland area in the southeastern part of the study area that receives shallow groundwater from the nearby uplands that keeps those soils poorly drained. The longitudinal gradient of the terrace surface (0.0075) parallels that of the channel and floodplain. The elevation of channel lag gravels within the terrace indicates that the streambed was one to two meters higher than it is now when terrace sedimentation began, and that the channel subsequently incised to its present level (Fig. 6b). Apparently, migration of the channel was from east to west in the southern part of the project area

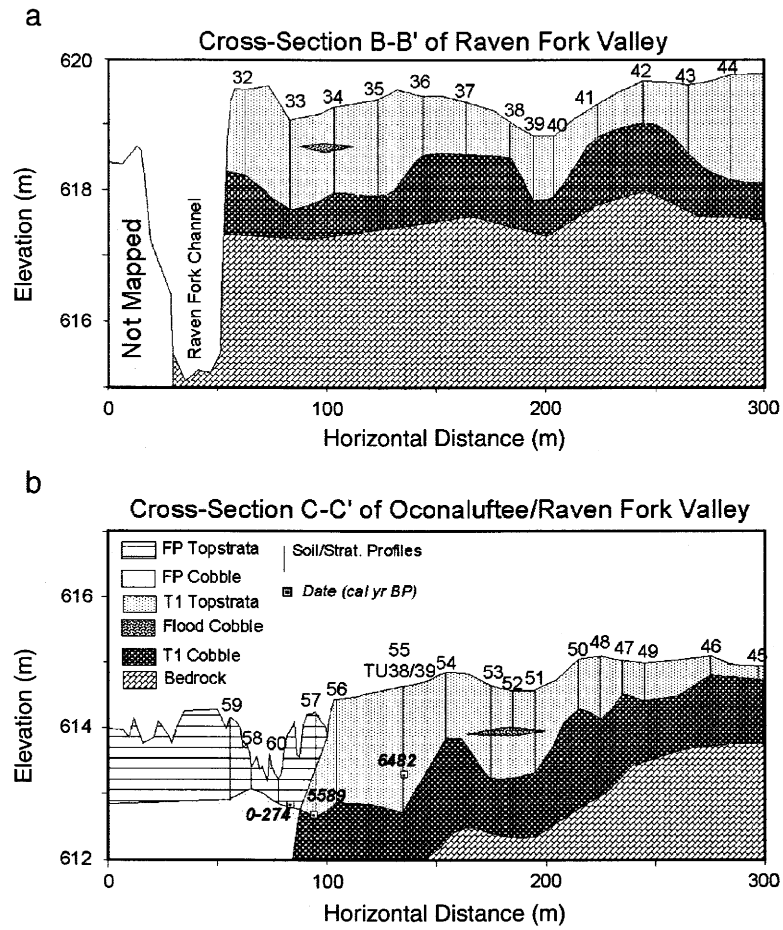

Fig. 6. Transverse stratigraphic cross-sections of the floodplain and terraces looking upstream through B–B′ (6a) and C–C′ (6b) on Fig. 2.

during the late phase of T1 sedimentation based on scroll patterns visible on aerial photographs.

The first terrace (T1) is the only mappable terrace in the project area, but patches of higher/older terrace gravels exist buried beneath hillslope sediments on the eastern side of the valley. Also, a remnant of a second terrace (T2) is apparent along the eastern side of the Oconaluftee river immediately upstream of the confluence with Raven Fork. The terraces higher than T1 predate the Holocene, however, based on the chronology presented below, and thus are beyond the scope of this paper.

3.3.2. T1 sedimentology, stratigraphy, and soils

Terrace sediments generally consist of normally graded dark yellowish-brown (10YR 4/4 to 10YR 4/6) to yellowish-brown (10YR 5/4 to 10YR 5/6) silt loam to fine sandy loam vertical accretion facies (top-stratum) that abruptly overlie bedload facies (bottom-stratum) of sand, gravel, and cobbles at depths of about 0.5–2.0 m below ground surface (Fig. 6). The fine sandy and silty vertical accretion facies of T1 exhibit slightly weathered soils (Inceptisols) that typically have cambic horizons (Bw) and in a few instances exhibit incipient argillic (Bt) horizons. Least developed soils are on the western side of the terrace, which is consistent with the apparent direction of lateral migration (westward) indicated above. Characteristics (horizons, color, texture, structure) of the soil profile are rather uniform, except that the depth to cobbles can vary from 0.2 to 2.5 m.

The silty top-stratum is composed of vertical accretion facies derived from suspended sediment load, whereas the bottom-stratum of gravel and cobbles is composed of bedload facies derived from the former river bed. A thin graded sandy facies infrequently occurs between the bedload cobbles and silty overbank facies, which represents lateral bars and stream beds with low-energy environments. The vertical accretion facies typically exhibit a graded (fining-upward) sedimentary sequence that is sandy at the base and becomes siltier with increasing elevation. The vertical accretion facies

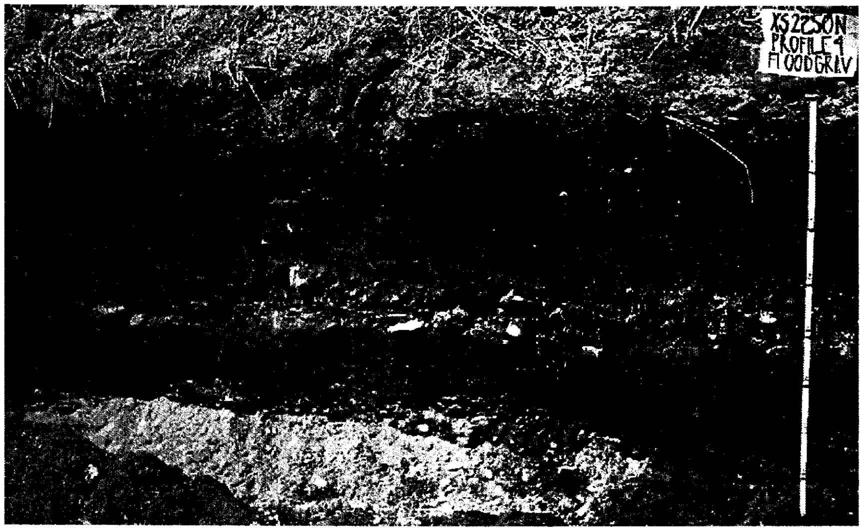

Fig. 7. Photograph of T1 sediments with a layer of flood gravels and cobbles bounded by overbank silty facies. The white ruler is 1.2 m long for scale.

exhibit massive sedimentary structures, and are typically not more than 1.5 m thick.

Distinct beds of flood gravels and cobbles occur in the midst of the silty vertical accretion facies at several localities (Fig. 7). At TUs 24–27 the average intermediate axis calculated from the five largest overbank cobbles was 146 mm (230 mm max.), and at TUs 30/31 the average of the five largest overbank cobbles was 182 mm (270 mm max). According to the equation of Knox (1993) ([depth (m) = 0.0001(axial mm)1.21 slope$^{-0.57}$]), these overbank cobbles indicate that flood waters ranged from 0.7 to 1.4 m deep over the T1 surface. These flood gravels indicate pronounced overbank flooding during the first half of the Holocene, given the relative position within nearby profiles that have good age control.

3.3.3. T1 age and sedimentation rates

The deposition of most alluvium within the first terrace occurred between 10 and 3 ka, except for swales where sedimentation continued throughout the late Holocene. A terminal age of 3 ka is based on many excavation units that revealed dense terminal Late Archaic (ca. 3 ka) artifacts within and immediately beneath the plow zone on T1 (15–20 cm depth), indicating that only a small increment (10–20 cm) of sediment accumulated on the terrace after 3 ka. The flat surface of T1 excludes any possibility of mechanical erosion because of plowing of the surface. All of the more recent artifacts, including Early Woodland, Middle Woodland, Mississippian, Cherokee, and historical materials occur in the plow zone on the flat treads of T1. Small increments of sediment continued to fill isolated swales on T1 until circa 0.5 ka, as indicated by Mississippian artifacts and a radiocarbon age of 1531 cal yr BP (UGA-9840) from TUs 42/43 within a swale, but no historical (< 150 cal yr BP) sediment occurs on T1. The oldest age from T1 is 6482 cal yr BP (UGA-9923) from charcoal near the base of overbank facies in TUs 38/39 (Table 1, Fig. 6b), and it is substantiated by another age of 5589 cal yr BP (UGA-9838) from uncarbonized wood recovered from soil profile 56. Given that these 6 ka ages for samples are from the young end of the terrace (Fig. 6), and allowing a lateral rate of migration of about 0.2 m/yr, then the initial sedimentation underlying the T1 landform extrapolates to about 10 ka.

The radiocarbon chronology indicates that the river channel incised to the level of the modern channel bed during the time of T1 sedimentation. Radiocarbon ages along transect C–C′ (Figs. 2 and 6) indicate that incision to the level of the modern channel bed was achieved by 6 ka, and that the "entrenched" condition of the channel (Figs. 4 and 6a) is a remnant feature of the middle Holocene. Rates of sedimentation in T1 overbank facies are variable, ranging from 0.3 to 0.8 mm/year. The low-elevation swales appear to have the highest rates of sedimentation, whereas the higher parts of the terrace exhibit the lower rates. The only apparent change in rates of sedimentation is that of diminished rates (< 0.1 mm/year) after 3 ka (plow zone) at the top of the vertical accretion facies.

3.4. Floodplain (FP)

3.4.1. Floodplain morphology

The floodplain is the alluvial surface that is being constructed by the modern regime of Raven Fork and the Oconaluftee River. The highest surface on the floodplain is about 1.0–1.5 m above the present channel bed, and the topography is characterized by many ridges and swales, some of which function as flood chutes. The low-lying swales generally contain gravel and cobbles, whereas the higher surfaces are composed of overbank facies of sand and silt overlying gravel. Two large areas of floodplain exist, one at the southern end of the project area and another at the northern end of the study area (Fig. 2). Between these areas, the floodplain is absent or very narrow and the river channel is entrenched beneath the T1 surface. Development of the southern floodplain area appears to have been influenced by a base-level effect caused by the Oconaluftee River at its confluence with Raven Fork, based on the scroll patterns observed in the field and on aerial photographs. The scroll patterns indicate migration of the channel to the west in the southern area and to the northwest in the northern area. The floodplain contains wetland soils in the swales and chutes, and the water table is generally at or within 1.5 m of the ground surface.

3.4.2. Floodplain sedimentology, stratigraphy, and soils

Deposits on the floodplain are characterized by an unweathered topstratum of overbank sands and silts that abruptly overlie a bottom-stratum of channel bed gravels and cobbles. The facies assemblage is like that of T1, except that less soil development occurred in the vertical accretion sediments of the floodplain. Soils in the overbank deposits are characterized by unweathered Entisols (typically Fluvaquents) that commonly exhibit A, C and A, C, Ab, C profile sequences. Boulders commonly occur in the northern floodplain area and in the narrow strips of the Raven Fork floodplain in the midst of the study area, which indicates these areas are subject to strong flood forces that do not favor deposition of fine sediments.

3.4.3. Floodplain age and rates of sedimentation

Most of the sediment on the floodplain appears to be decades to centuries old. A radiocarbon age, on hemlock cones buried by 1.6 m of overbank sediment at profile 74, yielded an age of 70±40 ^{14}C yr BP (UGA-9922), which falls within a two-sigma calendar age range of 0–274 cal yr BP. Profile 74 appears to be at the older end of the scroll pattern of the westward migrating floodplain, thus implying that the floodplain is relatively young (<300 years). Stratigraphy and radiocarbon dates indicate, however, that the riverbed incised to its modern level by about 6 ka. This suggests either long-term stability of a previously entrenched channel, or that the channel recently reworked and replaced older floodplain deposits in the same localities as the present floodplain. Rates of sedimentation on the floodplain, observed in the southern floodplain of the Oconaluftee River, are the most rapid in the entire valley, at about 6 mm/year, which is more than an order of magnitude greater than the average of prehistoric rates of sedimentation on T1. This rate is indicated by tree ages and the depth of the buried root crowns, because radiocarbon dating is not reliable for such young deposits.

3.5. Channel

The Raven Fork stream channel typically is 20–30 m wide, with coarse gravel, cobbles, boulders, and bedrock comprising the bed. Most of the channel bed consists of riffles and glides, but a few deep scour pools are found within the study reach. The pools commonly have sandy beds. The average channel gradient in the study area is about 0.0075. The sinuosity of the channel is 1.5. The depth of the "bankfull" or channel-full condition varies from three to four meters where it is entrenched beneath the first terrace (T1) to about one to two meters where the modern floodplain forms the riverbank (Fig. 2). In some places T1 forms one bank and the floodplain forms the other bank. Reconnaissance for several kilometers in the upstream direction of the study area revealed that the entrenched condition of the Raven Fork channel is common, rather than a unique attribute of the study area.

Flood modeling was applied to the channel at cross-sections A–A′ and B–B′ (Fig. 6) to estimate the flood discharge needed to inundate the tread of T1. Discharges corresponding with the 2, 5, 50, 100, 200, and 500 year recurrence interval floods were calculated as 80, 128, 266, 315, 370, and 452 m^3/s, based on the regional equations in Pope and Tasker (1999) and using the Raven Fork drainage area of 194 km^2. A roughness coefficient (Manning's n) of 0.055 was used for the channel, and a roughness coefficient of 0.10 was used for the overbank environment. A measured gradient of 0.0086 was input for the channel gradient upstream of cross-section A–A′, and 0.0055 was input for the channel gradient downstream of cross-section B–B′, based on a two-foot contour map of the study reach. Results indicate that the channel at cross-section A–A′ contains all floods up to and including the 500-year event (not including the artificial berm along a former log pond south of the river). The channel at cross-section B–B' relates to an overbank event that just barely enters the lowest swale on T1 with the 100-year event, and the swales become progressively more filled with the 200- and 500-year events. However, the highest parts of T1 were still emergent during the 500-year event on cross-section B–B′. These data indicate that the "entrenched" condition of the Raven Fork channel easily accommodates a 100-year flood.

4. Discussion

4.1. Holocene sedimentation

We believe that mass movement was the primary source of erosion and sediment production on the lower hillslopes along Raven Fork during the prehistoric Holocene. Debris flows and landslides are recognized as dominant modes of Holocene sediment production in forests of the Southern Blue Ridge Mountains (Eaton et al., 2003a,b), whereas overland flow and surface erosion are relatively insignificant under native forest cover (Swift et al., 1988). Although limited overland flow probably occurred on bare ground surfaces exposed by forest fires, storm blow-downs, and fresh mass-movement deposits and scars, these sources are less likely to have influenced variation in prehistoric rates of sedimentation because of the random and sporadic distribution through time and space. Pleistocene mass movement has long been recognized as a key agent of denudation in the Southern Blue Ridge Mountains (i.e., Hack and Goodllet, 1960; Jacobson et al., 1989; Eaton et al., 2003a,b), but only a few studies, including this one, have recognized significant amounts of mass movement and sediment production during the Holocene (Kochel, 1987; Shafer, 1988; Eaton et al., 2003a,b). Our data clearly show significant rates of sedimentation on lower hillslopes and alluvial/colluvial fans that varied from 0.02 to 1.14 mm/yr during the prehistoric Holocene, with most rapid rates indicated during the first half of the Holocene. Human-induced erosion and sedimentation resulted in much more rapid rates of sedimentation (2.0 to 2.7 mm/yr) during historical time, which far exceeds rates of sedimentation documented throughout the prehistoric Holocene.

Taken together, the hillslope and alluvial/colluvial fan data presented here suggest a period of somewhat more rapid footslope sedimentation (0.3–1.1 mm/yr) during the first half of the Holocene versus the last half of the Holocene. Interestingly, a similar pattern was noted by Kite et al. (1997) for the Appalachian Plateau of West Virginia, which they attributed to widespread environmental change. More rapid hillslope sedimentation during the first half of the Holocene possibly indicates a distinct shift at about 5–6 ka in the paleoclimatic drivers of Holocene sedimentation (i.e., heavy rainfall) in the Southern Blue Ridge Mountains. Several authors indicate that mass movement in the Southern Appalachian Highlands is driven by extrinsic climatic factors such as heavy rainfall (e.g., Hack and Goodlett, 1960; Kochel, 1987; Jacobson et al., 1989; Liebens and Schaetzl, 1997; Wieczorek et al., 2000; Springer et al., 2001). Wieczorek et al. (2000) indicate that a rainfall rate of 70 mm/h for 2 h represents the triggering threshold for debris flows in the Blue Ridge Mountains of central Virginia. Climatic conditions that favor such heavy rains include tropical storms that move inland from the Atlantic Coast and prolonged thunderstorms. We believe that such conditions may have been more frequent during the first half of the Holocene.

Paleoclimate change is a driver that is reasonably well understood, but its influence on Earth surface processes in the Southern Blue Ridge province is not well known. It offers one of the best explanations for the apparent contrast in early versus late Holocene rates of sedimentation. The time period of 12–6 ka is modeled as having the warmest summer temperatures on the sea surface during the last 21,000 years (Kutzbach et al., 1998:476), and the data of Bard (2003) clearly indicate that the North Atlantic Ocean was warmer during the first half of the Holocene by 1–1.5 °C. Such warm ocean waters may have been favorable for a higher frequency of tropical storms that produced heavy rains in the Appalachians during the late summer and fall. Elsner et al. (2000) indicate that a high frequency of tropical storms occurs along the Atlantic Coast when the Bermuda High is in a more northerly position during strong periods of the North Atlantic Oscillation. Liu and Fearn (2000) suggested that the position of the Bermuda High would have been farther north during the middle Holocene thermal maximum at 6 ka, thus focusing more tropical storms (including hurricanes) and moist air directly onto the eastern seaboard and Appalachian Highlands. A greater supply of moist air would also enhance summer thunderstorms as a mechanism for heavy rain. Liu and Fearn (2000) indicated that the Bermuda High had shifted back to the south prior to 3 ka, and caused hurricanes to become more focused on the Gulf Coast. Additional evidence supporting a wetter and more flood-prone first half of the Holocene in the eastern United States is provided by Leigh and Feeney (1995), Dwyer et al. (1996), and Goman and Leigh (2004). In addition, Delcourt and Delcourt (2004, p. 99) indicate that a marked reduction in sediment supply to the lower Little Tennessee River valley occurred at some time between 7.8 and 4.0 ka. Thus, it is very possible that heavy rains were more frequent in the early

Holocene, producing high rates of sedimentation on footslopes and on alluvial/colluvial fans via a higher frequency of mass-movement and fluvial reworking of mass-movement deposits and scars.

The timing of incision and terracing of T1 described here correlates well with the mid-Holocene timing of T1 formation described by Delcourt and Delcourt (2004) for the lowest reaches of the Little Tennessee River valley. They indicate that (1) relatively rapid T1 sedimentation occurred as valley floors aggraded between 17 and 7 ka, (2) that a marked decrease in sediment supply stabilized the Little Tennessee River between 7.8 and 4.0 ka, and (3) that channel incision after 4 ka resulted in the formation of T1 and establishment of a new floodplain. We document incision of the channel and formation of the floodplain earlier, circa 6 ka, and it is possible that the headwater mountain streams, like Raven Fork, incised somewhat earlier than the lower reaches of the Little Tennessee River, resulting in time-transgressive response of the river system or an example of "complex response" (Schumm, 1973). Another detailed alluvial chronology in the southern United States (Brackenridge, 1984) documented a major shift in fluvial activity for the Duck River in western Tennessee at about 6–7 ka, when fluvial stability during the warm–dry Hypsithermal was followed by renewed fluvial activity and overbank accretion coinciding with increasingly moist conditions during the last half of the Holocene. Although early and middle Holocene precipitation in western Tennessee may have been out-of-phase with that of western North Carolina, both regions apparently manifested responses of the fluvial system to middle Holocene climate change.

Renewed levels of rapid sedimentation resulted in historical time (last 150–200 years) from human impact in the form of timber harvest and its affect on increased rates of soil erosion. Although this human-induced erosion and sedimentation was short lived and of a limited spatial extent in the watershed, it left a distinct mark on the landscape in terms of historical sediment deposits that accreted approximately an order of magnitude faster than in prehistoric time. Similar examples of rapid historical sedimentation are documented for the southern United States (Trimble, 1974; Costa, 1975; Brackenridge, 1984; Jacobson and Coleman, 1986), but these examples are for lower-relief regions that experienced intensive mechanical cultivation for agriculture. Although the Southern Blue Ridge is generally considered to have experienced less intensive human-induced erosion, historical rates of sedimentation are of a similar magnitude when compared to other regions more heavily influenced by agriculture.

The rates of sedimentation presented here provide a framework for understanding the relative magnitude of climatically- versus human-induced impacts on mountain streams of the Southern Blue Ridge Mountains. The result is that human impacts, such as timber harvest, provide very distinct changes in rates of sedimentation compared to subtle variations that are indicated during the prehistoric Holocene time. Historical rates of sedimentation observed at Raven Fork are on par with more heavily impacted and lower-relief provinces of the Appalachian Highlands such as the Piedmont (Trimble, 1974; Costa, 1975; Jacobson and Coleman, 1986), and indicate that human-impact on fluvial systems of the Southern Blue Ridge is very significant and overshadows impacts caused by natural variation in climate. A similar implication is made by Price and Leigh (this volume).

Another significant aspect of fluvial sedimentation at Raven Fork is that fine-grained vertical accretion facies (sand, silt, and clay) comprise a large part of the floodplain and terrace depositional system, accounting for more than half of the typical alluvial stratigraphic sequence. This is unlike other relatively youthful mountainous regions, such as the Rocky Mountains that lack thick saprolite, where floodplains and terraces are typically composed of coarser lateral accretion sands and gravels, and where vertical accretion silts and clays comprise a relatively smaller part of the depositional sequence. We attribute the abundance of fine-grained sediment in streams of the Southern Blue Ridge province to the widespread mantle of saprolite as a source of fine sediment to the fluvial system. A similar observation of thin sandy to gravelly "bottom-stratum facies" overlain by thick clay-rich "top-stratum facies" was made by Brackenridge (1984) for the Duck River floodplains and terraces in the Interior Low Plains province of western Tennessee. Although far from a mountainous watershed, the Duck River is in another region with a thick residual weathering mantle of fine sediment, and Brackenridge (1984) argued that it provides an example of stream systems where deposits by lateral accretion "are not an important part of the flood-plain-forming process".

Our data indicate that prehistoric or "pristine" streams of the Southern Blue Ridge certainly had a significant component of suspended sediment and muddy water during floods, derived largely from fresh debris flows, landslides, and other sources of disruption to the otherwise erosionally-protective forest cover. The turbidity of historical streams, however, certainly has been (and is) greater during historical time, because of land-disturbing human impacts such as timber harvest as indicated by Price and Leigh (this volume). Our data indicate that historical rates of sedimentation are about one to two orders of magnitude higher during historic time versus prehistoric parts of the Holocene, which may serve as a proxy for how historic versus prehistoric suspended sediment concentrations stand in comparison.

4.2. Archaeological implications

The chronology and sedimentary sequence presented here illustrate that high potential exists for deeply buried (>0.7 m or beyond the reach of conventional archaeological subsurface survey methods) archaeological materials in lower hillslopes (footslopes and toeslopes). Archaeological materials commonly were recovered in this study at depths of one to two meters below ground surface in lower backslope and footslope positions. This is significant, because most archaeological surveys in the region tend to consider all artifacts to be near the ground surface in hillslope settings, and typically little consideration is given to deeply buried artifacts on hillslopes. Our data should encourage future investigators to carefully consider the potential for deeply buried artifacts in lower hillslope positions.

Another important archaeological finding is that of pronounced development of lateral migration and floodplains during the Holocene. The relative lack of pre-Clovis, Paleoindian, and Early Archaic sites in the Southeast is commonly attributed to settlement patterns and low population densities, and to some extent burial of cultural assemblages in alluvial settings (Anderson and Sassaman, 1996; Goodyear, 1999). Our data show that the Raven Fork valley contains little sediment of the appropriate age to contain Early Archaic or older artifacts, and where those deposits exist they typically are buried by colluvium. Thus, erosion and site burial in colluvial settings also must be considered along with settlement density and alluvial deposition as contributing factors in the scant distribution of Early Archaic and older archaeological sites in the Southern Blue Ridge.

4.3. Entrenched pristine channel

Although the Raven Fork watershed is one of the most "pristine" basins in the Southern Blue Ridge Mountains, the river channel is entrenched throughout much of its length, requiring floods greater than an expected recurrence frequency of 100 years to overtop the channel banks. Many practitioners of stream "restoration" consider entrenchment to be a negative attribute of streams and a morphological condition that needs to be repaired to restore the channel to a more "natural" state (e.g., 105,000 Google hits on "entrenched channel restoration"). Although the association between stream entrenchment and increased runoff because of denudation or urbanization is undoubtedly true in many cases, our data show that entrenchment occurred by 6 ka in the study area because of entirely natural processes. For Raven Fork, the entrenched condition of the channel may also indicate that the late Holocene channel (<6 ka) was less competent to laterally scour the older fluvial sediment and underlying residuum and rock than the early Holocene channel. This is consistent with the interpretation that floods were of greater magnitude during the first half of the Holocene than during the last half as suggested above.

5. Conclusions

The data indicate that sustained sedimentation occurred on the lower hillslopes and alluvial/colluvial fans during the Holocene. We suggest that relatively rapid hillslope sedimentation occurred during the earlier half of the Holocene, and that it was driven by changes in global paleoclimate that favored a high frequency of heavy rainfall including tropical storms and/or severe thunderstorms. The later half of the Holocene appears to represent rates of sedimentation and flood conditions that were more representative of modern climate conditions. Human land uses, such as farming, timber harvesting, and road construction, however, have caused a pronounced increase in rates of sedimentation during historical time that exceed anything observed during the prehistoric Holocene. Although the level of human impact in the study area was spatially limited and of a relatively short duration, it left a distinct imprint on the landscape in terms of rates of sedimentation that are approximately an order of magnitude greater than the prehistoric rates of sedimentation and on par with other parts of the South that experienced more intensive and prolonged agricultural land use.

Hillslope and valley floor sedimentation throughout the Holocene have resulted in deep burial and limited "visibility" of archeological sites. Thus, it is important for future archeological survey and testing projects to consider lower hillslopes, alluvial/colluvial fans, terraced alluvial deposits, and floodplains as high-potential areas for encountering deeply buried archeological sites in the Southern Blue Ridge province, especially in locations that are otherwise highly favorable for past human occupation.

The entrenched condition of Raven Fork channel illustrates that entrenchment can be caused by natural processes, casting doubt on the negative connotation that commonly is given to entrenched channels by practitioners of stream "restoration."

Acknowledgements

This work was made possible by cooperation and funding provided by the Eastern Band of Cherokee Indians, the National Park Service (Great Smoky Mountain National Park), and the National Science Foundation (award # DEB-0218001). The archaeological fieldwork was conducted under Archaeological Resources Protection Act (ARPA) Permit GRSM 99-001, Amendment 1. Tasha Benyshek directed the archeological field work. The manuscript was improved by thoughtful reviews provided by James Knox and one anonymous reviewer.

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