Biomantle Formation and Site Preservation on Terraces of Low Order Streams in the Ozark Uplands

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Abstract   Many terraces of low order streams in the Ozark uplands appear to have been stable since at least the early Holocene, indicated by strongly expressed soils with argillic horizons and early Holocene artifacts recovered from surface and shallow sub-surface contexts. These terraces hold sites that likely represent land use practices very different from those along better-studied large streams in the area. Artifact depth distribution curves show that a biomantle with accompanying stone zone has not formed under many of these terraces, despite their age. This contrasts markedly with much swifter rates of biomantle formation reported elsewhere. The lack of a fully formed biomantle in a soil of this age may be due to forces countervailing the downward movement of clasts through bioturbation, or slower rates of bioturbation overall.

Archaeological investigations in the Ozark highlands have a long and rich history, and include many interdisciplinary projects. Geoarchaeological studies along the Pomme de Terre (Ahler 1973; Haynes 1976; Brakenridge 1981), the White (Guccione 1999) and Sac (Hajic et al. 1998; Lopinot et al. 2005) Rivers have detailed many of the relationships of sites and sediments in these river valleys. With thick accumulations of sediment and an abundance of well preserved, stratified archaeological sites, high order streams are an obvious location for such intensive research. Subsurface investigations along small streams in the Ozark uplands have been comparatively rare. The uplands contain plentiful archaeological sites, however, if somewhat sparser and less dramatic than those in the large river valleys (Kay 1997, 1999; Ray 1991; Wood 1998).

Archaeological deposits ranging in age from Dalton (ca. 11,000 to 10,000 B.P.) to recent historic are found in the uplands on ridge tops and in stream floodplain and terrace sediment assemblages, sometimes in stratified contexts. These settings afford the opportunity for directed, intensive archaeological research where little has been done before. Because several important land use characteristics, especially topography, water availability, and

biological and mineral resources, are very different in the uplands from those in the larger river valleys, it is likely that sites in uplands areas represent prehistoric land use patterns and behaviors quite different from those in large order stream valleys. An understanding of sites in both areas is necessary for any large-scale or regional cultural synthesis, and an understanding of landform development and site formation processes in both settings is necessary for a rigorous understanding of the area's archaeological record. Stemming from a survey and assessment of archaeological resources in a portion of the Ava District of Mark

Figure 1. Study location and physiographic provinces. (Figure after Madole et al. 1991.)

Twain National Forest (Kay 1997, 1999; Vogel 2000), this study begins to address the geoarchaeology of low order streams in the Ozark uplands, specifically biomantle formation and its effects on sites. The multi-component Havens site is the focus of this study, with information from six other area sites used for comparison.

Setting

The Ava District of Mark Twain National Forest is situated within an outlier of the Springfield Plateau physiographic region (Madole et al. 1991) (Figure 1). This region is a highly dissected portion of the Ozark Dome character-
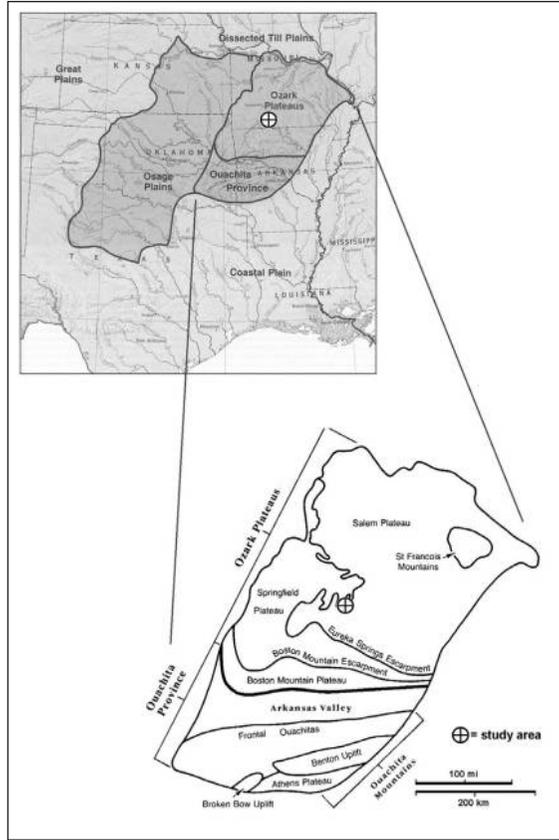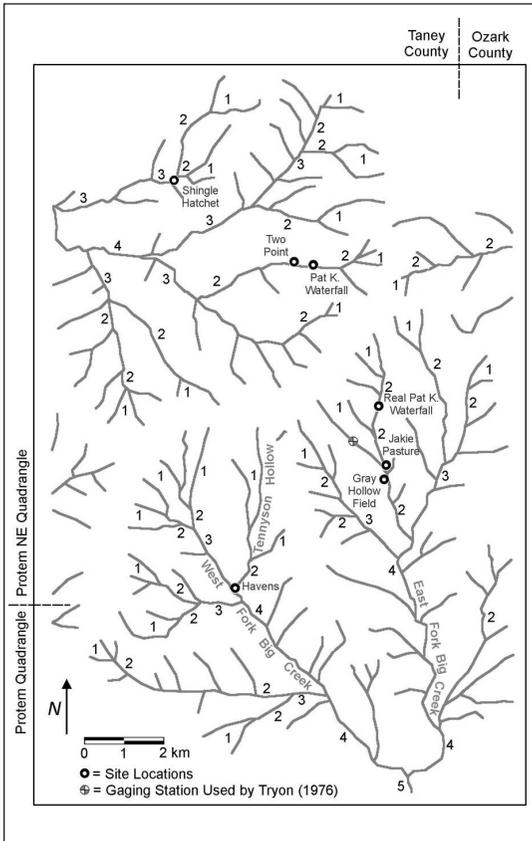
Figure 2. Study area streams and site locations. Stream orders are numbered after system devised by Strahler (1952). Gaging station used by Tryon (1976) recorded stream height and rainfall data from 1966 to 1972. Stream courses digitized from Protem and Protem NE USGS 1:24,000 quadrangle maps.

ized by sinuous, dry interfluves (generally less than 100 m wide and commonly more than 100 km long), and steep valley walls (with typical slopes ranging from 20 to 45%). Numerous Paleoindian and Early Archaic sites found at the surface along the ridge tops, low-order valley bottoms, and valley walls (Kay 1997, 1999, Ray 1991) indicate that this landscape was established by Late Glacial times, and has since been relatively stable.

The specific study area centers around the Mark Twain Glade-Top Trail, and includes several first through fourth order streams (Figure 2). Area streams drain into the White River through a well-developed dendritic network. Five of the sites used in this study are situated on terraces of second order streams (Two Point, Pat K. Waterfall, Real Pat K. Waterfall, Jakie Pasture, and Gray Hollow Field), and two are situated on terraces of third order streams (Havens and Shingle Hatchet).

Stream profiles in the study area show gradients ranging from greater than 45 degrees at the headwaters of first order tributaries, to less than 4 degrees at the intersections of third order streams. Figure 3 shows two typical drainage profiles in the study area: West Fork Big Creek and Tennyson Hollow channel, converging at the Havens site. Alluvial terraces in the study area occur on streams of second and higher order, and at gradients from about 5 degrees to about 10 degrees. A sharp drop in gradient along most area
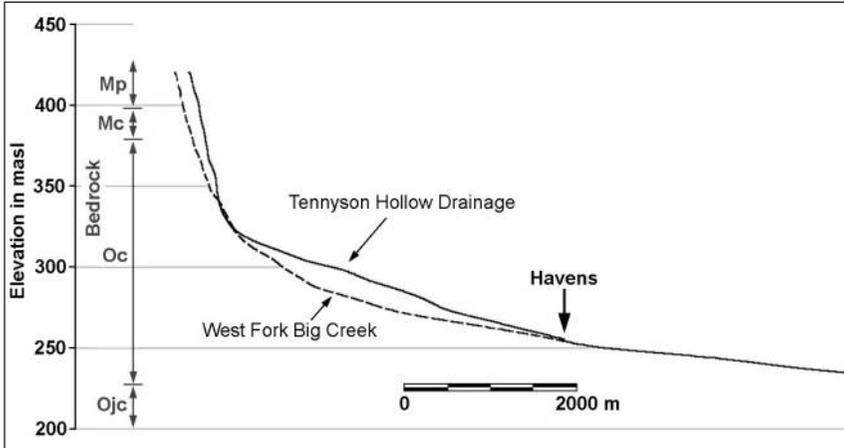
Figure 3. Stream profiles of Tennyson Hollow drainage and West Fork Big Creek, converging at the Havens site. The sharp break in gradient at 325 meters corresponds to the convergence of first order streams. Bedrock types are Mc: Early Mississippian age Compton Formation Limestone, Mp: Mississippian age Pierson Formation Limestone, Oc: Ordovician age Cotter Formation Dolomite, and Ojc: Early Ordovician age Jefferson City Formation Dolomite.

streams between 325 and 375 meters above sea level generally corresponds with the convergence of first order streams.

Ordovician and Mississippian age carbonates and sandstones comprise the bedrock of the region, serving as the source for most unconsolidated parent material (Miller et al. 1981). Bedrock outcrops are common, occurring along ridge tops, steep slopes, and channel beds. A thin layer of residuum mantles the ridges, and the valley walls and floors contain localized accumulations of colluvium and alluvium, primarily in and adjacent to floodplains.

The first systematic observations of the area uplands come from Henry R. Schoolcraft, who traveled through the Ozarks in 1818 and 1819 in order to survey the area for commercial lead deposits. His observations of the uplands in the vicinity of Taney County almost 200 years ago are still a faithful depiction of much of the landscape today:

> The Country we passed over yesterday, after leaving the valley of the White River, presented a character of unrivaled sterility, consisting of a succession of limestone ridges, skirted with a feeble growth of oaks, with no depth of soil, often bare rocks upon the surface, covered with course wild grass; and sometimes we crossed patches of ground of considerable extent, without trees or brush of any kind, and resembling the Illinois prairies in appearance, but lacking their fertility and extent. Frequently these prairies occupied the tops of conical hills or extended ridges. (Quoted from Park 1955:106)

Rainfall data for Taney County between 1951 and 1988 (Dodd and Dettman 1996), and from within the project area itself between 1966 and 1972 (Tryon 1976), record maximum annual precipitation occurring between April and November, with the minimum falling between December and March. Stream height information along a first order stream in the project area (Tryon 1976) reveals average maximum peak flow in April, tailing off to a minimum in July and August. The local moisture regime thus consists of plentiful rainfall but very little running water in the uplands during summer months. Snowmelt helps feed the streams during winter and early spring months, while rapid runoff and evapotranspiration severely deplete water resources during the summer. Streams of fourth order or less are essentially dry for one third of the year or more, with only a few spring-fed streams retaining water year round (Tryon 1976).

Methods

Pedestrian archaeological survey was conducted along selected tracts of the Ava District, and limited excavation was conducted at selected sites. Excavated sediment was screened through 1/4 inch (0.635 cm) hardware cloth mesh. Access to much of the Ava District is by logging road or hiking only, therefore material was rough sorted in the field and natural clasts were discarded. Soil profiles from Havens site were cleaned, photographed, and described in the field following the procedures of National Soil Survey Center (Schoenberger et al. 1998). At least one sample (minimum 500 grams) was taken from each field-defined soil horizon from each profile. More than one sample was taken from horizons of 20 cm or greater thickness.

Soil samples from Havens site were analyzed at the University of Arkansas Geology Laboratory for particle size by the pipette method (modified from Day 1965). Because most samples contained abundant pebbles and gravel, and large clasts were not systematically collected, field samples were first passed through a 1/4 inch hardware cloth screen and clasts larger than 1/4 inch were not used for quantitative analysis. Grain sizes were calculated using the following size divisions: 2.0mm to 62.5µm sand; 62.5 to 2.0 µm silt; and <2.0µm clay.

Site age determinations were based on time-diagnostic chipped-stone tools. Most diagnostic artifacts were recovered from the surface or in disturbed contexts. A fluted point base was recovered from 0–10 cm depth at the Real Pat K. Waterfall site, and several diagnostic points were found below the surface at Havens site (discussed below).

Archaeological material was size-graded into the categories small (1/4

Table 1. Archaeological Sites used in this Study

Site	Stream Order	Component age(s)	Downward decreasing depth distribution?
Havens	2 and 3	Dalton, Early Archaic, Historic	Yes
Pat K. Waterfall	2	Dalton, Late Archaic	Yes
Real Pat K. Waterfall	2	Dalton, Early Archaic, Late Archaic, Woodland	Yes
Shingle Hatchet	3	Late Archaic, Woodland	Yes
Two Point	2	Early Archaic, Middle Archaic	Yes
Jakie Pasture	2	Early Archaic	No
Gray Hollow Field	2	Unknown Prehistoric	No

to 1/2 inch, or 0.6 to 1.3 cm), medium (1/2 to 1 inch or 1.3 to 2.5 cm), and large (>1 inch or > 2.5 cm). Because not all test units were of the same size, and not all levels of the same thickness, depth distribution curves in this study reflect artifact counts normalized to 100,000 cm^3 (a standard 10 cm level in a 1 by 1 meter test unit), and artifact counts are placed at the mean depth of the levels they represent.

In addition to Havens site, artifact information from several terrace sites excavated in 1997 (Kay 1997) was re-analyzed and graphed for consistent comparison. Only test units with more than 25 artifacts were used. Soil profiles from the sites excavated in 1997 were not sampled and only cursorily described in the field. Soil horizons indicated in for these sites are therefore provisional. All sites used are listed in Table 1. (See Vogel 2000 for a summary of all sites investigated in 1999.)

Streams were digitized from 1:24000 scale USGS quadrangle maps (Protem and Protem NE), and stream orders defined using Strahler's (1952) method. Informal field observations confirmed the overall accuracy of stream locations and orders.

Discussion and Results

Havens Site

Havens site (23TA379) is used as representative of area archaeological sites and illustrative of low order stream terrace sediment assemblages. Havens is located at the confluence of West Fork Big Creek (a third order stream) and Tennyson Hollow channel (a second order stream) (Figures 4–9). Figure 4
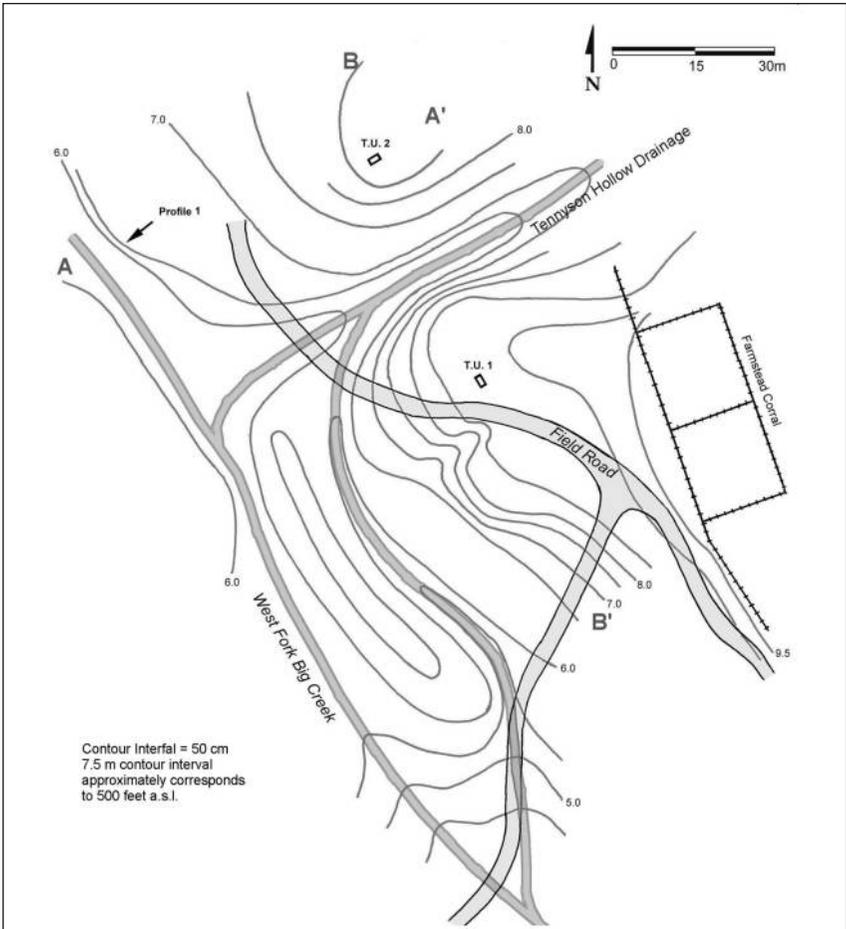
Figure 4. Havens site topographic map. Stratigraphic cross-sections from A to A′ and from B to B′ are shown in Figures 5 and 6. West Fork Big Creek is a third order stream, and Tennyson Hollow drainage is a second order stream.

is a topographic map of the site; just east of this area was an early historic homestead. No structures remain, but portions of a corral still stand. The site is accessible through a rough logging road, passable only during dry times of the year. The site is currently in open pasture, with no direct evidence of previous plowing or large-scale alteration of the landscape.

Investigations at Havens included topographic mapping, surface collection where visibility permitted, and the excavation of two 1 × 2 meter archaeological test units (Figures 5 and 6). An additional soil profile was cleaned, described, and sampled from a cutbank of West Fork Big Creek (Figure 7).
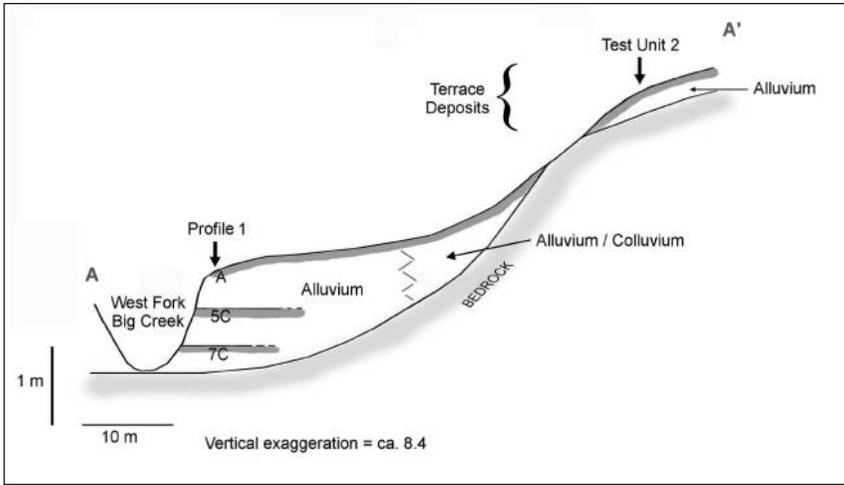
Figure 5. Profile and particle size graphs for Havens site Test Unit 1. Scale in the graph and photograph are approximately the same. Total percent <2 mm and total percent 0.2 cm to 0.635 cm are independent.

Figure 6. Profile and particle size graphs for Havens site Test Unit 2. Scale in the graph and photograph are approximately the same. Total percent <2 mm and total percent 0.2 cm to 0.635 cm are independent.
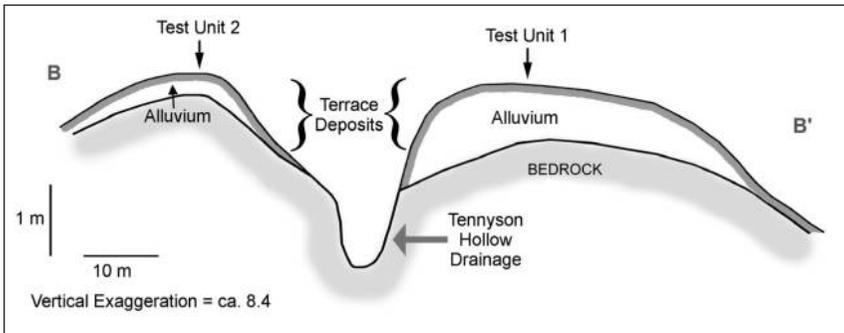
Tennyson Hollow channel splits into two short distributaries upon entering the active floodplain of West Fork Big Creek. These distributaries were dry at the time of field investigations (June of 1999) as were most area streams, but both are seasonally active channels, and were observed with flowing water in March of 1999. West Fork Big Creek and Tennyson Hollow channel are cut into Ordovician-age Cotter Dolomite, which is exposed along much of the stream courses. Channel lag deposits of angular and sub-angular chert, quartzite, and carbonate pebbles and cobbles are also present in much of the active stream channels.
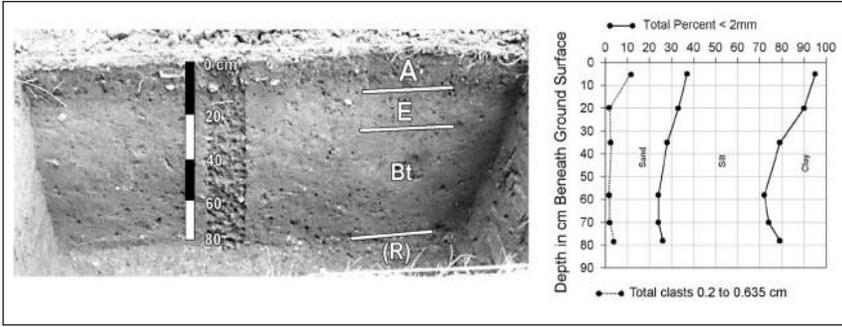
Figure 7. Profile and particle size graphs for cutbank of West Fork Big Creek (Profile 1 in Figure 4). Scale in the graph and photograph are approximately the same. Total percent <2 mm and total percent 0.2 cm to 0.635 cm are independent. Organic-rich horizons 5C and 7C are both radiocarbon dated to early historic times and probably represent re-deposited A horizon material from higher up the watershed.

Both historic and prehistoric artifacts were recovered from Havens site. Historic material was recovered from Test Unit 1, primarily within the 0 to 10 cm level. One piece of historic ceramic was recovered from the 10 to 20 cm level. Prehistoric artifacts recovered consisted entirely of chipped-stone tools and debris. All stone tool material was local chert and quartzite, easily procurable from area streams, residual hill slope deposits, and bedrock outcrops. Diagnostic prehistoric material consisted of a fluted point base (probably Dalton, 11,800 to 12,500 B.P.) from 0 to 10 cm within Test Unit 1, a complete Dalton point from 40 to 60 cm within the same test unit, and Jakie Stemmed points (6500 to 7800 B.P.) from 0 to 10 cm in both Test Units 1 and 2.

Landforms and Soils

A weakly developed A-Bw-C profile is developed on the floodplain of West Fork Big Creek (Figure 7, soil description in Table 2). Particle size data of the clay-free fraction show the sediments to be composed of a series of upward-fining deposits. No argillic horizon was observed in the field, and particle size data show no significant increase in clay content throughout the profile. Sediment below 56 cm shows no soil development in the form of translocated clay or ped structure. Thin bedding (lenses) of lighter colored gravel are present even in the dark, organic-rich horizons (5C and 7C). Bulk samples from these two horizons were submitted for radiocarbon dating and returned early historic ages. Horizon 5C dated to 340+/−30 BP, and horizon 7C dated to 230 +/160 BP (Beta-134040 and Beta-134041 respectively, uncalibrated).

Table 2. Soil Descriptions from Cutbank of West Fork Big Creek (Profile 1 in Figure 4).

Depth in cm beneath ground surface	Horizon	Parent material	Description
0-20	A	Channel deposits	Very dark grayish brown (10YR3/2) loam; moderate medium granular structure; common fine roots and biopores; noneffervescent; clear, smooth boundary.
20-30	2A2	Channel deposits	As above with ca. 50% chert and limestone pebbles 2mm to 5cm diameter, rounded and sub-rounded; clear, smooth boundary.
30-48	3Bw	Channel deposits	Dark brown (10YR3/3) and yellowish brown (10YR5/4) loam; weak fine angular blocky structure; few fine roots, common fine biopores; few pebbles; noneffervescent; clear, smooth boundary.
48-56	4Bw	Channel deposits	Very dark gray (10YR3/1) and very dark grayish brown (10YR3/2) sandy loam; abundant pebbles <2cm diameter; massive structure; noneffervescent; abrupt, smooth boundary.
56-85	5C	Channel deposits	Very dark gray (10YR3/1) loam grading down to sandy clay loam; massive; common thin lenses of lighter colored gravel; few fine roots; common fine biopores; common pebbles <2cm diameter; noneffervescent; gradual, smooth boundary.
85-101	6C	Channel deposits	Very dark gray (10YR3/1) grading down to brown (10YR4/3) sandy loam; fine pebbles grading down to 90%+ pebbles, subrounded to subangular; massive; noneffervescent; clear, smooth boundary.
101-130	7C	Channel deposits	Very dark grayish brown (10YR3/2) 90%+ pebbles 2mm to 8cm diameter, matrix is sandy clay loam; massive; few thin lenses of lighter colored gravel; pebbles are imbricated and clast supported; noneffervescent; gradual boundary.
130+	8C	Channel deposits	Predominantly (80%+) clast supported angular chert pebbles and cobbles; matrix as above; boundary not observed.

Particle size samples taken in cm beneath ground surface: 1-10, 10-20, 20-30, 30-40, 40-48, 48-56, 56-66, 66-75, 75-85, 90-100, 101-110, 120-130.
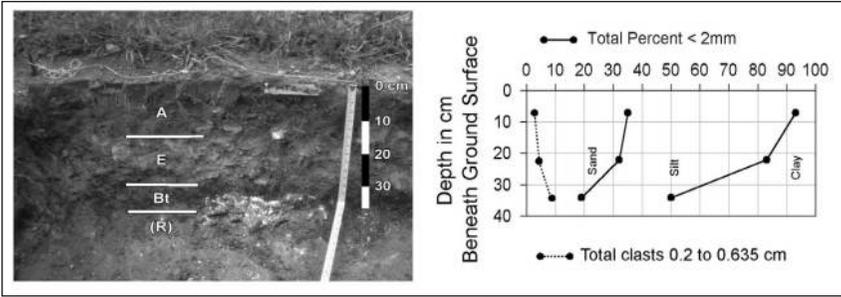
Figure 8. Stratigraphic cross-sections of Havens site, facing north. Profile location A to A′ shown in Figure 4. 5C and 7C are organic-rich horizons radiocarbon dated to early historic times. The terrace deposits have been stable since at least the Early Holocene.

These two horizons are interpreted as consisting primarily of organic-rich A horizon material eroded from somewhere higher up the stream system, possibly due to protohistoric and/or historic land-use practices. Floodplain sediments in the study area generally consist of coarse lag deposits. Although no systematic survey of floodplain sediments was conducted, this restricted package of fine sediment within a floodplain does not appear to be typical.

To the north and south of Tennyson Hollow channel, and east of West Fork Big Creek, are low (T_1) terraces (cross-sections shown in Figures 8 and 9), with treads about two meters above the active floodplain. These sediments underlying these terraces (and all terraces encountered in this study) are primarily fine-grained overbank deposits. The treads of the terraces to the south and north of Tennyson Hollow channel (represented in Test Units 1 and 2, respectively, Figures 5 and 6), occur at the same elevation, but deposits on the south side are more than twice as thick as those on the north.

Both terraces are underlain by strongly developed A-E-Bt soil profiles (full soil descriptions in Tables 3 and 4). Field observations and particle size data from Test Unit 2 (Figure 6) reveal a strongly developed argillic horizon bottoming on bedrock. The maximum clay content measured in this profile is 49% at 34 cm depth, immediately above bedrock. Field observations and particle size data from Test Unit 1 (Figure 5) reveal a strongly developed argillic horizon with a decrease in clay content near the bottom of the horizon, forming a classic Bt horizon "clay bulge". The maximum clay content measured in this horizon is 22% at 61 cm depth, about 20 cm above bedrock. The higher percentage of clay in the Bt horizon of Test Unit 2 may simply be due to the shallower depth to bedrock. Translocated clay in this setting may not be able to reach the depth it would given deeper sediment, concentrating in a thin layer just above the bedrock.
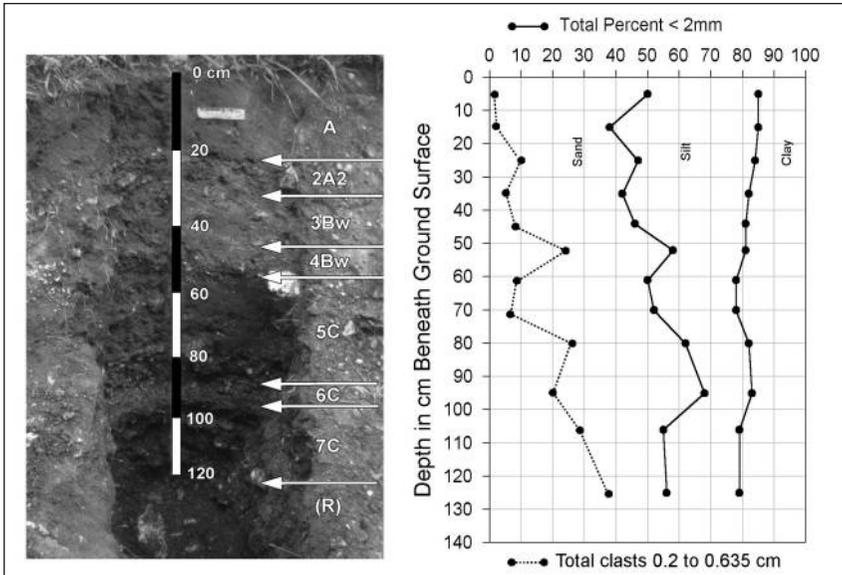
Figure 9. Stratigraphic cross-sections of Havens site, facing northeast. Profile location B to B′ shown in Figure 4. The terrace deposits have been stable since at least the Early Holocene.

Because of the well developed soils and Early Archaic to Dalton age artifacts near the surface, these terraces appear to have been relatively stable since at least late Pleistocene times, with area streams downcutting into bedrock. An increase in chert and carbonate pebbles and cobbles at the base of Test Units 1 and 2 may be channel lag deposits immediately above bedrock, or may represent the pedogenic break up of local bedrock.

Biomantle Formation and Artifact Depth Distributions

The mixing of soil through bioturbation processes, particularly the burrowing of rodents, worms, and insects, has long been understood as an important factor in archaeological site formation (Bocek 1986, 1992; Darwin 1882; Johnson 1989, 1990; Nash and Petraglia 1987; Pierce 1992; Van Nest 2002). A recently proposed model of landscape evolution (Johnson 2002; Johnson et al. 2004) presents a theoretical framework termed dynamic denudation to more fully incorporate bioturbation processes in the formation of soils. Key to this model is understanding regional dynamics and rates of bioturbation, particularly the long-term effects of burrowing. The net effect of burrowing through time (in the absence of active deposition or erosion) is to move large artifacts and natural clasts downward in relation to

Table 3. Soil Description from Havens Test Unit 1.

Depth in cm beneath ground surface	Horizon	Parent material	Description
0–10	A	Alluvium	Brown (10YR5/3) silt loam; weak medium angular blocky to granular structure; common 1-5cm diameter angular, subangular, and rounded chert pebbles; common fine and medium roots, common fine biopores; gradual, smooth boundary.
10–23	E	Alluvium	Primarily brown (10YR5/3) and slightly grayer silt loam; weak medium angular blocky structure; few 1-5cm diameter angular, subangular, and rounded chert pebbles; common fine roots and biopores; gradual, highly burrowed boundary (burrows 2 to 4 mm diameter).
23–40	Bt1	Alluvium	Strong brown (7.5YR5/6) silt loam; moderate medium blocky structure; few small pebbles; common fine roots; few fine biopores; common irregular brown (10YR5/3) redox depletions; thin discontinuous strong brown (7.5YR4/6) cutans; gradual, smooth boundary.
40–76	Bt2	Alluvium	Strong brown (7.5YR5/6 and 7.5YR4/6) clay loam; moderate medium angular blocky structure; few small pebbles; few fine roots and biopores; common discontinuous strong brown (7.5YR4/6 and slightly darker) cutans; common fine FeMn nodules; gradual, smooth boundary.
76–81	Bt3	Alluvium	Brown (7.5YR5/4) silt loam; weak fine angular blocky; common pebbles; few discontinuous black (2.5Y 2.5/1) cutans (FeMn concentrations); abrupt, irregular boundary.
81+	Bt4	Alluvium/ Residuum	70%+ chert and dolomite pebbles and cobbles; matrix as above; boundary not observed.

Particle size samples taken in cm beneath ground surface: 0-10, 15-25, 30-40, 53-62, 65-75, 76-81.

Table 4. Soil Description from Havens Test Unit 2

Depth in cm beneath ground surface	Horizon	Parent material	Description
0-14	A	Alluvium	Brown (10YR4/3) (top 3cm slightly darker) silt loam; weak medium angular blocky to granular structure; common angular and subangular chert pebbles 2-10cm diameter; common fine roots and biopores; noneffervescent; clear, smooth boundary.
14-29	E	Alluvium	Very pale brown (10YR7/4) silt loam; weak fine blocky to granular structure; abundant (50-70%) angular and subangular chert pebbles 2-10cm diameter; common fine roots and biopores; noneffervescent; abrupt, smooth boundary.
29-38	Bt2	Alluvium	Brown (7.5YR4/4) clay; strong fine angular blocky structure; common angular to subangular chert pebbles 2-10cm diameter; common fine roots and biopores; noneffervescent; abrupt, irregular boundary.
38+	Bt3	Alluvium/Residuum	70%+ limestone and chert pebbles and cobbles, matrix as above; boundary not observed.

Particle size samples taken in cm beneath ground surface: 0-14, 14-29, 29-38.

the soil surface. As insects, worms and mammals tunnel through the soil, all clasts larger than the burrows they construct are undermined and moved downward, while soil matrix and clasts smaller than the burrows are moved both laterally and ejected onto the soil surface behind the burrower. The end result of these clast segregation dynamics is a profile with three distinct zones: an upper layer of relatively fine sediment, an accumulation of coarser particles at the base of the biomantle (the "stone zone"), and a relatively unaffected zone beneath the effects of burrowing. The upper two zones, a direct result of size-sorting through bioturbation, are termed the biomantle (Johnson 1990). The size of the clasts in the stone zone is dependent upon the size of the predominant burrowing agent—the larger the burrower, the larger the clasts moved upward and laterally. When the distribution of clasts through these processes reaches equilibrium in a soil, a fully developed
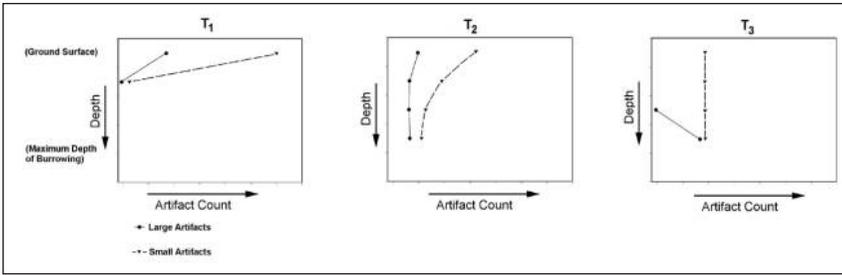
Figure 10. Idealized depth distribution profiles of a site at three stages of biomantle formation. Times represent: (T1) immediately after deposition of artifacts; (T2) midway through biomantle formation; and (T3) after full development of biomantle. "Large" artifacts are those larger in diameter than the burrows of the predominant bioturbator, and "small" artifacts are those smaller in diameter than those burrows.

biomantle is achieved (Johnson 1989, 1990). Biomantle formation may be said to "disturb" archaeological sites by altering the vertical disposition of artifacts and obliterating soil-based evidence for features. Van Nest, however (1997, 2002), notes that the downward movement of artifacts can have a preserving effect by sparing sites the negative effects of plowing.

Plotting the abundance of clasts of various sizes against depth is one way to test for biomantle development. Figure 10 shows idealized depth distribution profiles at an archaeological site with a stable surface (no significant deposition or erosion). Time 1 represents the site immediately after abandonment. Both large (larger in diameter than the burrows of the dominant bioturbator) and small (smaller in diameter than the burrows of the dominant bioturbator) artifacts are represented. Most artifacts at time 1 are at or near the soil surface, as yet unaffected by bioturbation. Time 2 represents a hypothetical "mid point" in biomantle formation—both large and small artifacts have been displaced down the soil profile to some extent. Time 3 represents the end result of biomantle formation, with all large artifacts concentrated in a stone zone near the maximum depth of burrowing, and small artifacts mixed homogenously throughout. Such end-stage biomantles with well developed stone zones are commonly reported in areas with long-stable surfaces (Johnson 1989, 1990, 2002).

Ideally, this study would compare the depth distribution of artifacts with the depth distribution of natural clasts within the same profile. Because bioturbation processes affect both natural and cultural clasts equally, comparing the similarity or difference of their distributions throughout the profile could provide greater insight into their relationship with one another. If the artifacts in a profile exhibit a very different distribution from the natural clasts, for example, this would be a strong indication that the two were not

deposited simultaneously. In areas where artifacts may have been entrained and deposited with the natural sediment (creating the false appearance of an archaeological site in primary context), this would be especially useful. Unfortunately, given the great quantity of natural clasts occurring in the study area, and the remote location of the sites, logistics and limited time in the field precluded such a sampling strategy. Artifact depth distributions alone, however, may still give insights into the nature of bioturbation as a site formation process in this area.

All artifacts in this analysis consist of chipped-stone tools and debitage. Size grade data demonstrate a natural distribution of this material. Experimental studies of stone tool manufacture and maintenance (Ahler 1989; Brown 2001) have demonstrated that the ratio of small to large flakes is invariably high, and at nearly all scales smaller flakes predominate over larger ones. Although detailed lithic size grade analyses are outside the scope of this study, the same general pattern is expressed at all sites used here. Viewing the site lithic assemblages as a whole, small (0.6 to 1.3 cm) flakes predominate, medium (1.3 to 2.5 cm) flakes generally account for less than one half of the assemblage, and large (>2.5 cm) flakes are uncommon.

Adding a depth component shows that the majority of samples exhibit a strong downward decreasing tendency in artifact depth distributions. Nine test units, including both from Havens site, show this pattern (Figure 11). Six samples do not fit this pattern (Figure 12). Note that some of these samples contain relatively few artifacts (particularly from Jakie Pasture, Figure 12 d–f), and may not be comparable. Soil horizon interpretations from both sites in Figure 12 are tentative, but both underlie second order terraces and the landforms differ in no significant way from those in Figure 11. The depth distributions described at these two sites show no clear pattern in relation to the ground surface or soil horizons.

Although the sample is quite small (39 artifacts), the depth distribution in Jakie Pasture Test Unit 7 (Figure 12e) strongly resembles the classic "end-point" biomantle distribution presented in Figure 10. If this is the case, the artifacts represent a stone zone at or near the maximum depth of local burrowers. On the other hand, the distribution also resembles that expected for a site that was buried quickly and sheltered from the effects of bioturbation. More detailed soils information, or depth distribution curves for the naturally occurring clasts would likely answer this question.

What the six samples in Figure 12 may represent in terms of geomorphic processes is unknown. The artifacts now buried may have been deposited at or near the current surface and subsequently moved down the profile through bioturbation, or they may have been deposited near their current elevation on surfaces subsequently buried by sedimentation. In either case,
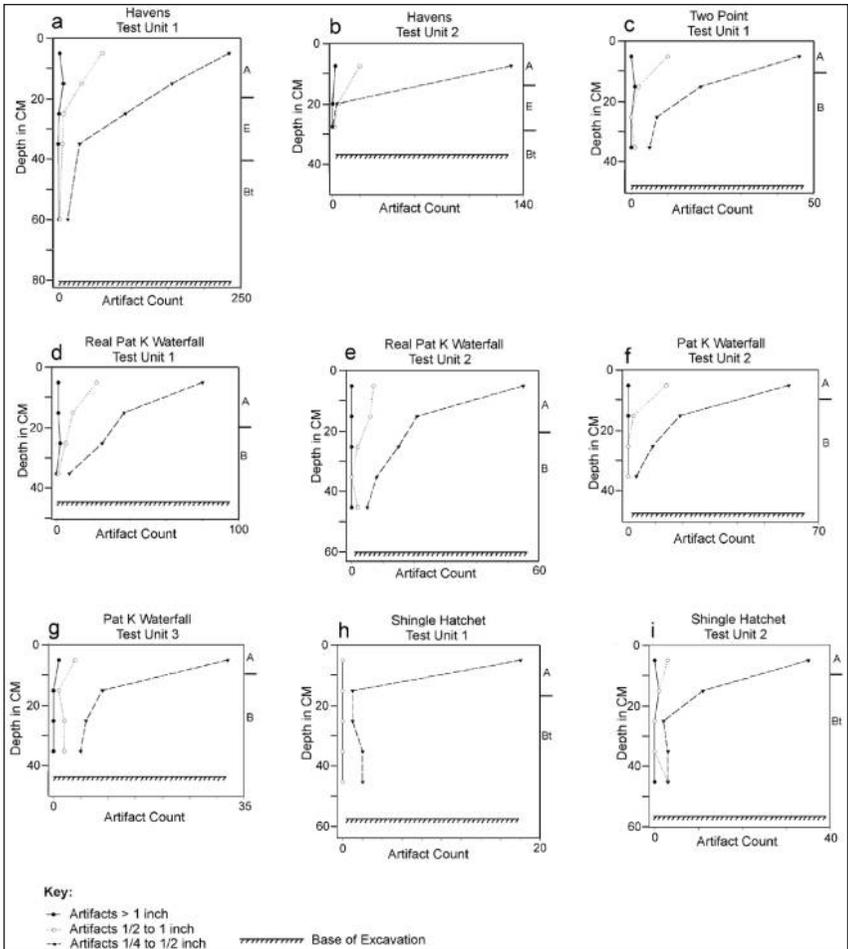
Figure 11. Artifact depth distribution graphs for sites with clear downward-decreasing artifact depth distributions. Note that the X-axis (artifact count) varies from graph to graph. Soil horizons are given on the right side of each graph.

these examples represent dynamics clearly different from the more common downward decreasing pattern.

The downward decreasing trend is most apparent in the small and medium artifact classes, with very few large artifacts represented. This depth distribution pattern clearly resembles the mid-point of biomantle formation presented in Figure 10: the majority of the artifacts are at or near the surface, some have been moved down the profile, but no stone zone has been formed. Note that the deepest artifact count in Havens Test Unit 1 (Figure 11a) represents a 40 cm thick level (40 to 80 cm), and the count has
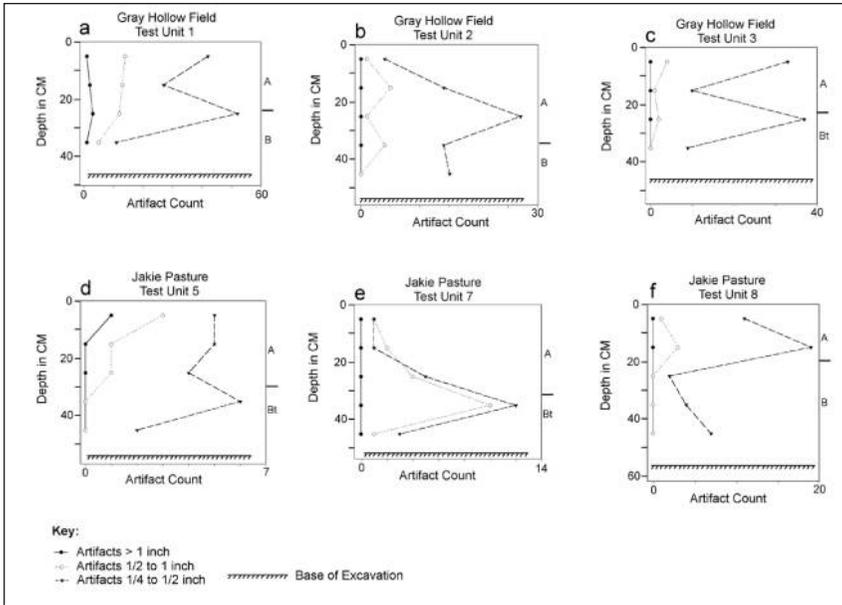
Figure 12. Artifact depth distribution graphs for sites without downward-decreasing artifact depth distributions. Note that the X-axis (artifact count) varies from graph to graph. Soil horizons are given on the right side of each graph.

been normalized to reflect a 10 cm level average. The majority of the artifacts in Havens Test Unit 1 (>80%) are above the Bt horizon boundary, and in Test Unit 2 all of them are. Johnson (2002) notes that in fully formed biomantles, the stone zone is typically located at the top of the soil B horizon, marking the maximum depth of the most intense bioturbation.

Seven other depth distribution samples from this analysis fit a similar pattern (Figure 11c–i). Judging the artifact distributions in relation to a textural B horizon in these cases is not as easy because the soils were only given a cursory description (Kay 1997). Most descriptions from these sites do not distinguish between textural and non-textural B horizons, and it is also likely that E horizons were present in at least some of the profiles but were not recognized in the field. Clearly the majority of the artifacts are located near the top of the profiles, however, and only a small percent have been moved very far down into the E/B horizons.

Because of the well developed textural B horizon at Havens site and elsewhere, and because of the wide range of time periods represented in close association (Dalton to historic in the top 10 cm of Havens site alone), it appears that these surfaces have long been relatively stable. No evidence for

subsurface pits was found in the form of soil staining or patterned artifact concentrations at any site in this study. The artifacts were likely deposited at or near the current soil surface.

Very few large (>1 inch) artifacts were found in any test unit. Small (1/4 to 1/2 inch) and medium (1/2 to 1 inch) artifacts describe very similar curves in the downward decreasing depth profiles, indicating that bioturbation processes are affecting them more or less equally, and moving them down the profiles at approximately equal rates. The maximum diameter of the burrows of the predominant bioturbating agent are therefore smaller than the smallest size class represented (1/4 inch), or the smaller clasts would likely describe different depth profiles from the larger ones. Davis et al. (1938) report the average gopher burrow diameter at about 6 cm (2.4 inches), and Bocek (1986) and Johnson (1989) found this to be consistent with the approximate maximum diameter of clasts moved up as well as down the soil profile. This effectively rules out gophers or other similar sized burrowing mammals as the predominant bioturbating agent in the area.

The predominant bioturbating agent or agents must therefore construct burrows smaller in diameter than 1/4 inch, but just how much smaller is not possible to determine with the evidence gathered for this study. Earthworms are often cited as bioturbation agents, as are ants and other small insects. One or more of these agents is likely responsible for much of the bioturbation in the study area.

Early to Middle Archaic as well as Paleoindian artifacts were found at all of the sites used in this study except Gray Hollow Field, from which no time diagnostic artifacts were recovered, yet the bulk of these materials remains very near the surface. Generally 80% or more of the site material is no deeper than 20 cm. Van Nest's (1997, 2002) studies in the loess uplands of western Illinois demonstrated biomantle formation by small-sized soil fauna to be intense enough to fully bury Early and Late Archaic sites to a depth of 30 to 40 cm, well below the mixing effects of modern plowing. The depth of biomantle formation in the present study area is thus less than half that in western Illinois. This rate of bioturbation is also much slower than earthworm-induced biomantle formation observed by Charles Darwin (1882) and his son Horace Darwin (1901), who reported rates ranging from 2.2 to 7.6 millimeters per year. Even at the slowest of these rates, a Middle Holocene surface would exhibit a fully developed biomantle with a strong stone zone at the maximum depth of burrowing.

Two processes may be responsible for the lack of a fully formed biomantle below these Ozark upland terraces: fewer or less active bioturbation agents in this area, or the presence of forces countervailing the downward

movement of clasts. Few to common biopores were observed in the Bt horizons of both Test Units 1 and 2 at Havens site, and fine (2 to 4 mm) burrows were noted at the E to Bt horizon boundary in Test Unit 1 (Tables 3 and 4). These observations do not quantify the intensity of bioturbation in the soils, but they do demonstrate the presence of the type of biological activity responsible for the downward movement of clasts.

Forces countervailing the downward movement of clasts would have to preferentially move large clasts upward in relation to the soil surface. Potential agents within the study area include tree throws, the burrowing of animals larger than the clast sizes studied, and erosion of material finer than the clast sizes studied.

Tree throws have the potential to move both large and small clasts up and down the profile, and significantly alter the depth distribution of artifacts (Rapp and Hill 1998; Waters 1992). Johnson (2002) notes that tree throws may "reset" stone zone forming processes by bringing large artifacts to the surface. Trees can fall or be knocked over by wind, with soil material adhering to the root ball as it is ripped out of the ground. Subsequent weathering can wash the soil and clasts back into the pit created by the tree fall, and create a mound or ring of sediment adjacent to the pit.

Floodplain and terrace soils in the study area (primarily Cedargap gravelly loam, mapped by Dodd and Dettman 1996) support various hardwood and pine trees, with only slight potential for tree throw (termed "windthrow hazard" by Dodd and Dettman 1996), while many local slope and ridge soils have moderate to severe potential for tree throw. In some areas, surface evidence for tree throws, in the form of pits and mounds, can persist for more than 1000 years (Schaetzl and Follmer 1990). Both recent and relict tree throws (in the form of pit and mound topography) were observed on area slopes and ridges. No such features were visible at the Havens site or noted at any site used in this study.

Even if tree throws were common at the sites studied, however, they do not have the overall effect of preferentially moving artifacts upward in the profile through time. Clay to boulder sized material may be displaced through tree throws, and moved either upward (re-deposited on the soil surface), or downward (washed into the pit). The long-term effect of tree throws on a landscape is to homogenize clasts and soil material throughout the profile, not to simply move clasts upward.

Other biological agents in the area capable of moving large clasts include beavers, woodchucks, and muskrats (Sealander and Heidt 1990), although these are more commonly found along higher-order, seasonally wet streams. Various mice, moles, squirrels, and other small burrowing mam-

mals occur in the area (Sealander and Heidt 1990) and may be capable of moving clasts one inch or larger in diameter. Red fox occur through the Ozark highlands as well, and construct comparatively large burrows (six to nine meters long, commonly more than one meter deep [Sealander and Heidt 1990]), which could easily move large clasts throughout the profile. No active burrows or large krotovina were present in test units at Havens site, however, and none were reported from the other sites used in this study. As with tree throws, also, the long-term effect of burrowing on clasts smaller in diameter than the burrows is to homogenize them throughout the profile (Johnson 2002; Pierce 1992), not to simply move them upward.

Mature biomantles are formed by the downward movement of large clasts in relation to the soil surface through time, so any processes that alter the absolute soil surface elevation through time can impede biomantle formation. In the study area, sheetwash erosion of fine clasts and particles has the potential to impede biomantle formation, by steadily lowering the absolute elevation of the soil surface. If such erosion kept even pace with the downward movement of clasts through bioturbation, a "middle stage" biomantle (as postulated in Figure 10) would be the result. A slight increase in clasts near the top of Test Unit 1 at Havens site (Figure 5) suggests the possibility of some erosion of fine-grained sediments, but long-term or "fast paced" erosion is not indicated by the soils, and Test Unit 2 at Havens (Figure 6) shows no increase at all in pebbles near the top. Strongly developed argillic horizons in both units, overlain by well-developed A and E horizons, indicate that the landform has been relatively stable for a long period of time.

Because these potential forces countervailing the downward movement of clasts seem unlikely, it appears that the reason for an immaturely developed biomantle in this area, given more than 10,000 years, is that bioturbation is less intense than in areas with more quickly forming biomantles. Fewer bioturbation agents per unit of soil, or simply less active agents, would account for this. Such slower rates of bioturbation may not apply to the Ozark uplands as a whole, but may be specific to sediments underlying low-order streams terraces. A detailed comparison of the biomass and activity of soil flora and fauna in this area to that of areas with higher reported rates of biomantle formation may answer this question.

Conclusions

A common question geoarchaeological studies address is the potential for buried and preserved sites across a landscape. Perhaps the most important contribution of this study is the documentation of preserved and shallowly

buried archaeological sites in low-order stream valleys where few were previously thought to exist. These sites likely represent land use practices quite different from those in the large order stream valleys, and an understanding of them is essential for an understanding of regional prehistory.

Ferring (1986) notes that high rates of sedimentation aid in preservation of the archaeological record in two ways: by quickly covering sites, better preserving artifacts and their spatial patterning, and by better separating cultural remains of differing time periods vertically, minimizing the mixing of time periods and allowing for a more detailed stratigraphic record. As Van Nest (1997) has noted, however, the accumulation of sediments on top of archaeological deposits is not necessary for sites to be buried and preserved in good stratigraphic context. The processes of bioturbation alone may bury archaeological material, and if different occupation components of a site are separated by enough time, they may be separated vertically in the soil profile by these processes also. Even the earliest artifact assemblages in this area, however, do not appear to have been moved completely down the soil profile. Bioturbation processes along low order streams in these uplands, then, are not intense enough to completely bury even Late Pleistocene sites in this manner, nor will archaeological sites be separated stratigraphically through these processes as they may be elsewhere.

The reason for immaturely developed biomantles at most of the sites studied here is unclear. Of the possibilities presented (fewer or less active bioturbation agents or countervailing forces), the former seems more likely. A detailed comparison of soil flora and fauna between regions with different rates of artifact displacement may be able to answer this question. Further investigations in this area would also benefit by including depth distribution curves of natural clasts as well as artifactual material from excavated sediment.

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