Integrating Geochemistry and Micromorphology to Interpret Feature Use at Dust Cave, a Paleo-Indian Through Middle-Archaic Site in Northwest Alabama

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The authors develop an integrated method using geochemistry and micromorphology to examine the use of archaeological features at Dust Cave, a Paleo-Indian through Middle Archaic (10,650–3600 cal. B.C.) site in northwest Alabama. Samples analyzed using ICP-AES for aluminum (Al), barium (Ba), calcium (Ca), iron (Fe), potassium (K), magnesium (Mg), manganese (Mn), sodium (Na), phosphorous (P), strontium (Sr), sulfur (S), and zinc (Zn) <zaq;1>and suggest that cultural features differ chemically from geogenic sediments in several ways: (a) K-means cluster analyses indicate that features of known origin and suspected features of the same origin cluster together, thereby allowing for a preliminary separation into discrete functionalities; (b) phosphorus serves as an indicator of human occupation intensity; and (c) Sr/Ca and K/P ratios help identify anthropogenic materials. Micromorphological observations allow for a finer subdivision of feature types and help highlight postdepositional processes affecting cave sediments, and interpretation of activity at the site. These findings show that feature diversity and occupation intensity increased through time, peaking during the Middle Archaic. © 2006 Wiley Periodicals, Inc.

INTRODUCTION

We describe the use of integrated geochemical and micromorphological techniques to investigate archaeological features at Dust Cave, a Paleo-Indian through Middle Archaic (10,650–3600 cal. B.C.) site in northwest Alabama. Our ultimate goal is to elucidate how Dust Cave functioned within the hunter–gatherer landscape of the Middle Tennessee Valley. Hunter–gatherers have made use of caves and rockshelters for thousands of years, but the nature of the activities that took place in them is poorly understood (Anderson, 1994; Walthall, 1998). Many questions remain to be answered, such as what activities occurred in caves, and how intensively peo-

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ple occupied them. Cave and rockshelters' features represent the byproducts of myriad activities, such as food preparation and refuse disposal and burial; the study of them is a viable means of reconstructing such activities.

Feature function has received relatively little attention in traditional North American archaeological research, largely because poor feature preservation often makes such a goal exceedingly difficult, if not impossible. As a result, no precedent has been set for how to study such archaeological remains. Sherwood (2001) argues that the term "feature" is in and of itself an artifact, produced when archaeologists conceptualize the archaeological record as a series of artifacts and special intrusions into a sediment or soil "matrix." We can overcome this shortcoming by recognizing that features are fundamentally deposits (Stein, 1987); as such, they must be described and studied as sediments. This is not to suggest that archaeologists stop excavating features separately from the surrounding matrix, but as deposits, we should record and describe them within the same paradigm and using the same nomenclature as we would record and describe any sedimentologic unit (Stein, 1987). Recent research on feature function at archaeological sites has begun to move in this direction by employing geologic techniques including micromorphology (e.g., Courty et al., 1989; Goldberg, 2000; Schuldenrein, 2001; Sherwood, 2001) and geochemistry (e.g., Manzanilla and Barba, 1990; Schuldenrein, 1995; Middleton and Price, 1996; Homsey, 2003). This research integrates both of these techniques with more traditional morphological and content analysis.

METHODOLOGICAL FRAMEWORK FOR THE STUDY OF FEATURES

To study features as deposits, we must begin by thinking of them in terms of their depositional history. This history consists of four aspects: (a) sediment source, (b) transport agent, (c) environment of deposition, and (d) postdepositional activity (Stein, 1987). Studying features in terms of their depositional history promises to be a productive means by which archaeologists can better understand the formation, function, and diagenesis of complex anthropogenic deposits. By thinking of features as deposits, we avoid subjective interpretations of features based on presumed correlations between feature shape, content, and function. This is especially important because features can undergo a great deal of postdepositional alteration. If these changes are not taken into consideration, gross misinterpretations of function and site use may occur. More often than not, such processes can only be detected at a very fine scale, one at which macroscopic observations are useless. To study deposits at this small a scale, microscopic methods must be employed; micromorphology and chemical analysis are well suited to this kind of study (e.g., Eidt, 1985; Courty et al., 1989; Gé et al., 1993; Mathews et al., 1997; Hertz and Garrison, 1998; Macphail and Cruise, 2001).

Micromorphology

Micromorphology is the study of *in situ* soils and sediments. Thin sections are created from undisturbed samples in which the original components and their associated relationships can be observed microscopically (Courty et al., 1989). Micromorphological analysis allows for the observation of composition, texture, and fabric, all of which are vital to reconstructing depositional histories. Even within individual thin sections, microsedimentary structures may reflect small-scale changes in depositional and postdepositional processes (Courty et al., 1989).

Using micromorphology to generate information on human activity has been successfully applied in a number of contexts. It has helped archaeologists to understand the construction of earthworks, house floors, and stables (Gebhardt, 1992; Matthews, 1995; Macphail and Goldberg, 1995; Gebhardt and Lanhogr, 1999; Macphail et al., 2003); identify and interpret the nature of agricultural soils and the impact of farming and deforestation on them (Macphail et al., 1987; Courty et al., 1989; Gebhardt, 1992; French and Whitelaw, 1999); and determine the depositional histories of complex archaeological sites, such as caves and rockshelters (Goldberg 1979a, 1979b, 2000; Goldberg and Bar-Yosef, 1998; Goldberg and Arpin, 2000; Schuldenrein, 2001; Sherwood, 2001). Micromorphological studies have also allowed for a more refined analysis of burned deposits, including their form, function, and diagenesis (Courty et al., 1989; Schiegl et al., 1996 ; Goldberg and Bar-Yosef, 1998; Karkansas et al., 2000; Sherwood, 2001; Homsey, 2004).

Specific questions that are addressed in this study include: (a) Is the sediment source anthropogenic or geogenic? It has been argued that some of the “features” at Dust Cave are not anthropogenic at all, but rather geogenic in source, transport, and deposition; (b) By what agent are feature sediments transported? Are they transported by people (e.g., through dumping or sweeping), or by a natural agent (e.g., by flowing water)? (c) What is the environment of deposition for feature sediments? Are they created *in situ* (e.g., through burning), or are they redeposited (e.g., through discard)? If they are burned, at what temperature did they burn, and what was the fuel source used? (d) What postdepositional processes have acted on feature sediments which may have obscured the original sedimentary structure and morphology of the deposit? Postdepositional processes include natural processes such as bioturbation, fluvial activity, and decalcification, as well as cultural processes, such as trampling.

Chemical Analysis

Chemical analysis of soils and sediments has become an increasingly useful tool for archaeological research (Cook and Heizer, 1965; Eidt, 1973, 1985; Manzanilla and Barba, 1990; Schuldenrein, 1995; Middleton and Price, 1996). This is because human activities— including food preparation, burning, and waste disposal—chemically enrich soils and sediments in elements such as phosphorous (P), carbon (C), nitrogen (N), potassium (K), and calcium (Ca). This process is facilitated by decomposition of plant residues, animal bones, and human and animal excrement. Some of these elements (e.g., C and N) are mobile and are lost by both organic and inorganic processes. For example, both form gases (e.g., carbon dioxide; CO_2) and water-soluble compounds that can enter the atmosphere or be carried away in groundwater. Other elements, such as P, tend to remain in the soil system even over long time intervals by becoming adsorbed onto the colloidal fraction of soil particles, fixed into the lattice structures of clay minerals, or by forming water-insoluble compounds, such as Ca and iron (Fe) phosphates (Hertz and Garrison, 1998). The most common applications of chemical analysis focus on: (a) pre-excavation prospecting to locate and delimit archaeological sites; (b) identifying areas of concentrated activity for full-scale excavation; and (c) delineation of features and activity areas (Cook and Heizer, 1965; Lippi, 1988; Manzanilla and Barba, 1990; Schuldenrein, 1995; Sánchez and Cañabate, 1999; Wells et al., 2000; Parnell et al., 2001). Recently, researchers have successfully expanded this research to study not just open-air sites, but caves and rockshelters as well (Schiegl et al., 1996; Farrand, 2000; Karkansas et al., 2000; Schuldenrein, 2001; Braillard et al., 2004).

Researchers have found that different elements correlate with different activities and materials: K with *in situ* burning and residual wood ash (Schuldenrein 1995; Middleton and Price, 1996); P with food processing and animal remains (Schuldenrein, 1995); Ca with butchering and animal remains (Schuldenrein, 1995); strontium (Sr) with diets rich in plants, fish, and nuts (Rosenthal, 1981; Pearsall, 2000); and zinc (Zn) with nuts (Pearsall, 2000). The present research builds on these multi-element investigations. Our objectives are to: (a) identify which elements characterize the cultural sediments at Dust Cave, a Late Paleo-Indian through Middle Archaic (10,650–3600 cal. B.C.) archaeological site in northwest Alabama and (b) develop a technique for the identification and interpretation of archaeological features.

STUDY AREA

Geologic Setting

Dust Cave lies in the western portion of the Middle Tennessee River Valley, in northwest Alabama (Figure 1) (Driskell, 1996). The general stratigraphy of the region consists of the Upper Mississippian Fort Payne, Tuscumbia, Pride Mountain, and Hartselle Formations (Thomas, 1972) (Figure 2). The Fort Payne Formation, which forms the base of the local sequence at Dust Cave, is composed of finely crystalline to microcrystalline siliceous limestone containing irregular nodules of dark blue-gray chert (Raymond et al., 1988). The blue-gray variety of this chert comprises over 90% of the stone tool assemblage at Dust Cave (Johnson and Meeks, 1994). Overlying the Fort Payne Formation is the Tuscumbia Limestone, a generally thick-bedded fossiliferous limestone that forms an undulating karstic plateau on both sides of the Tennessee River (Raymond et al., 1988). Regionally, it is overlain by the Pride Formation and the Hartselle Sandstone, though neither is present at the Dust Cave locale.

Numerous limestone caverns, including Dust Cave, developed within the Tuscumbia Limestone, though only a few contain archaeological deposits (Collins et al., 1994). The cave's morphology results from dissolution of rectilinear joints (Goldman-Finn and Driskell, 1994). This development has produced a ~30-m-long composite profile from the entrance to the rear of cave (Goldberg and Sherwood, 1994) (Figure 3). Today, Dust Cave adjoins Coffee Slough, a paleo-tributary of the Tennessee River (Sherwood, 2001).

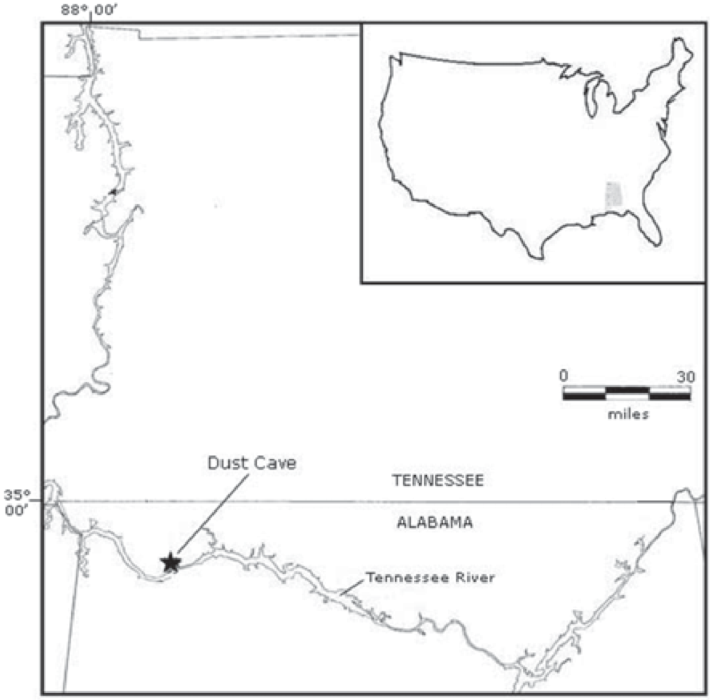

Figure 1. Location of Dust Cave in northwestern Alabama along the Tennessee River.

Three main sediment sources have been identified at Dust Cave: (a) colluvium from the talus slope in front of the cave, (b) Tennessee River alluvium, and (c) anthropogenic sediments (Goldberg and Sherwood, 1994). The upper 4 m of deposits are primarily colluvial sediments originating from the plateau soils above the cave. The lowest meter of archaeological deposits, lying directly above bedrock, are formed primarily in Tennessee River alluvium deposited during flood events. Sand- and silt-sized quartz dominates these sediments, though silt-sized grains of weathered muscovite, feldspar, and pyroxene are also present. These accessory minerals are considered diagnostic of Tennessee River alluvium (Collins et al., 1994; Goldberg and Sherwood, 1994; Sherwood, 2001). This characteristic mineralogy results from the periglacial weathering of igneous and metamorphic rocks comprising the southern Appalachian Mountains (Braun, 1989).

Anthropogenic sediments include charcoal, ash, lithics, bone, and shell. During Dust Cave's 5000 years of occupation, the sedimentation rate averaged 75 cm/1000 years; during the last 5000 years of nonoccupation; however, the sedimentation rate dropped to a mere 10 cm/1000 years (Homsey, 2003). Anthropogenic sediments are dominated by ash and charcoal that occur as either discrete entities (i.e., features) or as lenticular deposits up to 10 cm thick that can extend across much of the cave floor. Based on the sheer volume of ash and charcoal, burning constituted a major activity at Dust Cave.

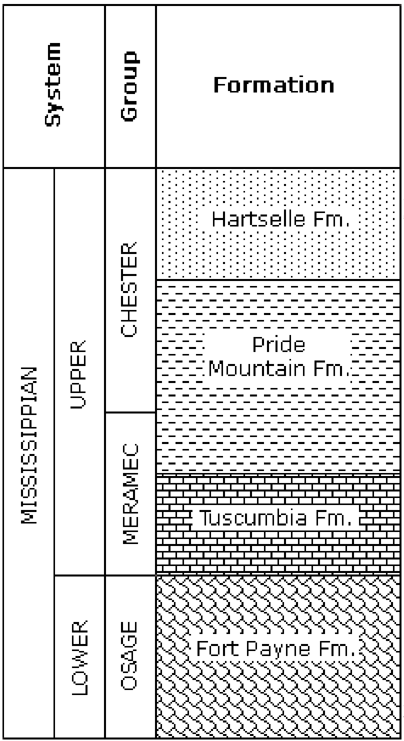

Figure 2. Generalized stratigraphy in the middle Tennessee River Valley.

Around 11,500 cal. B.C., regional springs became more active and flushed out the Pleistocene sediments choking Dust Cave, making it habitable for both people and animals (Sherwood et al., 2004). The lowest reaches of the cave contain remnants of these Pleistocene deposits, which include the partially fossilized remains of extinct fauna, including dire wolf (*Canis dirus*) and giant beaver (*Castoroides*) (Sherwood et al., 2004). At the time Dust Cave was first occupied, approximately 10,650 cal. B.C., it would have been located within a mile of the Tennessee River's main channel (Collins et al., 1994), making the cave an ideal location at which to collect mussels, fish, and waterfowl. Moreover, the cave's position within the bluffline offered access to both lowland and upland ecologic zones—an extremely favorable setting for early hunter–gatherer populations (Goldman-Finn, 1994).

Cultural Setting

Over 100 m^2 of cave floor and nearly 5 m of archaeological deposits are exposed within the entrance chamber (Driskell, 1996) (Figures 3 and 4). Five cultural components have been documented at Dust Cave (Goldman-Finn and Driskell, 1994). The earliest occupation dates to the Paleo-Indian period, from ~10,650 to 9200 cal. B.C.

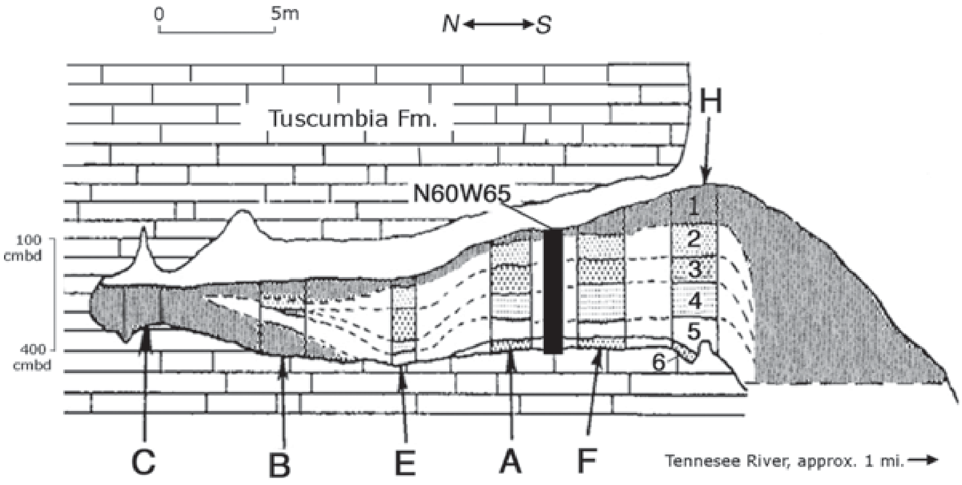

Figure 3. Schematic of Dust Cave cross-section showing original test units (A, B, C, E, F, H), column used in this study (unit N60W65), and cultural stratigraphy (1 = nonartifact-bearing deposits, 2 = Benton, 3 = Eva/Morrow Mountain, 4 = Kirk Stemmed, 5 = Early Side-Notched, 6 = Paleo-Indian). From "Stratified Late Pleistocene and Early Holocene Deposits at Dust Cave, Northwestern Alabama" by B.N. Driskell, 1996, in D.G. Anderson & K.E. Sassaman (Eds.), *The Paleoindian and Early Archaic Southeast* (pp. 315–330<zaq;12>). Tuscaloosa, AL: University of Alabama Press. Copyright 1996 by the University of Alabama Press. Adapted with permission.<zaq;11>

(Sherwood et al., 2004). Two Early Archaic occupations follow the Paleo-Indian: the Early Side-Notched component from 10,000 to 9000 cal. B.C., and the Kirk Stemmed component from 8200 to 5800 cal B.C. (Sherwood et al., 2004). Two Middle Archaic components overlie the Early Archaic components: the Eva/Morrow Mountain component from 6400 to 4000 cal. B.C. and the Benton component from 4500 to 3600 cal. B.C. (Sherwood et al., 2004). Well-preserved lithics, fauna, botanicals, bone tools, features, and microstratigraphy characterize all five components, making Dust Cave an ideal location at which to investigate how Paleo-Indian and Archaic cultures used caves.

Of particular interest is discerning the activities that occurred at Dust Cave. Analyses of stone tools recovered from Dust Cave suggest that a variety of activities took place here, including butchering, hide processing, and tool making (Walker et al., 2001). Botanical remains attest to the large concentrations of hickory nuts (*Carya* sp.); it has been suggested that perhaps the prehistoric populations occupying Dust Cave came here to collect and process hickory nuts (Hollenbach, 2003). Faunal remains indicate a subsistence economy focused on fish, waterfowl, and small mammals, supplemented by white-tailed deer (Walker, 1998). Food preparation of several types must have occurred, but just where within the site it occurred remains unknown. The answers to these questions are undoubtedly reflected in the various feature types at the cave. It is, therefore, imperative that Dust Cave's myriad features be examined to determine what kinds of activities they represent.

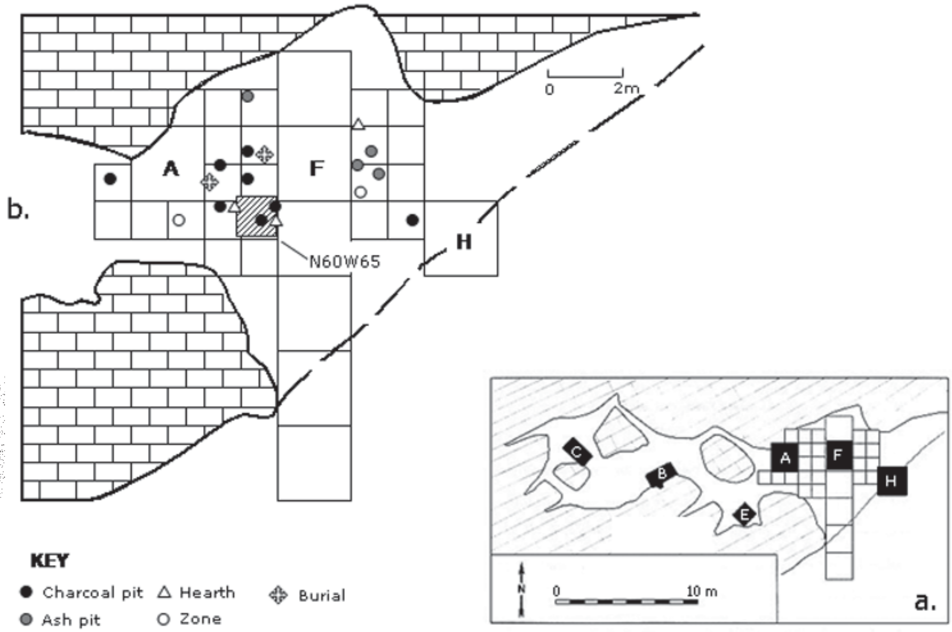

Figure 4. (a) Dust Cave plan view showing recent excavation units and original test units (A, B, C, E, F, and H). From "The Geoarchaeology of Dust Cave: A Late Paleoindian Through Middle Archaic Site in the Western Middle Tennessee River Valley" by S.C. Sherwood, 2001, unpublished doctoral dissertation<zaq;12>, University of Tennessee, Knoxville, TN. Adapted with permission.<zaq;11>. (b) Close-up of Dust Cave entrance chamber with location of features sampled in this study.

METHODS

Field Strategies

Archaeological staff at Dust Cave collected samples for chemical analysis from three broad categories: (a) anthropogenic features, (b) general "zone" matrix, and (c) sterile geogenic deposits. Feature samples (Table I) were taken from contexts of both known origin (e.g., burial and hearth) and unknown origin (e.g., unidentified charcoal and/or ash pits). Samples were selected using a nonprobabilistic point-sampling strategy (i.e., associated with identified features) designed to answer the question, "Are similar looking features genetically related?" and its corollary, "Do features that look different differ geochemically?" Three-point provenience was recorded for each sample; the location of each sample is shown in Figure 4, and sample depths are recorded in Table I.

Zone samples represent microstratigraphic units and consist of a mixture of geogenic and anthropogenic (e.g., charcoal, ash) sediments. To investigate occupation intensity through time, samples were selected from different zones in a column of sediment (unit N60W65) representing all five components (Table II). N60W65 (Figures 3 and 4) lies in the west-central portion of the entrance chamber, approxi-

Table I. Cultural geochemical samples.

Sample	Description	Depth (cmbd)
Feature 117	Known hearth	415
Feature 423	Possible hearth	410
Feature 120	Known burial	160
Zone P8a	Possible burial	345
Feature 301	Charcoal lens	280
Zone P14	Charcoal lens	345
Feature 354	Charcoal pit	335
Feature 405	Charcoal pit containing fish bones	385
Feature 410	Charcoal pit containing gastropod shell	385
Feature 420	Charcoal pit, associated with feature 423	405
Feature 429	Charcoal pit, associated with feature 117	415
Feature 438	Possible charcoal pit	440
Feature 440	Ash pit associated with prepared surface	300
Feature 443	Ash pit associated with prepared surface	315
Feature 445	Ash pit associated with prepared surface	305
Feature 341	Stratified charcoal/ash pit	295
Zone K7	Known dumping episode	275
Zone J1	Known dumping episode	210
Zone P3	Possible dumping episode	300
Zone P3g	Unknown “distinct activity”	320
Feature 450/Zone P18	Unknown, possible trampled	330
Feature 342	Clay pit (possible feature)	295

Table II. Samples from column N60W65 and their cultural affiliation and depth.

Stratigraphic zone	Depth (cmbd)	Cultural affiliation	cal. B.C.
A2	100	Sterile	< 3,600
D4	155	Benton	4,500–3,600
E4	190	Eva/Morrow Mt.	6,400–4,000
J1	210	Eva/Morrow Mt.	6,400–4,000
K7	270	Eva/Morrow Mt.	6,400–4,000
P3	300	Kirk Stemmed	8,200– 5,800
R3	400	Early Side Notched	10,000–9,000
U8	440	Paleo-Indian	10,650–9,200
Y3	460	Sterile	Late Pleistocene

Note. Cmbd, centimeters below datum.

mately 6 m behind the dripline and is one of the most highly utilized areas of the cave throughout the cultural sequence (Homsey, 2004).

Finally, we collected control samples from sterile deposits to establish a chemical frame of reference for natural, unmodified sediments (Table III). We also tested Tuscumbia Limestone, modern hickory nuts (*Carya* sp.), and burned periwinkle shell (*Pleurocera* sp.) with the goal of identifying the elements that each may introduce to the cave’s geochemical system.

Table III. Sterile geochemical samples.

Sample name	Description	Depth (cmbd)
Lmst	Mississippian-age limestone, Tuscumbia Fm.	
Y3	Sterile Pleistocene alluvium in joint in cave floor	460
T.U. G 80	Sterile colluvium from talus slope outside cave	80
T.U. G 350	Sterile colluvium from talus slope outside cave	350
A2	Sterile colluvium inside cave	100
Bt	Bt horizon from soils above cave system	60
Allv	Modern Tennessee River alluvium, Florence, AL	
B.Allv	Pleistocene alluvium from Basket Cave	350
B.Clay	Modern clay residue from solution dome in Basket Cave	
Hickory nutmeat	Modern, unburned hickory nutmeat from Florence, AL	
Hickory nutshell	Modern, unburned hickory nutshell from Florence, AL	
Pwink	Burned periwinkle shell from zones K7 and J1 at Dust Cave	

Note. Cmbd, centimeters below datum.

Samples of approximately 100 g were collected from a freshly cleaned surface using a water-cleaned trowel, placed in plastic bags, and given an identification number. Information recorded for each sample includes three-point provenience, field texture, and Munsell color. Samples were air-dried at room temperature for 2–4 weeks.

Chemical Analysis

All samples were prepared at the University of Pittsburgh's geochemistry laboratories based on a method adapted from Middleton and Price (1996) and Stewart et al. (2001). Dried samples were gently crushed using a wooden rolling pin and sieved through a 2-mm mesh screen. Particularly compact samples were crushed using a Diamonite® <zaq;2>mortar and pestle. Tuscumbia Limestone and hickory nuts were crushed in a Spex Mixer Mill<zaq;2>. Approximately 2 g of each sample were sequentially leached in: (a) ammonium acetate (NH_4OHAc, buffered to pH 8.2) to extract the exchangeable fraction, and (b) 2N hydrochloric acid (HCl) to extract the mineral fraction from shell carbonate and bone phosphate (Stewart et al., 2001). Concentrations of aluminum (Al), barium (Ba), Ca, Fe, K, Magnesium (Mg), manganese (Mn), sodium (Na), P, sulfur (S), Sr, and Zn were determined using an axial Spectro-Flame Modula EOP inductively coupled plasma atomic emission spectrometer (ICP-AES<zaq;2>). QA/QC protocol followed EPA Method 6010 for ICP analysis of inorganic species<zaq;3>.

Micromorphological Analysis

Micromorphological samples from both features and zones were collected in the field as intact, fist-sized blocks. Prior to their removal, they were examined in the field for provenience, structure, and association with other zones and features. Once removed, the blocks were oriented, wrapped, and labeled.

After oven-drying, samples were impregnated under low vacuum with polyester resin and methylethyl ketone peroxide (a hardening catalyst). Blocks were then slabbed using a rock saw, mounted on 2" × 3" glass slides, and ground down to approximately 30 microns. Thin sections were examined stereoscopically (2 to 4×) and petrographically (4 to 40×) under plane- (PPL) and cross- (XPL) polarized light. Thin sections were analyzed in terms of their coarse and fine fraction, microstructure, void space, pedofeatures, mineral composition, and microartifacts (i.e., charcoal, ash, bone, shell, lithics, and fire-cracked rock). Several significant culturally created sediment signatures—including fire-cracked rock, burned sediment, and trampled sediments—were evaluated based on actualistic studies conducted at Dust Cave between 1996 and 2002 (Homsey, 2004). Thin-section descriptions follow Bullock et al. (1985) and Courty et al. (1989).

RESULTS

Ammonium-Acetate Leach

A two-tailed Student's *t* test of the ammonium acetate leachates indicate that cultural sediments are significantly enriched in Ba, Ca, P, and Sr at the 99.9% confidence level ($p < 0.001$) relative to sterile sediments (Table IV). Initially, P did not differ significantly ($t = 2.44$, $p = 0.220$); however, this result appears to be due to one sample high in P—the "sterile" colluvium (sample A2). The high P values in A2 most likely result from modern enrichment by organic matter, which can be observed in exposed sediments. If the A2 sample is considered anomalous and eliminated from the dataset, P is also significantly enriched ($t = 2.05$, $p < 0.001$).

Hydrochloric Acid Leach

A two-tailed Student's *t* test of the 2N hydrochloric leachates indicates that cultural sediments are significantly enriched in Ba, K, Mn, Sr, and Zn at the 99.9% confidence level ($p < 0.001$) when compared to sterile sediments (Table IV). Cultural sediments are also enriched in Ca and Mg relative to all geogenic samples except the carbonate-rich Tuscumbia Limestone and Pleistocene alluvium. Cultural sediments are not enriched in P relative to all sterile samples, but this appears to be because of the high P content of the basal Pleistocene alluvium sample (sample Y3, 4758 ppm). While Pleistocene alluvium does not contain artifacts, it does contain the remains of several extinct Pleistocene fauna, including dire wolf (*Canis dirus*) and giant beaver (*Castoroides*); mineralization of these bones (and/or paleofeces) could account for the high phosphate values. Alternatively, P may be mobilized from upper units and reprecipitated in lower units during P fixation. If Y3 is eliminated as anomalous, then cultural samples are also significantly enriched in P relative to the sterile samples at the 99.9% confidence level ($t = 2.04$, $p < 0.001$). Thus, the HCl leach serves as a more sensitive indicator of human activity; cultural sediments are significantly enriched in Ba, Ca, K, Mg, Mn, P, Sr, and Zn relative to sterile sediments.

Table IV. Results of Student's *t* test, NH_4OHAc and HCl leachates.

	NH_4OHAc		HCl	
Element	Significance	*t* value	Significance	*t* value
Ba	$p < 0.001$	2.10	$p < 0.001$	2.06
Ca	$p < 0.001$	2.21	$p < 0.001$	2.04
P	$p < 0.001$	2.05	$p < 0.001$	2.05
Sr	$p < 0.001$	2.11	$p < 0.001$	2.04
Mg	$p = 0.060$	2.57	$p < 0.001$	2.05
Zn	$p = 0.100$	2.37	$p < 0.001$	2.04
Mn	$p = 0.340$	2.77	$p < 0.001$	2.07
K	$p = 0.430$	2.57	$p < 0.001$	2.26
Al	$p = 0.700$	2.30	$p = 0.020$	2.29
Na	$p = 0.710$	2.45	$p = 0.240$	2.31
Fe	$p = 0.820$	2.36	$p = 0.630$	2.18
S	$p = 0.860$	2.50	$p = 0.760$	2.77

Anthropogenic Sources of Elements

Hickory nutmeat and nutshell proved to have the highest K values of any of the materials tested (107 mg/kg and 2061 mg/kg, respectively). Nutshell, in particular, appears to sequester K. Given that deposits enriched in ash correlate with high K values (Schuldenrein, 1995) and that nutshell contains nearly 100 times more K than other any other substance analyzed, then the burning of nutshell likely contributed most of the K to the cave sediments.

Hickory nutshell also appears to contribute Sr to Dust Cave sediments. In a study of common foods eaten by people worldwide, Rosenthal (1981) showed that foods such as red meat, poultry, vegetables, and fruit contain low levels of Sr (< 2 mg/kg); grains, legumes, and seafood contain intermediate levels (2–25 mg/kg); and nuts and spices contain the highest levels of the element (15–100 mg/kg). Nuts such as pecans (*Carya illinoensis*) contain approximately 14 mg/kg. Modern hickory nutmeat and nutshell sampled from Dust Cave yielded values of 14 mg/kg and 17 mg/kg, respectively, values consistent with the high values recorded for pecan nuts. These results lend persuasive, albeit circumstantial, evidence that hickory nuts contributed a significant amount of Sr to Dust Cave sediments.

Occupation Intensity

Plots for elemental concentrations by depth in unit N60W65 are shown in Figure 5. Interestingly, concentrations of P for all zones exceed 2500 mg/kg, a value that Schuldenrein (1995) classifies as "intense habitation." P concentrations greater than 2700 mg/kg occur at 210, 300, and 400 centimeters below datum (cmbd)***<zaq;4>***, corresponding to the late Eva/Morrow Mountain, Kirk Stemmed, and Early Side-Notched occupations, respectively.

Phosphorous enrichment generally corresponds to lithic density (Figure 5). Statistically, there is a strong positive correlation between P concentration and lithic

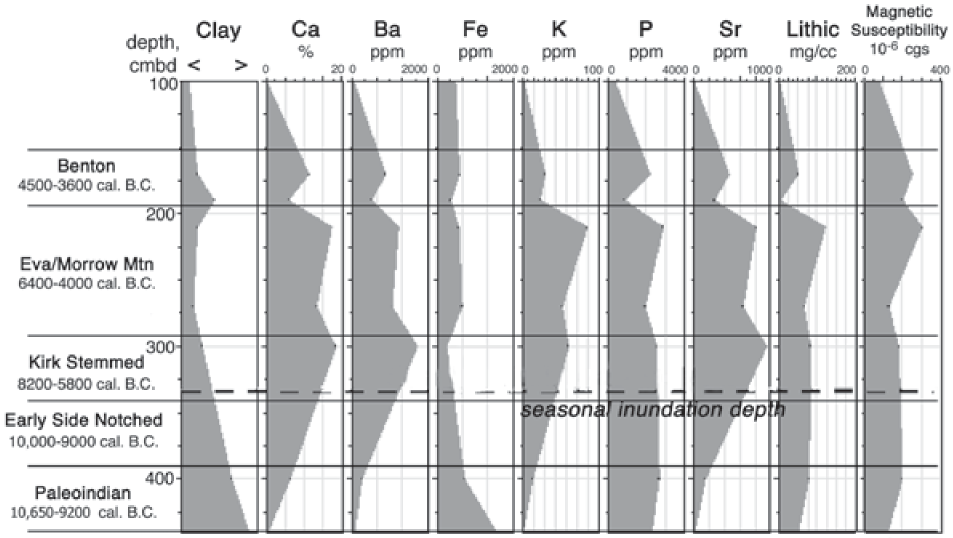

Figure 5. Elemental concentrations down core for unit N60W65. P concentrations mimic those generated by more traditional occupation proxies, including lithic density and magnetic susceptibility. K, P, and Sr concentrations mimic one another to approximately 325 cmbd, at which point K and Sr are leached out of the system due to seasonal inundation. Ca (and Ba) concentrations are leached out below 325 cmbd and above 150 cmbd, causing decalcification of cave sediments. Unlike the alkalis and P, Fe concentration peaks below the depth of seasonal inundation, suggesting mobilization and reprecipitation under variable redox conditions.

density ($r = .93, p < .05$) (Figure 6). The r^2 value is .860, meaning that 86% of the variation in lithic density can be accounted for by P concentration. Phosphorous trends also correlate strongly with magnetic-susceptibility data (Collins et al., 1994) (Figure 5). Because fire enhances the magnetic susceptibility of iron-rich sediments, it has been used as a relative indicator of burning activity (Bellomo, 1993; Tite and Mullins, 1971). As such, it serves as a proxy for human occupation at archaeological sites. Both P and magnetic susceptibility peak at 210, 300, and 400 cmbd before dropping off to sterile levels near bedrock.

Concentrations of Ca, Ba, K, and Sr follow that of P but decline markedly between 350 and 400 cmbd (Figure 5). The depth at which these four elements decrease closely corresponds to the change from colluvial to alluvial parent materials. It also corresponds to the approximate depth at which cave sediments have been seasonally flooded since impoundment of the Tennessee River during the 1930s (Goldman-Finn and Driskell, 1994). Thus, Ba, Ca, K, and Sr all appear to form water-soluble compounds that leach out at depth, thereby making them less useful indicators of occupation intensity than P.

In contrast to P and the alkali and alkaline earth elements, Fe enrichment does not correlate with intensity of occupation (Figure 5). Rather, peaks appear to cor-

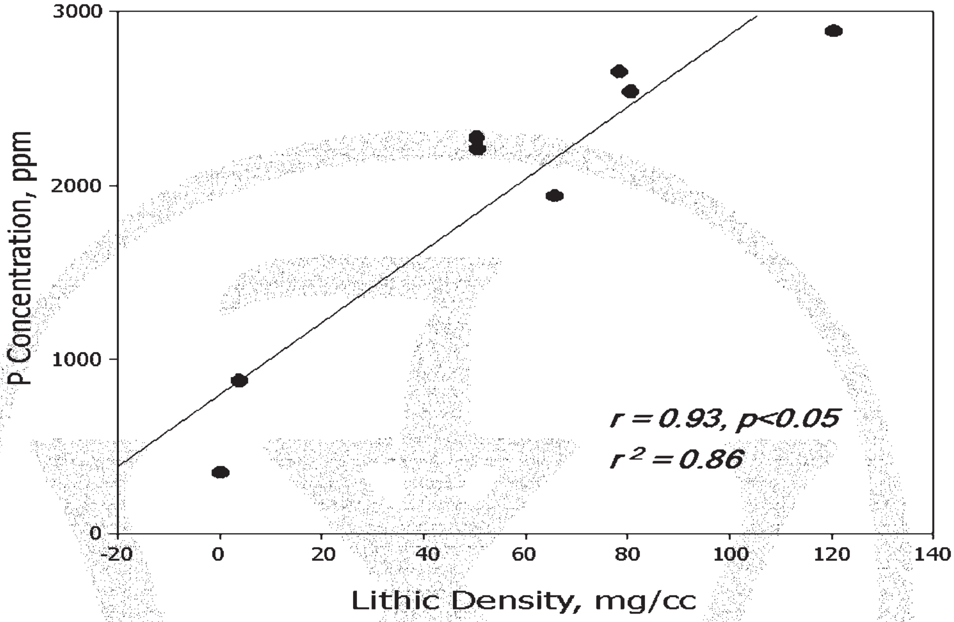

Figure 6. Linear regression showing the strong positive correlation between lithic density and P concentration.

relate with increasing clay and decreasing ash content. The greatest peak occurs around 450 cmbd, indicating mobilization and reprecipitation of Fe under variable redox conditions. Iron may also accumulate at depth via the translocation of Fe-rich clays. These results indicate that some *in situ* weathering and translocation of clay minerals have occurred at the site.

Cluster Analysis

Using SYSTAT (Version 7, SPSS, Inc., Chicago, IL), we performed a nonhierarchical, K-means cluster analysis for P, K, and Sr, all of which positively correlate with human activity. When divided into two clusters, samples clustered with their respective parent material. In other words, all the samples in alluvium clustered together, while all samples in colluvium clustered together, suggesting that features cannot be compared across parent materials.

When divided into five clusters, samples grouped intuitively according to artifact content (i.e., ash vs. charcoal) and parent material (Table V). Known and hypothesized features of the same type also tend to cluster together (e.g., known and hypothesized burial). Cluster 1 consists of the seven sterile control samples and E4, with the latter containing clay-rich pockets lacking the P-rich ash characteristic of other anthropogenic zones. Cluster 2 consists of features and zones in colluvial parent material, including the known and hypothesized burials (120 and P8/346, respectively) and the

Table V. Physical characteristics of clusters derived from K-means cluster analysis, five clusters.

Cluster	Physical characteristics	Samples	
Cluster 1	• Sterile samples	A2 Allv Bt E4	Lmst T.U. G 80 T.U. G 350
Cluster 2	• Middle Archaic, colluvium • Charcoal > ash • Known and hypothesized burial • High Sr/Ca and K/P	120 301 342 354 450/P18	D4b P3g P8a P14
Cluster 3	• Early Archaic, alluvium • Charcoal pits with burned bone or shell • Known and hypothesized hearths • Low Sr/Ca and K/P	117 405 429 423	410 Y3
Cluster 4	• Late Paleoindian/Early Archaic, colluvium • Mostly small charcoal pits • Low Sr/Ca and K/P	420 438 486	T2 U8
Cluster 5	• Middle Archaic, colluvium • Ash > charcoal • Known and hypothesized dumping • High Sr/Ca and K/P	440 443 445 341	P3 J1 K7

two charcoal-rich lenses hypothesized to have similar origins (301 and P14). Cluster 3 consists of five features in alluvium, including the known and hypothesized hearth (117 and 423, respectively), and three charcoal pits. Cluster 4 contains features and zones in alluvium, including a known and hypothesized charcoal pit (420 and 438, respectively). Cluster 5 consists of ash-rich features in colluvium, including the known and hypothesized dumping episodes (K7 and J1, and P3, respectively).

Element Ratios

Scatterplots of K/P to Sr/Ca (Figure 7) reveal two discrete groups: Group 1 consists of Paleo-Indian and early Early Archaic features (> 350 cmbd, alluvial parent material) while Group 2 consists of late Early and Middle Archaic features (< 350 cmbd, colluvial parent material) (Figure 7a). This grouping reflects the loss of Sr and K with depth, as previously discussed. As indicated by the cluster analysis, the scatterplot suggests that features cannot be compared across parent materials. The colluvial samples can be further divided into two subgroups (Figure 7b). Group 2A samples have more charcoal than ash, and Sr/Ca < 0.005 and K/P < 0.10. Examples include shallow (< 5 cm) charcoal pits and lenticular charcoal lenses (> 1 m). In contrast, group 2B features have more ash than charcoal, and Sr/Ca > 0.005 and K/P > 0.10. Examples include small ash pits and thick, ashy zones extending for several meters.

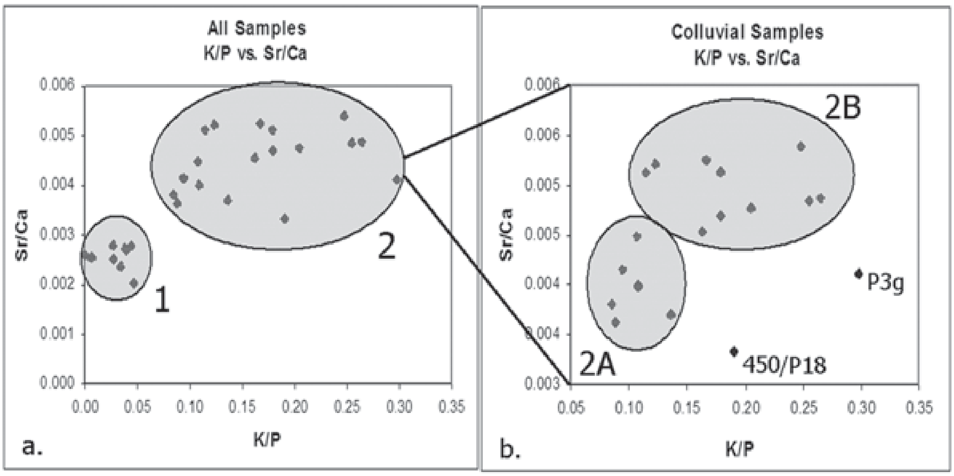

Figure 7. (a) Scatterplots of Sr/Ca versus K/P. Features originating in alluvium (cluster 1) cluster separately from features originating in colluvium (cluster 2). (b) Charcoal-rich features have low Sr/Ca and K/P ratios (cluster 2A) while ash-rich features have high Sr/Ca and K/P ratios (cluster 2B).

Micromorphology

Micromorphological analyses supplement geochemical data and provide a more holistic picture of feature function at Dust Cave. While geochemical parameters provided a tentative division of feature types, micromorphological attributes allowed refinement of feature function by further dividing the geochemical clusters from Figure 7.

Group 1

Group 1 (Figure 7a) consists of features and zones below 350 cmbd in Tennessee River alluvium and dating to the Paleo-Indian and early Early Archaic. Micromorphological observations are consistent with the geochemical data that indicate substantial decalcification at this depth; limestone, shell, and bone showed variable stages of dissolution, ranging from slightly decalcified to nearly completely dissolved (Figure 8). Because the samples in Group 1 cluster tightly together and cannot be subdivided based on geochemical parameters, micromorphological analysis allowed us to make more detailed observations concerning function and postdepositional alteration.

Both the known and suspected hearths (117 and 423, respectively) are part of Group 1. In the field, feature 117 appeared as a large (> 1 m) ashy hearth with an intensively burned outer edge (Figure 9a). Microscopic examination of the feature confirmed this visual interpretation. The periphery was highly rubified (2.5 YR3/4), desiccated, and interjected with ash (Figure 9b). The thin section also contained numerous burned bones (Figure 9c) and sand-sized fragments of fire-cracked rock (Figure 9d). Feature 423 was also more than 1 m in diameter (Figure 10a). Rocks surrounded it; hence, excavators tentatively labeled it as a hearth, but a lack

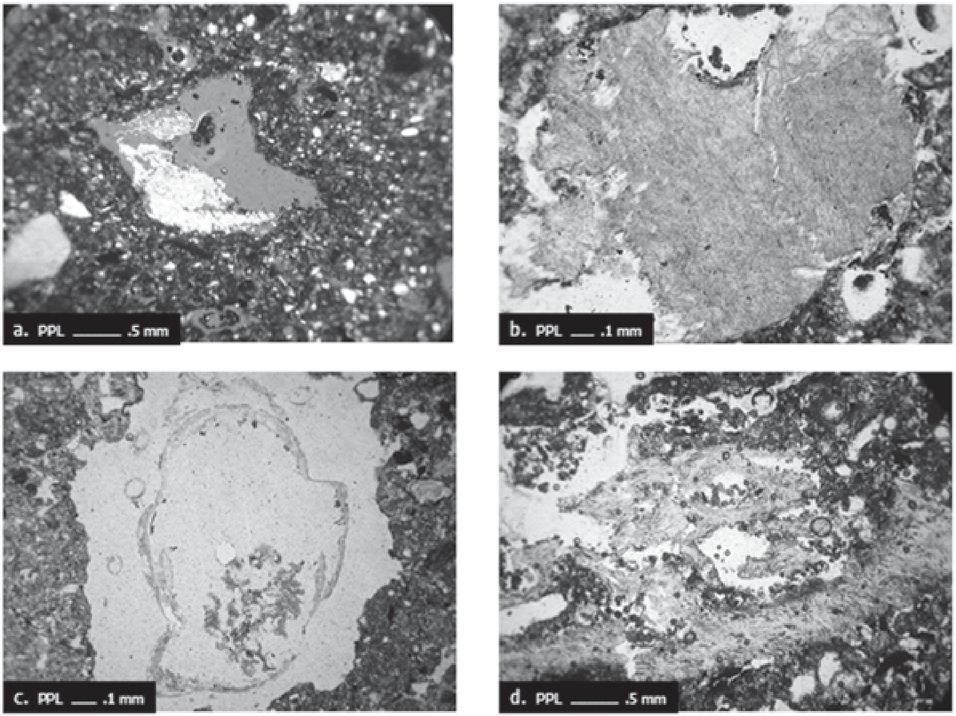

Figure 8. (a, b) Photomicrographs illustrating decalcified limestone, (c) shell, and (d) bone.

of charcoal and ash made this designation questionable. However, in thin section, graded bedding and bedded charcoal grains indicate that postdepositional fluvial activity flushed out the original ash and charcoal (Figure 10b). Interestingly, feature 423 lies in zone T2, in which Sherwood (2001) noted extensive fining-upward laminations, suggesting the importance of sheetwash over these sediments. Charcoal trapped along the underside of the rocks surrounding the feature further corroborates the hypothesis that water postdepositionally altered the morphology of this feature.

Group 1 also consists of several shallow charcoal pits and stringers. Feature 429, a charcoal pit intruding feature 117, contains dense charcoal and dispersed sand-sized fragments of fire-cracked rock, but shows no indication of being burned *in situ*. Features 405, 410, 420, and 438 look similar to 429 in that they also contain dense charcoal, little ash (< 20% of coarse fraction), and fragments of sand-sized, fire-cracked rock, and are not burned *in situ*. They differ in the microartifacts present: 405, 420, and 438 contain burned fish bones, while 410 contains burned gastropod shell.

In contrast to charcoal pits, which have discrete boundaries, charcoal stringers vary in depth and may extend for several square meters with ephemeral boundaries

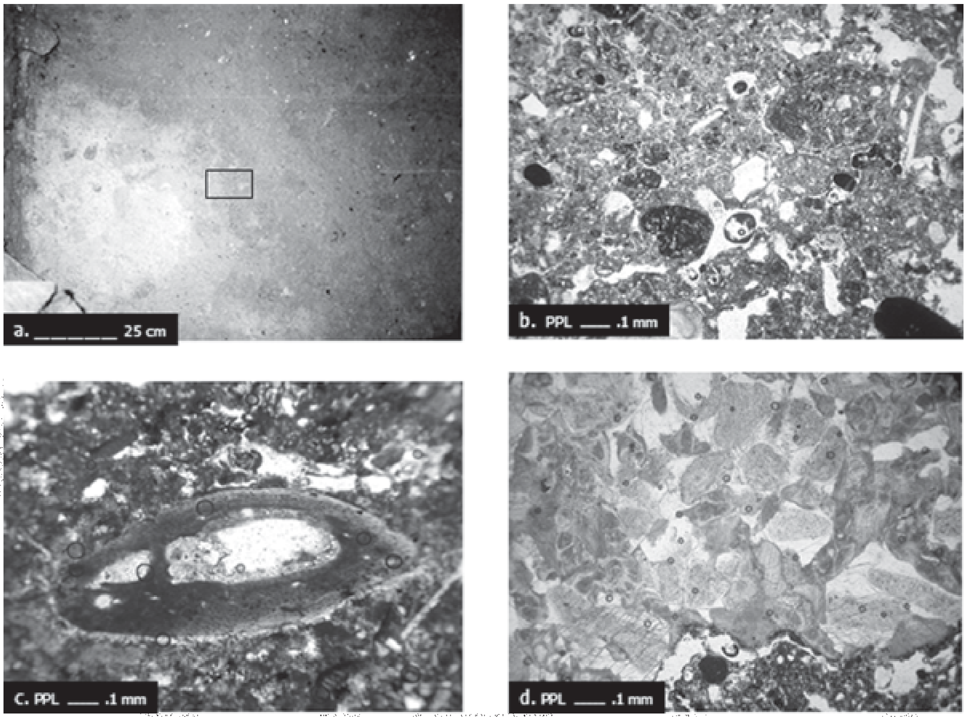

Figure 9. (a) Field image of feature 117 in plan view (rectangle shows location of micromorphology sample). (b) Photomicrographs showing interface between dense ashy feature fill and burned red clay periphery, (c) moderately burned bone, and (d) thermally altered limestone.

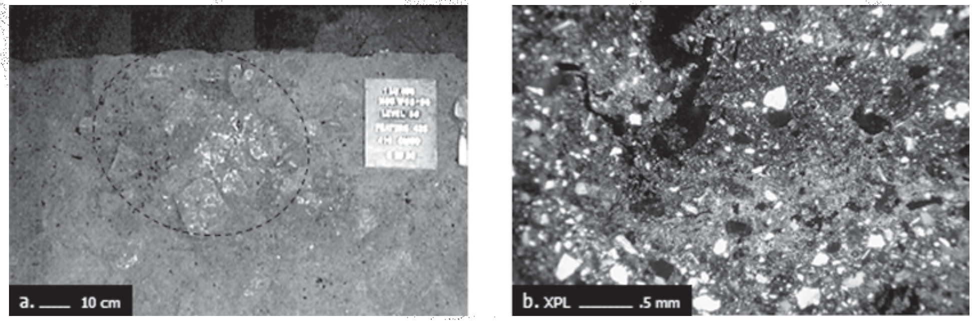

Figure 10. (a) Field image of feature 423 in plan view. (b) Photomicrograph of upward fining sediments.

that come and go (Figure 11a). They consist of bedded charcoal grains which have an undulatory appearance and which coat other grains and aggregates (Figure 11b). Bedded charcoal and erosional disconformities characterize stringers, suggesting small-scale erosional events (Figure 11b).

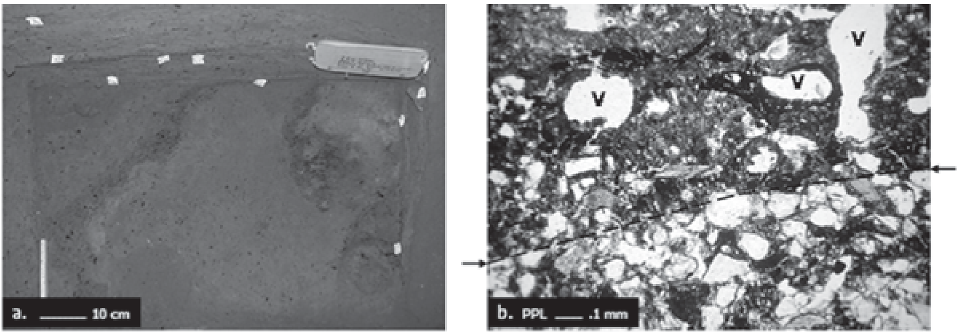

Figure 11. (a) Field image of feature 486, a charcoal stringer, in plan view. (b) Photomicrograph of charcoal-coated voids (top of image) and erosional disconformity (middle of image).

Group 2

Group 2 (Figure 7b) consists of features and zones formed in colluvial parent material and dates to the late Early and Middle Archaic. Samples in this group can be further divided into two groups: group 2A and 2B.

Group 2A

The samples in group 2A contain more charcoal than ash, with ash comprising 20 to 40% of the coarse fraction. Features 301 (Figure 12a) and P14 contain large, intact, sand-sized fragments of wood and nut charcoal. The fabric is loosely consolidated with no bedding visible, though 301 has a slight preferred orientation of charcoal grains, suggesting that they may have been redeposited by sweeping (Figure 12b). They occasionally contain burned microartifacts, but lack evidence of *in situ* burning. After charcoal, shell is the most common microartifact (Figure 12c).

Group 2B

All the features in group 2B contain more ash than charcoal, with ash comprising more than 50% of the coarse fraction. Ash may appear as individual crystals, rounded aggregates, or calcitic pseudomorphs representing the internal structure of the original plant material. Features 440 and 443—both circular ash pits with a diameter-to-depth ratio of 3.5 (Figure 13a)—contain a higher percentage of incompletely combusted plant material (Figure 13b) than the other features, suggesting that these fires burned at lower temperatures than the others did. Also plentiful are charred nutshell fragments and calcium oxalate spherulites (Figure 13c); the latter have been associated with the reproductive organs of angiosperms (e.g., nuts) (Wattez and Courty, 1987; Courty et al., 1989). Rounded ash aggregates, clasts of burned red clay, and microartifacts of all types are mixed together in a poorly sorted, porphyritic fabric (Figure 13d).

Features 341 and 445, also circular ash pits, have a diameter-to-depth ratio of about 4.5 (Figure 14a). Like the deeper pits described above, they were burned *in*

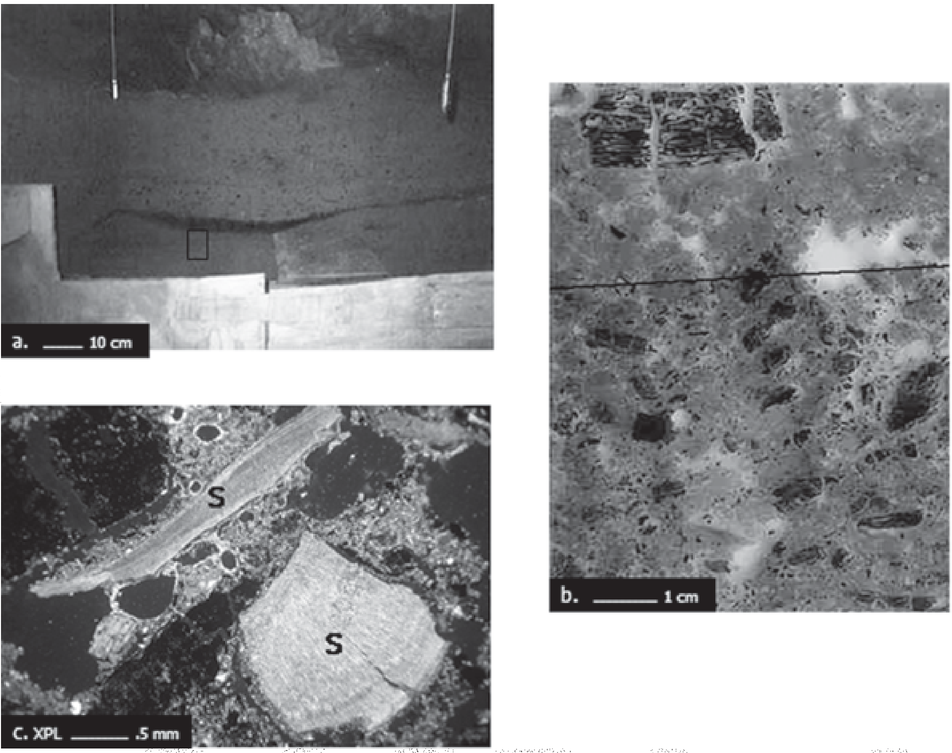

Figure 12. (a) Field image of feature 301, a lenticular charcoal pit, in cross-section. (b) Scan of thin section showing slight orientation of charcoal grains. (c) Photomicrograph of burned shell (S).

situ, but unlike them, they contain stratified layers of ash and charcoal, as well as a high percentage of calcitic pseudomorphs (Figure 14b, c). Both of these characteristics indicate minimal transport and postdepositional activity. Finally, fish bones are the dominant microartifact after ash (Figure 14d).

Zones K7, J1, and P3 are a heterogeneous mix of poorly sorted, loosely packed charcoal, rounded ash aggregates, burned microartifacts (shell, bones, charcoal), burned red clay clasts (2.5YR3/4), and fragments of fire-cracked rock embedded in a calcitic groundmass of silt-sized rhombic and spherulite ash crystals (Figure 15a). These deposits are highly bioturbated (Figure 15b) and frequently exhibit rhizomorphic features with micritic calcitic coatings. Sherwood (2001) has previously interpreted K7 and J1 to represent the byproducts of burning. P3 clusters with them geochemically, and looks similar microscopically; thus, we consider it to represent a dumping episode as well.

Outliers

Two samples occur as outliers—450/P18 and P3g (Figure 7b). 450/P18 appears to have been a large hearth that intruded multiple burned layers. Thin sections

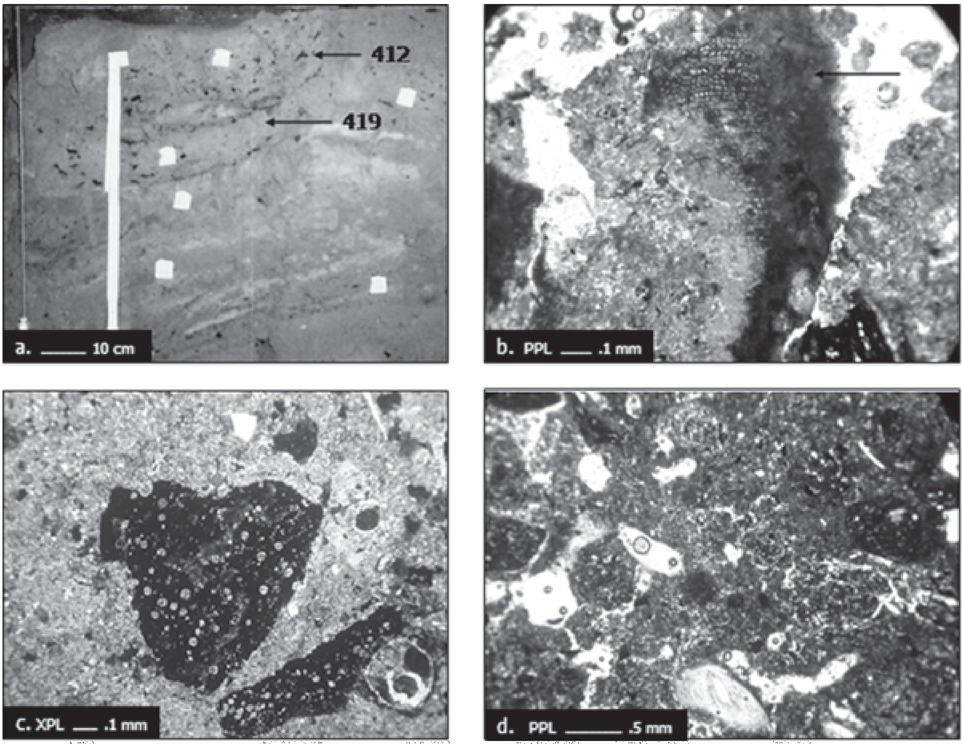

Figure 13. (a) Field image of features 412 and 419 in cross-section. (b) Photomicrographs of partially combusted organic material, (c) nutshell incompletely combusted to calcium oxalate spherulite ash crystals, and (d) poorly sorted, porphyritic fabric.

were not available for 450/P18, but in the field it resembles P7, for which samples were available. Frequent plane and channel voids, as well as an overall undulatory and compressed microstructure, give the impression that this feature experienced much post-depositional trampling (Figure 16a, b). Zone P3g has the highest K/P ratios of any of the sampled features (> 0.25) (Figure 7b). Sherwood (2001) has described P3g as a calcareous deposit containing much partially combusted plant material, a feature "distinct" from the others. Interestingly, the other features containing partially combusted material are ash pits, such as 445, 440, and 443—all of which intrude zone P3g.

Integrating Geochemical and Micromorphological Attributes into a Feature Typology

The primary goal of this research was to develop a technique for the identification and interpretation of archaeological features at Dust Cave. By integrating geo-

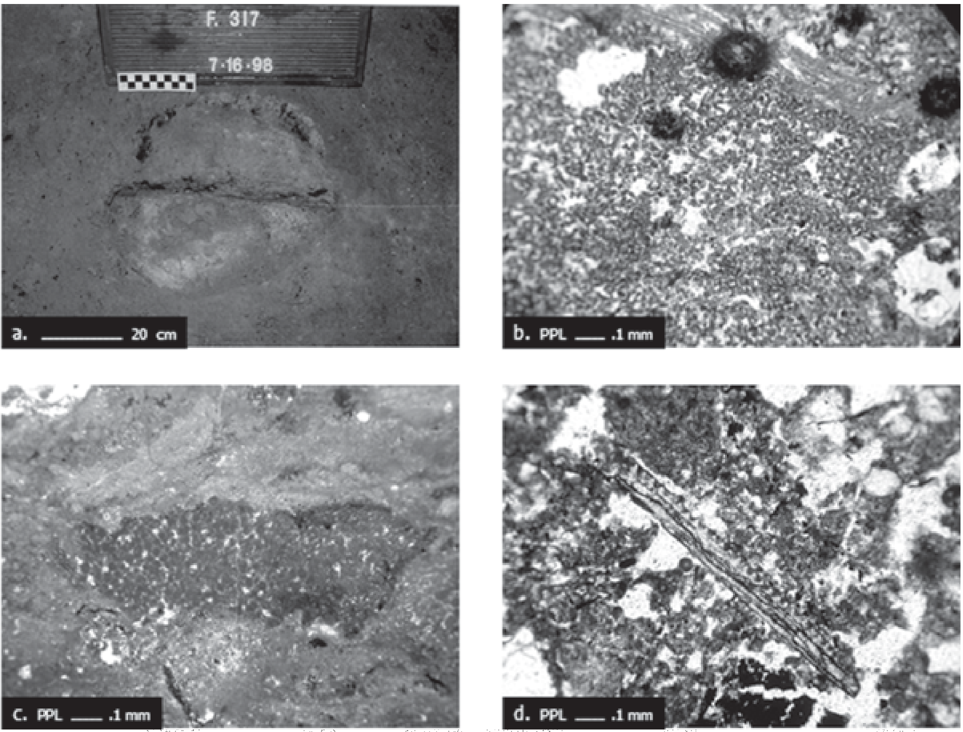

Figure 14. (a) Field image of stratified charcoal/ash pit, Feature 317 (bisected). (b) Photomicrographs of bedded ash lenses, (c) calcitic pseudomorph, and (d) lightly burned fish bone.

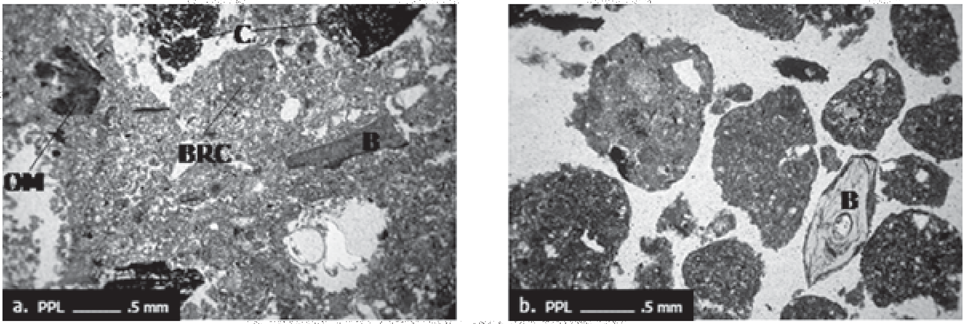

Figure 15. (a) Photomicrograph of poorly sorted porphyritic clasts of burned red clay (BRC), burned bone (B), charcoal (C), and partially combusted organic material (OM) embedded in a calcitic groundmass of silt-sized ash. (b) Photomicrograph of ellipsoid fecal pellets formed during bioturbation.

chemical and micromorphological attributes with feature size and shape, we developed a feature typology that allows for a more accurate identification of archaeological deposits while in the field. Expanding on a preliminary typology of burning

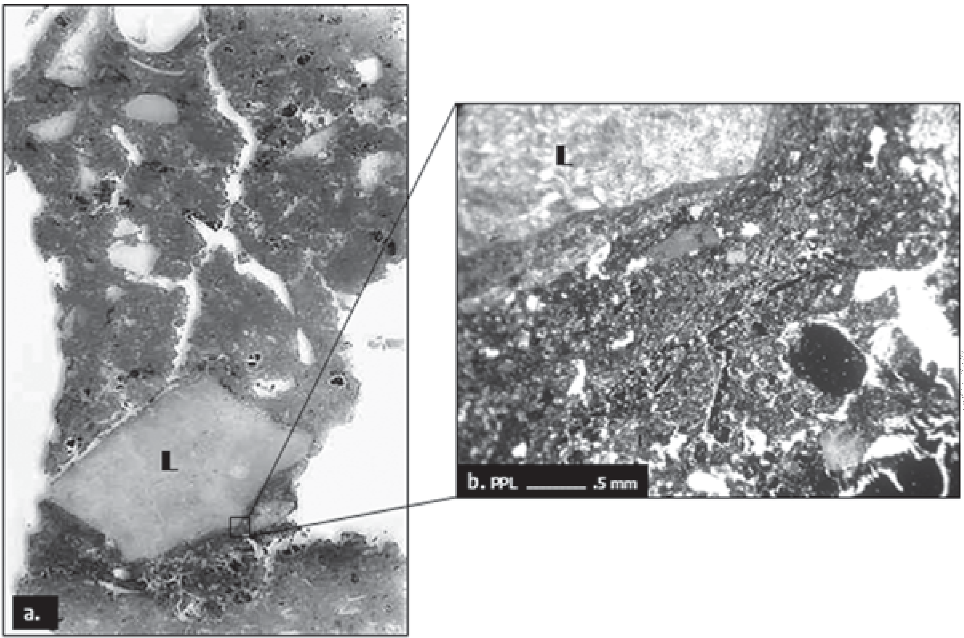

Figure 16. (a) Scan of oversized thin section (2" × 3") of zone P7 illustrating multiple burned clay layers interbedded with ashy lenses. (b) Photomicrograph showing a thermally altered limestone fragment (L) compressed into underlying fine fraction. Note splintered fragments of charcoal below limestone fragment.

deposits developed for Dust Cave (Sherwood, 2001), we identify 10 feature types, ranging from *in situ* burning to mixed burning to fireplace rake-out. Table VI summarizes the macromorphology, micromorphology, geochemistry, and possible function of each of the feature types identified.

In situ Fireplace

In situ fireplaces are features that have been burned in place, with no subsequent mixing or redeposition. They include prepared surfaces, surface hearths, expedient hearths, pit hearths, and rock basins. Prepared surfaces (Table VI, #1; samples K3c, R6b) have been previously identified and described (Sherwood, 2001; Sherwood and Chapman, 2003). They are defined as discrete, localized, red (2.5 YR, 5Y) clay deposits intentionally fired to a hard consistency. While their function is still undetermined, they are clearly culturally constructed and appear to have played a role in food processing and cooking technology (Sherwood and Chapman, 2003).

Surface hearths (Table VI, #2; samples 117, 423) are about 1 m across, about 15 cm deep, and have saucer-shaped profiles (see Figure 9a). They are characterized by large amounts of charcoal and rock. They vary in their geochemical sig-

Table VI. Typology of burning deposits at Dust Cave (prepared surfaces after Sherwood, 2001).

Burning deposit type	Macromorphology & contents	Micromorphological & chemical attributes	Possible function	Examples
In situ fireplace				
Prepared surfaces	• 1.5–3-cm thick • Sharp upper & lower boundaries • Two aspects: hard and soft	• Aggregated structure, limited void space • Packing, channel, and planar voids • Charcoal/ash articulated to upper surface	• Multipurpose	K3c R6b
Surface hearths	• ~80 cm in diameter, ~14 cm deep • Frequently rock-lined • Located centrally • Typically oval with saucer profile • Often superimposed Md. Archaic	• Red, burned periphery • Microartifacts burned, ~400–600°C • Articulated ash aggregates • Thermally altered rock • Variable chemistry	• Cooking • Light • Warmth • Social activity	117 450/P18
Pit hearths	• 40 cm diameter, ~15 cm deep • Intrude prepared surfaces • Basin-shaped profile • Mostly on east side of cave • First appear in Kirk Stemmed	• Ash > charcoal • Burned red clay clasts • Nut charcoal; spherulite ash crystals • Partially combusted organic matter • Sr/Ca > 0.005, K/P > 0.20	• Nut processing	440 443
Expedient hearths	• ~40 cm diameter, < 10 cm deep • Overlie prepared surface; saucer profile • Two aspects: charcoal rich or ash rich • May contain thermally altered rock	• Two aspects: charcoal-rich, ash-rich • Much partially combusted organic matter • Calcitic cellular pseudomorphs • Sr/Ca > 0.005, K/P > 0.20	• Grilling/smoking • Nut parching?	341 445
Rock basins	• ~80 cm diameter, ~15 cm deep • Little-to-no ash or charcoal • Basin-shaped profile • Charcoal lines underside of rocks	• Burned microartifacts, mostly bone • Thermally altered rock • Graded bedding • Variable chemistry	• Surface hearths altered postdepositionally	423

Burning deposit type	Macromorphology & contents	Micromorphological & chemical attributes	Possible function	Examples
Fireplace rake-out				
Accessories	• ~30 cm, circular basins, ~5 cm thick • Saucer-shaped profile • Contain FCR • Typically associated with hearths	• Charcoal > ash • Burned microartifacts present • FCR present as sand-gravel fragments • $Sr/Ca < 0.005$, K/P values < 0.15	• Cooking stone piles	429
Rake-out	• ~1 m lens < 5 cm thick • < 30 cm diameter pits, < 5 cm deep	• Charcoal > ash • > 20% porosity • Slight orientation of charcoal grains • $Sr/Ca < 0.005$, K/P values < 0.15	• Redeposited coals, may be swept	301
Mixed burning				
Midden	• Heterogeneous units > 10 cm thick • Ash > charcoal • Burned red clay clasts • Bioturbated	• Burned microartifacts present • Red clay, compound, & mixed clasts • Much void space; loose, chaotic fill • $Sr/Ca > 0.005$, $K/P > 0.25$	• Dumping of combusted materials	J3(b) K7 P3
Multiple-sequence burned layers	• Superimposed lenses of ash, charcoal, & prepared surfaces	• Burned red clay and compound clasts • Splintered, fragmented charcoal • Burned microartifacts	• Multipurpose	P3g 450/P18
Charcoal Stringer	• < 2 cm thick and > 1 m^2 • Predominately below 400 cmbd	• Graded bedding, elongated charcoal • Alluvial disconformities • $Sr/Ca < 0.003$, $K/P < 0.05$	• Rake-out reworked by water	T2c 381

Note. Cmbd, centimeters below datum.

nature, depending on parent material and, ostensibly, the food cooked in them (e.g., meat vs. plant). Based on the degree of burning seen in bone, and the complete combustion of organic material, these features appear to have burned at high temperatures.

Subsurface pit hearths (Table VI, #3; samples 440, 443) are deep, circular ash pits about 50 cm in diameter and 15 cm deep, with a width-to-depth ratio of 3.5 (Figure 13a). They always intrude prepared surfaces. They contain a great deal of partially combusted plant material, suggesting that these fires did not reach very high temperatures. Nutshell shows incomplete combustion and calcium oxalate spherulites, also suggesting lower burning fires. Such a fire is consistent with the expectations for parching, in which foods are slowly dried by heat (Stafford, 1991). They have exceptionally high Sr/Ca ratios (> 0.02), indicative of materials such as nuts. For these reasons, we hypothesize that pit hearths represent the byproducts of nut processing.

"Expedient hearths" (Table VI, #4; samples 341, 445) are shallow, circular ash-rich pits, about 40 cm in diameter and less than 10 cm deep (Figure 14a). They overlie prepared surfaces, but are not dug into the substrate. Calcitic pseudomorphs indicate minimal transport or disturbance. They are stratified, often with a thin lens of charcoal lining the base. Ash is also layered, with several microlenses of ash, sometimes with different fuel types visible (Figure 14b). The layering of charcoal and ash is suggestive of coals that smoldered for a long time and were eventually smothered by ashes. The preponderance of burned fish bone suggests that fish were cooked in them. Interestingly, experimental studies at Dust Cave have shown that fish can be expediently smoked in small fires built on prepared surfaces (Sherwood and Chapman, 2003; Homsey, 2004).

Rock basins (Table VI, #5; sample 423) are thought to be hearths that have been postdepositionally altered such that the combusted materials are no longer recognizable (Figure 10a). Basins occur in the lowest meter of deposits—mostly in zone T, a zone in which Sherwood (2001) noted extensive fluvial activity and small-scale erosional events. In some cases, the rocks are clearly thermally altered. Usually, the rocks surround the periphery of the deposit. In the field, they contain little, if any, charcoal or ash, but in thin section, graded bedding, bedded charcoal, and charcoal infillings of voids all point towards extensive reworking of feature fill by water. Rock-basin and surface-hearth dimensions are not significantly different, lending some support for this assertion (Homsey, 2004).

Fireplace Rake-Out

Fireplace rake-out consists of combusted materials (i.e., ash and charcoal) that have been redeposited from the original burning location (Figure 12a). Rake-out (Table VI, #7; sample 301) tends to come in the form of thin lenses of charcoal which have low Sr/Ca and K/P ratios, reflecting the dominance of charcoal versus ash. They are not burned *in situ* but do contain abundant quantities of burned microartifacts. Rake-out occurs almost exclusively in the rear of the cave, a pattern that has been documented ethnographically (Gorecki, 1991).

Associated with surface hearths are fireplace “accessory” features; these are small charcoal pits, about 30 cm in diameter and 6 cm deep (Table VI, #6; samples 429, 438, 410). They always intrude another feature (often a hearth), but show no evidence of being burned in place. Sand-sized fragments of fire-cracked rock are common; indeed, when these pits are found with larger, fire-cracked rocks, they have charcoal articulating to the underside of them. Such characteristics suggest that these features may be the remnants of piles of boiling stones, a cooking accessory known ethnographically to have been kept ready by the side of the hearth (Gorecki, 1991).

Mixed Burning

Mixed burning consists of features in which the original combusted materials are recognizable, but that have been mixed through postdepositional processes, such as bioturbation and trampling. This category consists of middens, multiple burned layers, and charcoal and/or ash stringers. Middens are not pits, but rather thick, heterogeneous ash-rich zones occurring across substantial portions of the floor of the cave in all five components (Table VI, #8; samples K7, J1, and P3). Based on detailed micromorphological observations, Sherwood (2001) previously described K7 and J1 as the byproducts of intensive burning and subsequent dumping. Geochemically, they have exceptionally high Sr and K values, indicative of wood ash, especially from hickory nut and/or fish bones. Despite being labeled and excavated as “zones,” the depositional history of these deposits clearly has an anthropogenic source, transport agent, and deposition mechanism. Because they derive from dumped combusted materials, they can be thought of as exceptionally large rake-out deposits, but because the original sedimentary structures are extensively disturbed by bioturbation, we classify them as mixed burning deposits, using the term “midden” to differentiate them from less disturbed rake-out deposits.

Middens are frequently interbedded with prepared surfaces, suggesting that rather than removing the combusted materials, a new surface was constructed over the old. This activity results in multiple burning layers (sensu***<zaq;6>*** Courty et al., 1989) (Table VI, #9; samples P3g, 450/P18). Compaction by trampling is indicated by planar and channel voids, splintered charcoal fragments, overall low porosity, and a compressed and deformed microstructure (Figure 16b). These layers occur throughout the cave, and are stacked vertically, suggesting that the same space was used repeatedly for burning at Dust Cave.

A third type of mixed burning is the charcoal stringer. In the field, excavators referred to charcoal stringers as “stains” because they appeared as thin veneers staining the underlying deposits (Table VI, #10; samples T2c, 381) (Figure 11a). Fluvial laminations of fining-upward silt and clay, bedded grains of charcoal, and erosional disconformities (Figure 11b) all indicate that stringers are postdepositionally reworked by sheetwash over these deposits. Geochemically speaking, stringers have very low Sr/Ca ($< .003$) and K/P ($< .05$), which reflects the loss of Sr and K below the seasonal inundation depth. Charcoal dominates stringers because decalcification has leached and dissolved fragile ash crystals. Based on these data, stringers appear to be former charcoal and/or ash deposits (perhaps rake-out) that have experienced much postdepositional fluvial activity—enough to destroy the original shape and sedimentary structures of the deposit, and spread charcoal and ash across a large area.

DISCUSSION

Anthropogenic sediments clearly differ chemically from geogenic sediments at Dust Cave. All deposits within the cave entrance show enrichment in Ba, Ca, K, Mg, Mn, P, Sr, and Zn. The presence of an anthropogenic suite demonstrates that postdepositional processes have not entirely overprinted the human presence. This chemical enrichment can be traced back more than 12,000 years. The elements comprising the Dust Cave signature come from a variety of cultural activities, including human-introduced plant and animal residues, hickory nut processing, cooking, and burning.

Phosphorous serves well as an indicator of occupation intensity. Because it tends to be immobile, P enrichment corresponds to significant indicators of prehistoric occupation, such as artifact density and magnetic susceptibility. Potassium and Sr are also useful indicators of occupation intensity, with concentration enrichment similar to trends in P for deposits lying above the seasonal water table. This suggests that cores analyzed for P, K, and Sr using ICP-AES would greatly assist in determining major occupation events through time, as well as identifying significant cultural strata. The major caveat of this technique is that it must take postoccupation leaching of mobile elements into consideration. Any sudden relative depletion may indicate mobilization of these elements by infiltrating water or by inundation due to a seasonally high water table. While the loss of elements such as K and Sr preclude the comparison of features from above and below the seasonal water table, the loss of other elements (i.e., Ca) proved vital to recognizing the impact of postdepositional decalcification on feature preservation. Thus, despite some unpredictable overprinting due to seasonal hydrologic perturbations, geochemical analysis proved to be a valuable tool in the reconstruction of human behavior at Dust Cave.

Plots for elemental concentration by depth revealed P enrichment greater than 2500 mg/kg at 210, 300, and 400 cmbd, corresponding to the late Eva/Morrow Mountain, Kirk Stemmed, and Early Side-Notched occupations, respectively, with the greatest peak—greater than 3000 mg/kg—corresponding to the late Eva/Morrow Mountain. Artifact density, feature diversity, and field-observed ash all support these geochemical data. The geochemical data are especially noteworthy in regards to the Early Side-Notched component (400 cmbd), where sparse features give one the impression of an ephemeral occupation. However, the Ca plot (Figure 5), as well as thin sections, clearly show substantial decalcification of deposits at this depth. This component lies below the seasonal inundation depth, and selective depletion of Ca, Ba, K, and Sr is consistent with decalcification. Decalcification leads to dissolution of ash and subsequent compaction of sediments, explaining the paucity of ash pits at this depth. This probably also accounts for the presence of only shallow features in the earliest two components. Despite the ephemeral occupation suggested by these small features, enrichment in both P and lithics provide evidence for a more substantial Early Side-Notched occupation.

Based on geochemical parameters alone, features do not cluster discretely enough to determine function definitively. However, coupled with micromorphological data, we identified 10 distinct feature types that clarify the nature of the activities occurring at Dust Cave. These features include cooking hearths, nut processing pits, fireplace rake-out, and middens. Of special interest is that middens and pit hearths have extremely high K/P and Sr/Ca ratios. As previously discussed, high Sr/Ca ratios typify foods low in the food chain, such as fish and plants—especially nuts. Features exhibiting such high Sr values indicate that the materials being burned and thrown away are these kinds of foods. Thus, the geochemical data further corroborate the hypothesis that nut processing figured prominently at Dust Cave. Moreover, the diversity of pit types attests to the diversity of activities occurring at the cave and suggests that the cave was used as more than a simple overnight stop for hunter–gatherers.

Interestingly, pit hearths first appear at Dust Cave during the Kirk Stemmed occupation (8200–5200 cal. B.C.), approximately contemporaneous with postglacial migration of hickory trees into the Middle Tennessee Valley (Delcourt and Delcourt, 1987). Pit hearths increase 10-fold during the Eva/Morrow Mountain occupation (6400–4000 cal. B.C.). If pit hearths did indeed function in nut processing, then it appears that nut processing took place on a greater scale during the Middle Archaic.

CONCLUSIONS

For decades, researchers have realized that we should not interpret the use of formal lithic tools based solely on morphology. Numerous studies confirm that interpretation of formal lithic tools should be based on microscopic and chemical analyses as well (Semenov, 1964; Keeley, 1980; Whitaker, 1994). Likewise, microscopic and chemical analyses can enhance the interpretation of archaeological features. Feature 301, a lenticular charcoal pit located in the rear of the cave, illustrates this point well. Based on the abundance of charcoal, its large size, and a basin-shaped profile, excavators identified it as a hearth. In thin section, however, this "hearth" showed no signs of *in situ* burning. Moreover, its loose fill, reworked ash aggregates, and a preferred orientation of charcoal grains indicate redeposition, most likely from sweeping. Feature 301 is now categorized as fireplace rake-out, redeposited in the back of the cave, away from the center of activity. Given the intensity of burning at Dust Cave, occasional cleaning would have been necessary, and the presence of rake-out should come as no surprise.

Thus, studying features as deposits allows for a more robust reconstruction of human behavior by helping us avoid subjective interpretations of features based on presumed correlations between shape and function. Multi-element geochemical analysis, coupled with micromorphological study of feature sediments, offers an integrative method for investigating feature function—a method well suited to stratigraphically complex archaeological sites. This integrated approach facilitates the identification of activities carried out at sites. Moreover, it allows for the recognition of postdepositional processes that alter archaeological deposits long after abandonment of a site, the recognition of which is vital to accurate interpretation of human behavior.

At Dust Cave, coupled geochemical and micromorphological analyses indicate that during all five components, burning was an important, if not dominant, activity at Dust Cave, arguably from processing hickory nuts. The diversity of feature types suggest that a wide array of activities occurred at the cave and that, at least during some portion (or portions) of the year, Dust Cave served as an important stopping point where people processed nuts on a large scale. These activities increased in intensity over time, peaking during the Middle Archaic.

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