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# ANALYSIS OF DESICCATED HUMAN PALEOFECES FROM BIG BONE CAVE (40VB103), VAN BUREN COUNTY, TENNESSEE

A Thesis

Presented for the

Master of Arts

Degree

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Charles Thomas Faulkner

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## ABSTRACT

Eight desiccated human feces recovered from Big Bone Cave (40VB103) were analysed for dietary contents, plant pollen, and evidence of endoparasitic infection. Radiocarbon dated materials from the cave indicated that it was a locus of human activity 2220 +/- 135 years ago. The dietary contents were primarily composed of three domesticated plant species: Iva annua, Chenopodium berlandieri ssp. jonesianum, and Helianthus annuus. Palynological evidence indicated that the primary focus of cave utilization occured during the spring months of the year. Endoparasitic species infecting the population using the cave were: Enterobius vermicularis, Ascaris lumbricoides, Giardia intestinalis,and an Ancylostomoid species tenatively identified as Ancylostoma duodenale. The evidence of endoparasitic infection preserved in the Big Bone Cave paleofecal sample is the most complete record available for Eastern North America. This information is a new contribution to understanding the relative health status and living conditions of the emergent horticultural societies of prehistoric Eastern North America.

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# CHAPTER 1

## INTRODUCTION

Big Bone Cave (40VB103) is an abandoned subsurface stream conduit located at the base of Bone Cave Mountain in Van Buren County, Tennessee (Barr 1961; Crawford 1982, 1989; Crothers 1987). The cave interior is characterized by a dry sedimentary deposit resulting from its situation between the erosionally resistant sandstones of the Hartsell Formation and the soluble limestones of the Monteagle Formation (Crothers 1987). Thus, the cave has a unique depositional environment which is well suited to the preservation of perishable prehistoric materials typically not found in other less protected archaeological contexts.

Although Big Bone Cave has a rich heritage of historical, paleontological, and archaeological research, the exploratory efforts of speleologists Larry Blair, and Joel and Carol Sneed are largely responsible for the renewed interest in studying the prehistoric utilization of the cave. A systematic archaeological survey of Big Bone Cave conducted by Crothers in 1985 firmly established that it was a focus of prehistoric mining activity during the late Early Woodland Period approximately 2100 years ago (Crothers 1986, 1987). This is a time period of

considerable significance in the prehistory of Eastern North America because human lifestyles were becoming increasingly more sedentary and a variety of indigenous weedy plant species were in the early stages of domestication.

This thesis reports the results of analyses conducted on eight prehistoric fecal samples recovered from Big Bone Cave during the early phase of the research prior to Crothers (1986) survey. Each of the eight feces was analyzed for the purpose of:

1. reconstructing the dietary pattern of the prehistoric population using the cave
2. determining the season(s) of the year in which cave utilization took place
3. describing the presence of parasitic infection among the population using the cave.

The basic premise underlying this research is that culture is an adaptive subsystem in which the components of technology, environment, and ideology are inextricably interrelated (White 1959). The subsistence remains present in the feces are assumed to be a reflection of the organizing principles involved in their procurement, storage and consumption. Seasonal differentiation in the dietary behavior and utilization of the cave by the population responsible for the fecal samples would be indicated

by the presence of characteristic pollen taxa preserved in the feces as a consequence of incidental ingestion of the atmospheric pollen rain or by intentional consumption of plant inflorescences which are limited in their seasonal availability. The presence of domesticated plant species in the dietary contents implies technological sophistication among the population using the cave wherein food is produced through horticultural activities rather than gathered from dispersed loci in the environment as would be expected of highly mobile foragers. Landscapes are modified as people become tied to specific locations and intervene in the natural processes of ecological succession to produce more of the plants they are interested in eating (McElroy and Townsend 1985). The tendency toward increased sedentary behavior and concomitant changes in population density provided new cultural and environmental contexts by altering patterns of settlement occupancy and contact with human waste (Cockburn 1971; McElroy and Townsend 1985). These newly created social and environmental contexts can be regarded as "cultural hazards" because they provide enhanced opportunities for exposure of the people to parasitic infections and the spread of infectious diseases, particularly those associated with crowded housing and poor sanitation (McElroy and Townsend 1985:127). The presence of these cultural

hazards in the environment may adversely affect a population such as the one using Big Bone Cave by altering their nutritional status and reproductive sufficiency through increased infant mortality and decreased life expectancy.

Thus, the Big Bone Cave paleofecal research was undertaken for the combined purpose of investigating the dietary behavior and prevalence of parasitic infection among the aboriginal population using the cave. The results of this research represent a unique contribution to understanding the relative health status and living conditions which prevailed in the emergent horticultural societies of central Tennessee approximately 2000 years ago.

# CHAPTER 2

# BACKGROUND

## Physical and Biotic Setting

Big Bone Cave is located on the south side of the Caney Fork River upstream from its confluence with the Collins and Rocky rivers near the town of Rock Island, Tennessee in Van Buren County. The cave is the principal feature of Bone Cave Mountain State Natural Area, which includes approximately 334 acres surrounding the cave. The entrance to Big Bone Cave is at the head of a hollow, formerly known to local residents as Beech Cove, located on the north side of Bone Cave Mountain (Mitchell Knob), at an elevation of approximately 1060' AMSL (Crothers 1987:5). The cave's passageways extend approximately 15.5 km (9.6 mi) into the mountain and have a total vertical extent of 65 meters (213 ft). Both Big Bone Cave and Bone Cave Mountain State Natural Area are managed and protected by the Tennessee Department of Conservation, Division of State Parks.

Bone Cave Mountain is a finger-like extension of the western escarpment of the Cumberland Plateau situated in the Appalachian Plateaus physiographic province (Fenneman 1938:279). The Plateau exhibits a classic tableland topography which is capped by

Pennsylvanian age sandstone, conglomerates and shales (Fenneman 1938:337). Beneath the caprock are Mississippian age limestones which are comparatively more susceptible to weathering and cave formation (Crawford 1982, 1989). The difference in lithology between the caprock of the Plateau and its underlying strata has resulted in an escarpment along the eastern and western margins (Fenneman 1938:335). The western escarpment trends in a northeast by southwest direction across Tennessee and is characterized by numerous deep gorges which open westward from the plateau proper and result in a ragged margin (Fenneman 1938:335). Erosion of the western escarpment has exposed the rocks represented in Bone Cave Mountain (Crothers 1987). The location of Big Bone Cave and its proximity to the western escarpment and major river valleys is illustrated in Figure 1 (after Crothers 1987:7). The local geology of Big Bone Cave and the karst processes responsible for its formation have been summarized extensively by Crothers (1987:6-8).

Bone Cave Mountain State Natural Area is situated in a broadly defined transitional zone between the Mixed Mesophytic and Western Mesophytic forest regions defined by Braun (1964:112). The principal species of this forest region include: Fagus grandifolia (grey beech), Liriodendron tulipifera (tulip polar), Tillia americana (basswood), Acer sacharium (sugar maple),

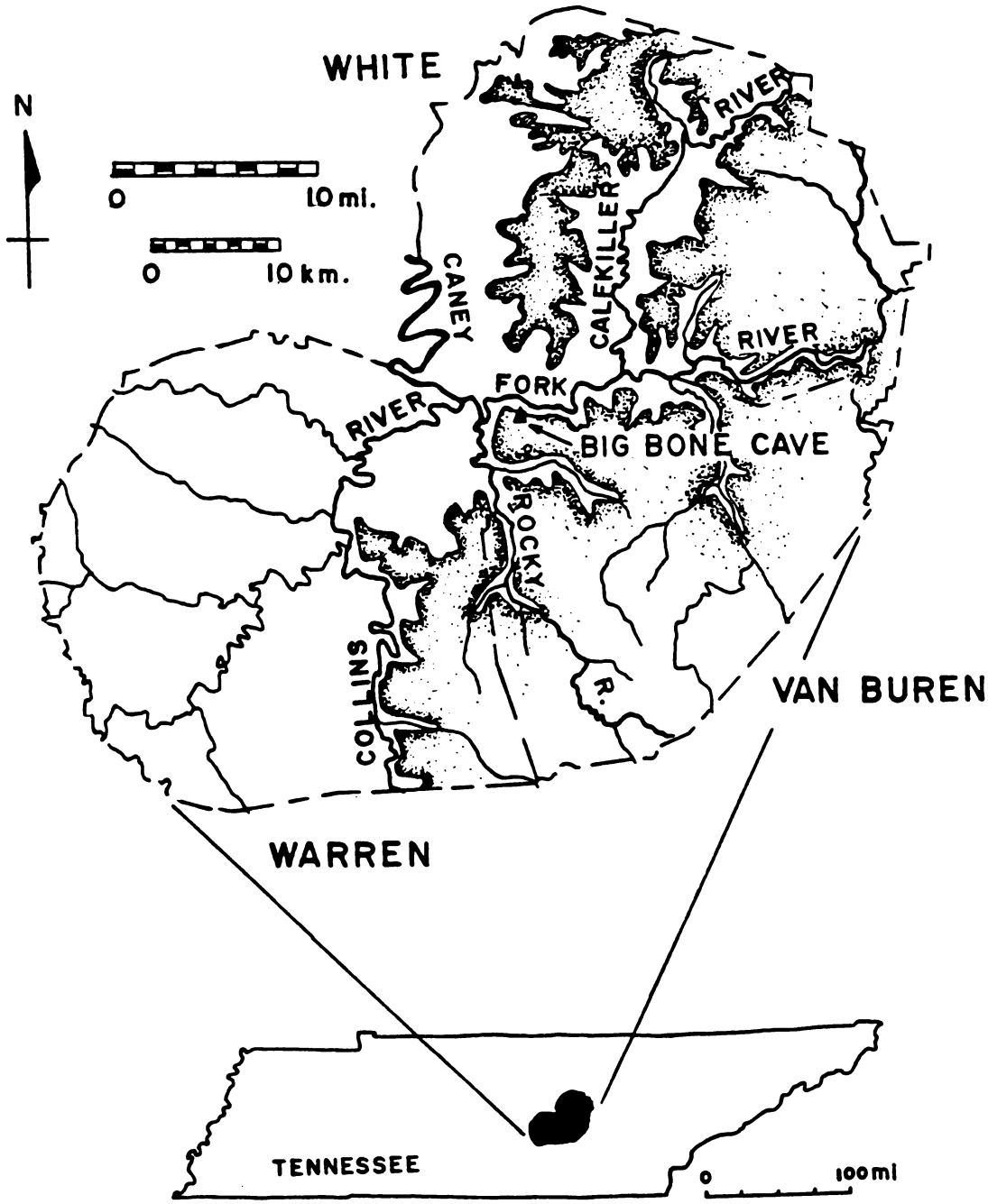



Figure 1. Location of Big Bone Cave (40VB103), Van Buren County, Tennessee (after Crothers 1977).

Aesculus octandra (buckeye), Castaena dentata (American chestnut), Quercus rubra (red oak) Q. alba (white oak), and Tsuga canadensis (eastern hemlock) (Braun 1964:40). Local differences in the edaphic characteristics of sites along the western escarpment have resulted in a vegetation that is best described as a mosaic of forest community types. In general, the shallow soils above Big Bone Cave support a relatively open vegetation dominated by mixed oak, oak-hickory and oak-pine forest communities (Braun 1964:113). The comparatively deeper soils of the valley slopes, in contrast, support a relatively closed forest canopy dominated by grey beech, sugar maple, basswood, buckeye and eastern hemlock (Braun 1964:109). Paleoecological data from Anderson Pond, in the Eastern Highland Rim of central Tennessee, indicate that the character of the forest communities in the region 2000 years ago were essentially comparable with these vegetational patterns (Delcourt 1979).

## Previous Archaeological Investigations

Big Bone Cave has been the subject of scientific investigation since the early 19th century following the discovery of the skeletal remains of an extinct Pleistocene ground sloth, Megalonyx jeffersoni, (Barr 1961:451; Crothers 1987:16-20). Henry Mercer, an archaeologist from the University of Pennsylvania, was

among the most notable of the researchers associated with Big Bone Cave (Crothers 1977:18). Mercer's excavations were directed at investigating the antiquity of early man in the New World (Crothers 1987:19). Mercer reasoned that it was possible to establish the age of prehistoric man in the New World by recording the stratigraphic position of the ground sloth remains relative to the aboriginal remains. In essence, as Crothers (1987:19) noted, Mercer used the ground sloth remains as an index fossil for establishing the relative age of aboriginal activity in the cave. Mercer's controlled excavation of the Big Bone Cave deposits conclusively demonstrated that the ground sloth remains were not contemporaneous with the evidence of aboriginal utilization of the cave. Following Mercer's excavations, Big Bone Cave was neglected by the professional archaeological community for the next 85 years despite the observation of abundant perishable prehistoric materials in the sediments overlying the ground sloth remains.

The exploratory efforts of speleologists affiliated with the National Speleological Society in late 1981 and early 1982 were largely responsible for the renewed interest in studying the prehistoric utilization of Big Bone Cave. Although their interest was the extensive remains of the saltpeter industry which flourished in the cave during the early and

middle 19th century, it was the discovery of abundant prehistoric fecal samples and other perishable debris associated with evidence of prehistoric mining activity that brought the cave to the attention of the professional archaeological community (Blair and Sneed 1983).

A systematic archaeological survey of the prehistoric materials present in Big Bone Cave was sponsored by the Tennessee Department of Conservation and carried out by Crothers in 1985 (Crothers 1986). The results of this survey documented extensive areas of largely intact prehistoric deposits and firmly established that the cave was a locus of mining activity during the Early Woodland time period approximately 2100 years ago (Crothers 1986, 1987).

## Cultural Context

The prehistoric utilization of Big Bone Cave is dated by nine radiocarbon determinations on twigs and cane torch material systematically collected from various passages in the interior and on one of the paleofecal samples reported in this study (Table 1). The dates span an approximate 1400 year period of time from 1050 B.C. to A.D. 355. Interpreted literally, these dates encompass the Terminal Archaic through late Middle Woodland time periods. Analysis of the dates using the procedures described in Crothers

Table 1. Big Bone Cave radiocarbon age determinations and error terms (modified after Crothers 1987).

| Sample Number | $A_i$ | $e_i^2$ | $f_i^2$ | $g_i^2$ | $S_i^2$ |
|---|---|---|---|---|---|
| SI-6013 * | 1595 | 55 | 50 | 70 | 100 |
| SI-6012 * | 1615 | 60 | 50 | 70 | 105 |
| Beta-13972 * | 2120 | 60 | 50 | 80 | 105 |
| Beta-12970 * | 2170 | 60 | 50 | 70 | 105 |
| Beta-13971 * | 2230 | 70 | 50 | 70 | 110 |
| Beta-13969 * | 2340 | 60 | 50 | 70 | 105 |
| Beta-13967 * | 2380 | 70 | 50 | 70 | 110 |
| Beta-32546 | 2550 | 80 | 50 | 70 | 110 |
| Beta-13968 * | 3000 | 95 | 60 | 70 | 130 |

* Dates originally presented by Crothers (1987)

Where $A_i$ is the radiocarbon date in years before present (1950 standard)

$e_i^2$ is the counting error associated with the sample (supplied by the laboratory)

$f_i^2$ is the calibration error after Clark (1975)

$g_i^2$ is the sunspot effect for short lived samples after Clark (1975)

$S_i^2$ is the sum squared error for each sample rounded to the nearest 5

(1987) indicated that each of the radiocarbon samples had a statistically consistent pooled mean age of 2220 +/- 135 years before present (270 B.C.). Thus, the primary focus of prehistoric activity at Big Bone Cave appears to coincide with the late Early Woodland and/or early Middle Woodland Period.

Prehistoric activity in Big Bone Cave seems to have been centered on mining of the sedimentary deposits for sulfate minerals, primarily gypsum crust and secondarily epsonite, mirabalite and selenite crystals (Crothers 1987:58-60). This interpretation is warranted by:

1. evidence of mineral and lithic resource exploitation at other cave sites, most notably Salts and Mammoth caves, Kentucky,
2. the abundance of available sulfate minerals in Big Bone Cave
3. the association of prehistoric artifacts, primarily digging sticks and fragments of gourd containers, relative to the sulfate deposits in the cave (Crothers 1987:58).

Evidence of prehistoric gypsum mining was first identified in the Mammoth Cave area of central Kentucky and thought to be a regional development (Watson 1969, 1974a). Although the temporal and spatial boundaries of this activity remain undefined, there is increasing evidence that the procurement of

gypsum and other exotic cave minerals was an organizationally integrated activity which coincides with the manifestation of widespread trade networks and the development of elaborate mortuary ceremonialism during the Terminal Archaic period (Crothers 1987; Munson et al 1989). Further research is expected to clarify the relationship between Big Bone Cave and other cave and archaeological sites in Eastern North America.

Archaeological research in the upper Duck River Valley is useful for defining the cultural context in which the utilization of Big Bone Cave occurred. Salvage excavations in the Tennessee Valley Authority's Normandy Reservoir Project area were undertaken by the University of Tennessee between 1972 and 1975. Prehistoric occupation of the area was documented for the Paleo-Indian through Mississippian cultural periods. Occupational loci of the Middle Woodland McFarland and Owl Hollow phases received considerable attention and were the focus of continued investigation subsequent to the Normandy Project. The McFarland and Owl Hollow projects have been instrumental in developing an understanding of Middle Woodland settlement and subsistence patterns in central Tennessee (Cobb and Faulkner 1978; Kline et al 1982).

Of the various cultural phases delineated during the Normandy Reservoir Project, the Neel phase/mortuary complex (250 B.C. to A.D. 150) is the most relevant to defining the cultural context of the prehistoric activity in Big Bone Cave (Bentz 1986:231). The Neel phase/mortuary complex was originally defined based on the analysis of a circular single post structure and three storage/refuse filled pits encountered during excavations of the multicomponent Eoff I site (40CF32) located in the upper Duck River valley (Faulkner 1977:163-169). Subsequent excavations at the Yearwood site (40LN16) on the Elk River also resulted in the delineation of a substantial Neel phase component (Bentz 1986:233; Butler 1977, 1979). Neel phase archaeological sites have been characterized as small seasonal to mutiseasonal encampments occupied by nuclear or extended families (Bentz 1986:235).

The degree of sedentism manifested in the Neel phase is not clear. Most sites have been interpreted as single phase occupations, due to the apparent absence of house rebuilding activity and the relatively thin accumulation of occupational debris. Settlement size is variable, ranging from three to as many as 13 dwellings (Bentz 1986:232-233; Butler 1977, 1979). Single post circular and square to subrectangular dwellings predominate. The floor area

of the structures range in size from 17.7 $m^2$ to 70.8 $m^2$. Fully enclosed and semi-circular open-cabana type shelters are known from Neel phase sites. The variable size of the structures may be functionally related to the activities occurring on the site during occupation (Bentz 1986:234). The Yearwood site, for example, appears to represent a warm weather seasonal congregation of several family-based social-residential units for the purpose of participating in a variety of group related activities including ritual, trade and disposal of the dead (Butler 1977:7-8).

The subsistence economy of the Neel phase is poorly documented. Faunal materials recovered from features at the Eoff I and Yearwood sites indicate a pattern of utilization based primarily on white-tail deer, turkey, and smaller terrestrial and aquatic resources (Butler 1979:152; Faulkner 1977:167). Plant food utilization appears to have focused primarily on arboreal seed crops like acorn and hickory and supplemented with the gathering of wild herbaceous seeds (Butler 1979:152).

The material culture assemblage of the Neel phase includes limestone-tempered ceramics which exhibit a variety of surface treatments, lanceolate spike-cluster projectile points, rectanguloid siltstone

elbow pipes and two hole shale gorgets (Bentz 1986:235). Interaction with prehistoric groups in other areas is indicated by the presence of distinctive lithic raw materials and finished artifacts. Greenstone celts, copper earspools, mica, galena, quartz crystals, serpentine, and Fint Ridge prismatic blades are among the exotic materials recovered from Neel phase sites.

Chronological placement of the Neel phase in the early Middle Woodland has been questioned because its material culture assemblage appears to be atypical of that known from the early Middle Woodland McFarland phase (Bentz 1986:235; Butler 1977:12-13, 1979:155-156; Faulkner 1977:168-169). It has been suggested that the Neel phase may represent an early Middle Woodland mortuary complex which is related to early McFarland phase settlement in the region (Bentz 1986:235). Alternatively, the Neel phase may be a distinct local early Middle Woodland manifestation centered in the Elk River Valley (Bentz 1986:235). Further research is necessary to fully elucidate the culture-historical relationship of the Neel phase with other Early and Middle Woodland Period archaeological complexes in Tennessee and the Mid-South.

# CHAPTER 3

## LITERATURE REVIEW

The study of desiccated human fecal material recovered from archaeological context is widely recognized for its suitability in reconstructing patterns of prehistoric parasitic disease and human dietary behavior (Bryant 1974b; Fry 1985; Wilke and Hall 1975). Given the scope of the field, it is not surprising that the research is interdisciplinary in nature. The analytical techniques employed in paleofecal research and the theories underlying their application are derived from such diverse fields as archaeobotany, palynology, parasitology, microbiology, and recently, immunology. This interdisciplinary sharing of method and theory has resulted in a considerable body of literature which serves to define research problems and appropriate methodologies for their investigation. An extensive summary of the available literature explicitly concerned with the study of paleofecal remains has been provided by Wilke and Hall (1975). The purpose of this chapter is not to duplicate their exhaustive efforts; rather, its intent is to summarize previous and current research which has relevance to the analysis and interpretation of the Big Bone Cave paleofecal sample.

## Early Studies of Paleofecal Material

John Harshburger (1896) is generally credited with being the first to recognize the potential contributions of the study of prehistoric fecal material (Bryant 1974a:1). Harshburger (1896:150) recognized that the examination of fecal material would permit inferences regarding the types of foodstuffs consumed by prehistoric Amerindians. However, Young's (1910) cursory analysis of desiccated feces recovered from Salts Cave, Kentucky was apparently the first systematic study of paleofecal material. The contents were tentatively identified as containing hickory nutshell (Carya sp.), and sunflower (Helianthus annuus) achenes, from which he concluded that these taxa were probably important dietary items. Gilmore (1931) and Jones (1936) identified most of the major prehistoric foodstuffs in subsequent analyses of ethnobotanical remains and paleofeces recovered from rockshelters in the Ozarks and the Newt Kash Hollow shelter in Menifee County, Kentucky. They recognized the existence of a subsistence pattern based primarily on the intensive utilization and possible domestication of indigenous seed crops like sunflower (Helianthus annuus), goosefoot (Chenopodium sp.), maygrass (Phalaris caroliniana), and sumpweed (Iva annua). This subsistence pattern became known as the

Eastern Agricultural Complex and was postulated by Jones (1936:163) as tentative evidence for the independent origin of agriculture in Eastern North America. Wakefield and Dellinger (1936) examined desiccated feces from a mummy recovered in a rockshelter in Arkansas. Sumac (Rhus sp.) and acorn (Quercus sp.) were identified in the dietary contents. Webb and Baby (1957) reported on an analysis of paleofecal material recovered from eastern Kentucky. The results of this study were consistent with Jones (1936) findings and indicated a diet composed of sunflower and goosefoot.

In summary, the early studies of paleofecal material are characterized by their descriptive approach to the analysis of prehistoric subsistence. The objective of each of these research efforts was fundamental to defining the role of paleofecal research in archaeology. Simply put, the primary question these studies sought to answer was "what did prehistoric man eat ?". The emergence of paleofecal research as an archaeological science is characterized by quantitative approaches to dietary reconstruction and efforts to address the issue of temporal and seasonal variability in prehistoric subsistence. Increasing emphasis on entomological, palynological, and parasitological analyses have given the field its interdisciplinary nature.

## Paleofecal Research as an Archaeological Science

The contributions of Eric O. Callen are largely responsible for the interdisciplinary nature of contemporary paleofecal research. Callen introduced the wet rehydration method to the study of desiccated feces (Callen and Cameron 1955, 1960). This technique has the effect of softening the stool sample so that the contents may be examined with a minimal amount of destruction to delicate items like small animal bone, fish scales, insect parts and small plant seeds. The introduction of this technique allowed for greater precision in the reconstruction of prehistoric dietary patterns. Callen's research fostered the trend toward comprehensive integrated studies of paleofecal material. Callen and Cameron (1955, 1960) reported the presence of human tapeworm eggs identified as Diphyllobothrium latum in a stool sample from Huaca Prieta, Peru. The subsistence economy of this culture was based on pre-maize agriculture supplemented by fishing (Callen 1963). Although numerous nets and floats were recovered in the material culture of this population, there were no fish remains present in the dietary contents of the feces (Callen 1963). The identification of the tapeworm eggs in the stool sample indicated consumption of poorly cooked fish, and served to illustrate the complimentary role of

ancillary studies like parasitological analysis in paleofecal research. Callen (1963) also presented the first quantified dietary content analysis in a study of desiccated fecal material recovered from the Ocampo caves near Tamaulipas, Mexico. The feces represented five cultural periods and enabled Callen (1963) to comment on diachronic trends in the consumption of particular dietary commodities. This research set a new standard for subsequent analyses of paleofecal material.

The issue of seasonal variability in prehistoric subsistence economies elicited the interest of a number of researchers working with paleofecal material. Martin and Sharrock (1964) analyzed pollen from feces in the Glen Canyon of Utah. This pioneering study served as the stimulus for subsequent palynological analyses which were explicitly concerned with addressing the seasonality of prehistoric diets and the seasonal use of particular archaeological sites (e.g. Bryant 1974a, 1974b; Cowan 1978; Shoenwetter 1974).

Yarnell (1969) and Marquardt (1974) addressed the problem of seasonal variability in prehistoric diets with their analyses of the Salts and Mammoth Cave paleofecal sample. They elucidated a general pattern

of seasonal dietary behavior characterized by:

1. reliance on storable seed crops primarily derived from oak, hickory, walnut, sunflower, sumpweed and goosefoot during the fall, winter and early spring months of the year, and
2. intensive utilization of other seasonally available plant foods which are either not amenable to storage (e.g. blackberries, strawberries), or available in sufficient quantities to warrant storage of the surplus (e.g. maygrass, panic grass) during the late spring and summer months of the year.

Statistically significant positive associations between plant foods harvested in the fall and negative associations with food items available during the late spring and summer months of the year suggested that there was little overlap between the two diets (Marquardt 1974:198). Cowan's (1978) analysis of the pollen and dietary contents of five paleofecal specimens recovered from the Haystack rockshelter, Powell County, Kentucky was consistent with these findings. The results indicated a winter-early spring diet almost exclusively composed of storable seed crops similar to those noted in the Salts and Mammoth Cave samples. Evidence of maygrass consumption was absent in the feces, although the taxon was present elsewhere in the deposit. This observation supported

Yarnell (1969, 1974) and Marquardt's (1974) contention that maygrass was not a stored plant food commodity.

Parasitological analyses increasingly assumed an important role in paleofecal research (Bryant 1974c:22; Fry 1985:139; Wilke and Hall 1975:7). The prevalence of parasitism in prehistoric populations is well documented in both the New and Old World (Horne 1985). Predictably, the best evidence of prehistoric parasitic infection in the New World has been found in feces from the Colorado Plateau and Great Basin regions of North America where a variety of helminth eggs have been recovered (Fry 1976; Reinhard 1988; Reinhard et al 1987; Samuels 1965). The report of human pinworm eggs (Enterobius vermicularis) in several fecal specimens from Hogup and Danger caves in western Utah document the 10,000 year old association of this parasite with humans (Fry and Moore 1969:1620). Paleofeces containing parasite products are also known from several localities in the midwestern and eastern United States. Mites and eggs resembling those of the common intestinal roundworm (Ascaris lumbricoides) have been recovered in feces from Salts and Mammoth Cave, Kentucky (Fry 1974:61; Yarnell 1969). McClary (1972) reported the occurrence of Taenia type parasite eggs which he tentatively identified as Echinococcus granulosus and broad fish tapeworm eggs (Diphyllobothrium latum) in two

paleofecal specimens recovered from Middle Woodland age sediments at the Shultz site in the Saginaw Valley of Michigan. A case of hookworm infection was reported from a single paleofecal specimen from Daws Island, an Early Coastal Formative site in South Carolina (Rathbun et al 1980:61). Evidence of infection with parasitic protozoa is known from two studies of prehistoric fecal material. Witenburg (1961) examined two 1800 year old fecal samples from a cave in Israel. He identified cysts of Giardia lamblia, Chilomasitix mesnili, Entamoebea coli and E. histolytica (Witenburg 1961). Fouant (1981) examined fecal samples removed from the colon of 88 prehistoric Chilean and Peruvian mummies for evidence of parasitic infection. The cysts of Entamoebea sp. were the most numerous parasite products encountered (Fouant 1981). Although unsuccessful, Fouant's (1981) study was the first attempt to use an immunological test for Entamoebea antigen in prehistoric feces.

Current studies of prehistoric parasitism are characterized by their emphasis on the refinement of analytical technique (Reinhard et al 1988), and attempts to relate evidence of parasitic infection to variability in the dietary behavior and settlement patterns of prehistoric populations (Reinhard 1988; Reinhard et al 1985).

## Unresolved Problems and Future Approaches

Although desiccated fecal material is an excellent source for obtaining information regarding the dietary behavior and presence of parasitic infection among prehistoric populations, researchers are confronted with a number of methodological and theoretical problems, many of which remain unresolved. Problems such as determining the unequivocal human origin of a fecal sample, the number of individuals represented by a sample of paleofeces, and the number of meals represented in the dietary contents of a single specimen have important consequences for interpretations based on the analyses of paleofeces (Bryant 1974c; Fry 1985; Watson 1974b). Bryant (1974c), Wilke and Hall (1975), and Fry (1985) have discussed the problem of determining the human origin of paleofeces at length and provided guidelines to make this assessment somewhat scientific. Nevertheless, there is agreement among researchers that determining the ultimate origin of paleofeces, in the absence of host-specific parasites like the human pinworm, is the most subjective aspect of the analysis (Fry 1985:130).

Questions regarding the number of individuals represented in a sample of paleofeces from an archaeological site have not been addressed in the

literature. This is an especially important concern for efforts aimed at investigating the epidemiology of parasitic disease in prehistoric populations. Interpretations of the prevalence of parasitic infection may be prone to overestimation if the series of parasite positive stool specimens from an archaeological site represent the same individual. At present, there appears to be no reliable means for estimating the number of individuals represented in a sample of paleofeces. The extraction and amplification of DNA as a "fingerprint for individuality" has not been tried, but may be a viable approach to this problem. DNA analysis might also be a technique for differentiating human from non-human feces as well.

Watson (1974b) and Fry (1985) considered the problem of how many meals are represented in the dietary contents of a single stool specimen. Although studies of digestive physiology permit one to estimate that a single stool sample might contain contributions of anywhere from two to four individual meals, this estimation is complicated by variation among individuals because of health and age factors, and cultural variation with respect to the timing and etiquette of elimination of bodily wastes. Differences in food processing techniques have the potential to cause particular food items to be overrepresented, while others might go unrecognized. Moore et al (1984)

explored the potential of gas-chromatographic analysis as a new method for the partial reconstruction of prehistoric diets. Variability in the dietary contents represented in paleofeces may also be due to functional differences in the archaeological contexts from which they are recovered. In other words, the feces recovered from cave sites such as Salts, Mammoth and Big Bone may represent special purpose diets composed of low-bulk high-energy foodstuffs and are not directly comparable to the feces deposited at open habitation sites. Although unresolved, this question has important implications for attempts to estimate the relative importance of particular dietary items in prehistoric subsistence economies. Questions concerning the contemporanity of paleofeces recovered from archaeological sites ultimately affect interpretations of diachronic trends in the importance of particular food items in the diet. This is especially important when considering feces recovered from cave environments which are characterized by slow sedimentation and artifacts from several time periods are found on the same surface.

To be sure, the above discussion and review of the literature regarding many of the methodological and theoretical difficulties inherent in paleofecal research is not exhaustive. Some of the problems discussed, such as establishing the contemporanity of

fecal samples are not unique to paleofecal research, but shared by archaeological science in general. Others, such as assessing the number of individuals represented in a sample of paleofeces or the number of meals represented in a single specimen will demand the attention of researchers. The willingness to recognize and attempt to resolve such problems characterizes contemporary paleofecal research as an archaeological science.

# CHAPTER 4

# MATERIALS AND ANALYTICAL METHODS

## Materials

The eight prehistoric feces reported in this study were recovered from Big Bone Cave in late 1981 and 1982 by speleologists affiliated with the National Speleological Society (Crothers 1987:21). Although the specific location of each of the fecal specimens within the cave is generally unclear, communication with the speleologists who collected the specimens indicated that the feces were recovered from a continuation of Bone Cave Branch beyond the area of intensive historic era saltpeter mining (survey area 2) and the crawlway between Bone Cave Branch and the AA Passage (Crothers 1987:31). Crothers (1987:31) noted that the Bone Cave Branch continuation was an area containing extensive prehistoric remains which appeared to be relatively undisturbed. The crawlway between Bone Cave Branch and the AA passage is likewise rich in relatively undisturbed prehistoric materials. An open-twined weave bag containing a selenite crystal was recovered from this passage in 1982 (Blair and Sneed 1983). Each of the eight paleofecal specimens is described below.

Specimen 1

This specimen resembles the top of a large ice cream cone. It is cylindrical and retains the shape of the lower bowel. The bottom of the specimen is flattened and it is tapered distally indicating that the stool was probably quite soft when deposited. Given its large size and shape, this specimen is probably a complete stool. Specimen 1 was collected on December 12, 1981 by Larry Blair et al (Blair and Sneed 1983) from the continuation of Big Bone Branch beyond the 10 foot climbdown (survey area #2). A radiocarbon determination (Beta-32546) on 3.15 gms of the dietary contents yielded an age of 2550 +/- 80 years B. P.. Dimensions: approximately 10.5 cm in length by 4.5 cm in diameter at the broad end, and tapering to 2.5 cm at the distal end. The total weight of the specimen is 130.3 grams.

Specimen 2

This specimen is roughly cubical in shape and slightly charred on one side. The cylindrical form of the lower bowel is preserved on one side of the specimen. The amorphous shape of the stool indicates that it was probably quite soft when deposited. Given its large size and shape this specimen is probably a complete stool. Specimen 2 was collected from Bone Cave Branch past the crawlway with the bag on July 25,

1982. Dimensions: approximately 7.5 cm by 4.5 cm by 5 cm. The total weight of the specimen is 126.4 grams.

Specimen 3

This specimen resembles a serpentine coil. It is cylindrical and retains the shape of the lower bowel. Given its shape and form, this specimen is probably a complete stool. The compact shape and form of the specimen is indicative of a normal healthy stool. The specific provenience of this specimen in the cave and its collection date are unavailable. The Tennessee Department of Conservation accession number associated with this specimen is listed as 82-28-30. Dimensions: approximately 11.5 cm in length by 1.5 cm in diameter at each end, maximum (coiled) width of the specimen is approximately 7.5 cm. The total weight of the specimen is 92 grams.

Specimen 4

This specimen is a small, broad cylindrical stool fragment which retains the shape of the lower bowel. The compact shape of the specimen is indicative of a normal healthy stool. Specimen 4 was collected on June 26, 1982 from on top of the woven bag in the crawlway between Bone Cave Branch and the AA Passage (Crothers 1986: Figure 3). The Tennessee Department of Conservation accession number associated with this specimen is listed as 82-28-3. Dimensions:

approximately 9 cm in length by 3.3 cm in diameter at the broad end, and tapering to a 1.5 cm diameter distal end; the maximum breadth of the specimen is approximately 3.7 cm. The total weight of the specimen is 36 grams.

Specimen 5

This specimen is a small cylindrical stool fragment with a curved midsection. The compact shape and form of the specimen is indicative of a normal healthy stool. The specific provenience of the specimen in the cave and its collection date are unavailable. The Tennessee Department of Conservation accession number associated with this specimen is listed as 82-28-30. Dimensions: approximately 7.5 to 8 cm in length by approximately 2.5 cm in diameter at the broadest end and tapering to 1.5 cm at the distal end. The total weight of the specimen is 27.13 grams.

Specimen 6

This specimen is a small, broad cylindrical stool fragment which retains the shape of the lower bowel. The compact shape and form of the specimen is indicative of a normal healthy stool. The specific provenience of the specimen in the cave and its collection date are unavailable. The Tennessee Department of Conservation accession number associated with this specimen is listed as 82-28-30. Dimensions:

approximately 5.5 cm in length by 3.5 cm in diameter at the broad end, and tapering to approximately 2.8 cm at the distal end. The total weight of the specimen is 27.2 grams.

Specimen 7

This specimen is a small, cylindrical stool fragment. The specimen appears to be segmented in approximate thirds, and retains the shape of the lower bowel. The compact shape and form of the specimen is indicative of a normal healthy stool. The specific provenience of the specimen in the cave and its collection date are unavailable. There is no Tennessee Department of Conservation accession number associated with this specimen. Dimensions: approximately 7.5 cm in length by 3 cm in diameter at the broad end, and tapering to 2.5 cm at the distal end. The total weight of the specimen is 28.3 grams.

Specimen 8

This specimen is a large, cylindrical stool which retains the shape of the lower bowel. Given its relatively large size, this specimen is probably a complete stool. The compact shape and form of the specimen is indicative of a normal healthy stool. The specific provenience of the specimen in the cave and its collection date are unavailable. There is no Tennessee Department of Conservation accession number

associated with this specimen. Dimensions: approximately 13.4 cm in length by 4 cm in diameter at the broad end, and tapering to 3 cm at the distal end. The total weight of the specimen is 54.3 grams.

## Analytical Methods

### Rehydration and Processing

Prior to analysis each of the feces was weighed, measured, and photographed. Observations on the size, shape, and color were also recorded. The surface of each specimen was examined for evidence of penetration by free-living soil nematodes and copraphagous arthropods. Each fecal sample was then bisected longitudinally and one half of the stool rehydrated in a 0.5% solution of trisodium phosphate for 48 to 72 hours according to the technique of Callen and Cameron (1960). Changes in the color and opacity of the rehydrating solution were monitored at the beginning of the rehydration procedure and at 24, 48, and 72 hour intervals. Color formation in the rehydrating solution was described for each specimen using the Munsell color system immediately following immersion and after 72 hours. Following reconstitution, each specimen was disaggregated with a magnetic stirrer and gently washed with distilled water through a graded series of brass geological sieves with 300 and 180 um opening mesh, respectively. The material remaining on

the sieves was macroscopically examined for arthropods, and helminths and slowly air dried for later analysis of the dietary contents. The material passing through the 180 um sieve was concentrated into a 50 ml tube by centrifugation, and preserved in 10% formalin for subsequent analysis of the sediment for pollen and evidence of endoparasitic infection.

Rehydration Analysis

Fecal samples were obtained from sheep, coyote, and skunk to evaluate changes in the color and opacity of the 0.5% $NaPO_3$ rehydrating solution. The coyote and skunk feces were obtained in a desiccated state from Ken Cannon (NPS Staff Archaeologist, Jackson Hole, Wyoming), and Dr. Paul Parmalee (Director McClung Museum, University of Tennessee, Knoxville). The sheep feces were obtained fresh and desiccated in an Isotemp 200 series incubator (Fisher Scientific Co.), at approximately 100° F. for 48 hours. Each of the fecal samples were rehydrated as previously described. Changes in the color and opacity of the rehydrating solution for each of the fecal samples were monitored at the beginning of the rehydration procedure and at 24, 48, and 72 hour intervals. Color formation in the rehydrating solution was described for each specimen using the Munsell color system immediately following immersion and after 72 hours. At the end of the

experiment each of the rehydrated fecal samples was photographed using 35 mm Kodachrome 40 ASA film under studio floodlights balanced for a color temperature of 3400° Kelvin. The resulting slides of the rehydrated animal feces were subjectively compared with Kodachrome slides of the Big Bone Cave fecal samples made under similar lighting conditions.

Dietary Content Analysis

Analysis of the dietary contents preserved in each of the fecal specimens was undertaken in two phases. During the first phase of the analysis all of the material from each of the specimens was examined to recover intact Iva annua and Helianthus annuus achenes, and Chenopodium sp. seeds. The intact Iva annua and Helianthus annuus achenes were metrically examined for evidence of prehistoric domestication after the procedure of Yarnell (1978). The Chenopodium seeds were analyzed with Scanning Electron Microscopy (SEM) by Dr. Gary D. Crites (Paleoethnobotanical Laboratory, University of Tennessee, Knoxville) at the Smithsonian Institute for morphological evidence of domestication using the criteria of Smith (1985a, 1985b).

Plant materials which were present in low frequencies and likely to be missed in the 25%

subsample of the dietary contents (described below) were also recovered.

The relative importance of the economically significant dietary items preserved in the feces was estimated by successively dividing the dried material from each fecal specimen with a riffel sorter until an unbiased 25% subsample of the dietary contents was obtained. The sample was weighed and separated into similar size fractions using a graded set of brass geological sieves (Fisher Scientific Co.) with 2 and 1 millimeter opening mesh, respectively. All materials greater than 1 mm were examined under low magnification with an Olympus Zoom Stereo Microscope (model SZ-III) and sorted into categories based on taxonomic affinity (in the case of plant seeds) or material type (bone, feathers, grit, etc.). Identifications of the plant materials were confirmed with the comparative collections of the Paleoethnobotanical Laboratory, Department of Anthropology, University of Tennessee, Knoxville. Reference manuals by Martin and Barkley (1973), and Landers and Johnson (1976) were also consulted throughout the analysis.

All of the sorted materials were weighed with a Sartorius Semi-Micro electronic balance (model R 200D) and cataloged according to specimen, identity, and size fraction. Fecal material which was heavily

cemented and could not be separated without destruction to the materials was classified as residual and weighed and cataloged accordingly. All weights are reported to the nearest 0.00001 of a gram. Materials too light to register an accurate scale weight are reported as 0.00001 grams. Each fecal specimen has a total weight (prior to bisection and reconstitution), a dried weight (post bisection and reconstitution), a sample weight (the 25% sample) and a category weight. These data have been summarized in tabular form and presented in Appendix A.

Early in the analysis it became apparent that materials less than 1 mm could not be practically sorted and quantified. Therefore, the less than 1 mm fraction was scanned for unusual dietary items which were not recovered in the sort of the greater than 1 mm fraction. Materials recovered in this manner have simply been reported as present.

Quantification and Statistical Analysis

The relative abundance of each of the dietary items identified in the feces was expressed as a percentage of the total weight of the sorted materials. This approach minimized the effect of the unsorted and residual materials and allowed for clear presentation and emphasis of the relative

representation of the dietary items identified in the fecal samples.

A statistical analysis of the dietary contents was conducted to determine if there were any statistically significant correlations between each of the food items and their representation in the feces. For the statistical analysis, the raw weights of each food item were calculated and reported as percentages of the entire 25% sample. Items which were too light to obtain an accurate scale weight were reported as 0.00001 grams. This approach had the effect of standardizing the relative abundance of each item in the feces and between each of the fecal samples. The relative percentages were transformed using the arcsin transformation to minimize the effect of autocorrelation inherent in the use of percentage data (Zar 1984:239). All data were screened for conformity with the normal distribution using the Chi-Square Goodness of Fit test with the aid of the Statgraphics (STSC Inc., Rockville, MD) statistical software package for the IBM personal computer. Because the data were not normally distributed due to the small sample size (n=8), correlation coefficients were calculated using Kendall's Tau, with alpha specified at $p < 0.05$, in lieu of the parametric Pearson's R (Thomas 1986:395; Zar 1984:318). Kendall's Tau was preferred over the Spearman's Rank Order correlation

analysis to circumvent the problems associated with the ranked ties between the items which were too light to register an accurate scale weight (Thomas 1986:406). The results of this exploratory analysis indicated that further statistical analysis of the dietary content data was unwarranted.

Palynological Analysis

Approximately 1 gram of sediment from the < 180 um fraction was processed for pollen recovery according to the protocol outlined by Delcourt (1981). Basically, the process entailed the following steps:

1. remove carbonates with hot 10% Hcl
2. disperse organics with hot 10% KOH
3. wash 5 times with $H_2O$ to remove excess organics
4. remove silicates with concentrated Hfl
5. remove silcoflouride gel resulting from above
6. dehydrate with glacial acetic acid
7. Acetolyze with acetic anhydride + concentrated $H_2SO_4$ in hot water bath
8. remove acid soluble products with glacial acetic acid
9. neutralize and disperse material with .3% cold KOH
10. stain with .05% Safrin O stain

11. dehydrate with Tertiary Butyl Alcohol and transfer to 1 dram vials with silicone oil (2000 centistokes viscosity)

For each step the samples were centrifuged and the supernate decanted. Slides for counting were prepared by placing a drop of the silicone-oil pollen mixture on a glass microscope slide and covering it with a 22 mm X 22 mm coverslip held in place with clear fingernail polish. Counts of 300 identifiable pollen grains were made for each fecal specimen along systematic non-overlapping transects of each slide with an Olympus compound binocular microscope (model CH) at magnifications ranging between 400x and 1000x. Pollen grains which were deteriorated or folded and, therefore, unidentifiable were excluded from the analysis. Each of the pollen taxa were identified with the aid of manuals by Kapp (1969), McAndrews et al (1973), and Lewis et al (1983). Relative percentages were calculated for the represented taxa based on total pollen sum from each of the fecal samples. Detailed pollen data for each of the Big Bone Cave fecal specimens has been summarized in tabular form and presented in Appendix B.

Parasitological Analysis

Helminth eggs, oocysts, and larvae were recovered using a commercially available formalin-ethyl acetate sedimentation procedure similar to that described by Young et al (1979). The FeKal Con-Trate System (Trend Scientific, Inc. Minneapolis, MN) is a self contained kit based on the formalin ether method of Richie (1948). The potential for incendiary hazard posed by the use of diethyl ether is reduced by the substitution of ethyl acetate. The sedimentation technique was employed because of its demonstrated ability to accurately diagnose a variety of gastrointestinal parasitic infections (Truant et al 1981). The concentration-flotation procedures routinely used in veterinary parasitology are limited in effectiveness by their inability to float many Trematode and Pseudophyillidian Cestode eggs. These are detectable only by sedimentation. Larval forms concentrated by flotation, are frequently distorted and accurate identification is impossible. Following sedimentation, wet mount preparations made from each specimen were examined with an Olympus compound binocular microscope (model CH) at magnifications ranging between 100x and 400x for the presence of protozoan cysts, helminth eggs, and larvae. Identifications were confirmed using fresh and commercially prepared slides of helminth eggs and

protozoan cysts. Reference manuals by Ash and Orihel (1984), Beaver et al (1984), Soulsby (1982) and Thienpont et al (1985) were also consulted throughout the analysis.

Immunofluorescent Assay

A commercially prepared monoclonal antibody to the cyst wall of formalin-fixed Giardia (Meridian Diagnostics, Cincinnati, OH) was used in the immunofluorescent assay (IFA). The IFA technique utilizes the principle of antigen capture by a monoclonal antibody produced against Giardia to attach a fluorescent label to the cyst for easy detection. The monoclonal antibody was demonstrated to be highly specific to Giardia and did not fluoresce a wide variety of protozoa, helminths, bacteria, yeast, and fungi in clinical trials prior to its release as a commercial kit.

Approximately 10 ul of the formalin-fixed fecal pellet was placed in a specimen well on a microscope slide. Positive and negative control samples were likewise placed in labeled wells. Human feces with a high concentration of Giardia cysts per microscopic field was used as the positive control. Big Bone Cave Specimen 3 was used as the negative control because the cyst-like features were never seen in this sample. Each sample was spread over the entire well with an

applicator stick and allowed to air dry completely. Diluted primary antibody agent was applied to each specimen and incubated in a humid chamber at room temperature for 30 minutes. The slide was rinsed in 7.5 PH Phosphate-Buffered Saline (PBS) and placed in a coplin jar for 5 minutes. During this period the slides were agitated several times. The slide was carefully blotted to remove excess PBS from the colored areas surrounding each of the specimen wells and 50 ul of the diluted fluorescent labeling reagent was applied to each specimen. The slide was once again incubated in a dark humid chamber for 30 minutes at room temperature. After rinsing, a drop of mounting medium and a cover slip was applied to each specimen well to preclude inter-well contamination. The slide was examined with epi-fluorescent microscopy by scanning at 100x and confirming at 200x. Giardia cysts exhibited a vibrant apple-green fluorescence with the outline of the cysts wall clearly delimited. Color transparencies were made of each specimen using 35 mm Ektachrome P-1600 film (Eastman Kodak, Rochester NY) for archival documentation of the results.

# CHAPTER 5

## DETERMINATION OF HUMAN ORIGIN

The first problem in the Big Bone Cave paleofecal analysis was determining that each of the specimens was unequivocally human in origin. The primacy of this concern is based on the logic that all behavioral and biological inferences regarding the dietary preferences and possible parasitic infection of the prehistoric population using the cave are dependent on the recognition that the feces are the result of human defecation in Big Bone Cave. In the brief discussion below, the problems associated with determining the human origin of archaeological fecal samples and approaches to their resolution are introduced. Following this discussion, the results of a preliminary analysis designed to test the assumption that human feces can be identified by the color and translucency of the solution used to reconstitute archaeological feces is presented. The criteria used to infer the human and prehistoric origin of the Big Bone Cave fecal samples are presented in the final section of this chapter.

## The Scope of the Problem and Approaches to its Resolution

The problem of differentiating human from non-human archaeological feces is still persistent, in spite of the sophisticated analytical techniques currently employed in paleofecal research. The magnitude of this problem, according to Bryant (1974c:4), is evidenced by the large numbers of misidentified fecal specimens annually sent to his research laboratory at Texas A&M University. Samples of allegedly human feces have, in the past, included rodent, rabbit, and horse dung, owl pellets, root fragments, quids, dirt clods and even pieces of rock (Bryant 1974c:4). Given the widespread anthropological interest in the study of paleofecal material, there is clearly a need for a more precise means of determining whether or not archaeologically recovered feces are of human origin.

Experienced analysts of paleofecal material are in essential agreement that the differentiation of human from non-human feces is the most subjective aspect of the analytical process because there are no objective tests for absolute determination of fecal origin (Fry 1985:131). There are, however, several well established criteria which permit one to differentiate human from non-human feces with a degree

of relative certainty. Human origin is traditionally ascribed to archaeologically recovered fecal material according to :

1. size and external morphology
2. fecal content which seems to reflect an omnivorous diet
3. evidence of infection with exclusively human endoparasites such as human pinworm (Enterobius vermicularis)
4. demonstrable changes in the odor, color and translucency of the $NaPO_3$ reconstitution solution.

With respect to criterion (1), human origin is determined by comparing the size and external morphology of the unknown paleofecal specimen with the feces of known animal species (Bryant 1974c). Generally, this is done with the use of a reference collection of desiccated feces of known origin or with an illustrated field guide to animal scats and tracks like the one published by Murie (1974). Unfortunately, human feces exhibit considerable variability with respect to size and shape (Fry 1985:131). The variability is, for the most part, conditioned by the size and composition of the meals represented in each specimen, the seasonal availability of foodstuffs, personal consumption habits, the health and age of the

donor, and perhaps most importantly, the time interval between bowel movements (Bryant 1974c:4; Fry 1985:131; Watson 1974b:239). Typically a meal that is high in fiber content results in feces larger than a meal with a low fiber-high meat content (Fry 1985:131). Stools eliminated by healthy individuals often appear as a compact coil and retain the cylindrical shape of the lower bowel (Fry 1985:131). Stools eliminated by constipated individuals may appear as small finger-like feces or compact pellets which resemble the feces of deer, goats or other small ruminants. Bacterial and parasitic infections may result in poorly formed stools eliminated in a liquid or semi-liquid state. Human feces, therefore, may appear in the archaeological record as segmented pellets, compact coils, cylindrical masses, or as amorphous masses which resemble the dung of large herbivores such as cow or bison (Bryant 1974c:4; Fry 1985:131). Given this widely recognized propensity for variability in stool form, it seems reasonable that one should look toward other less ambiguous attributes for inferring the origin of archaeological fecal specimens.

Fecal content which seems to reflect an omnivorous diet has been widely recognized as an indicator of human origin for archaeological fecal specimens (Bryant 1974c:5; Fry 1985:131; Yarnell 1969:41). According to Bryant (1974c:5), human feces

tend to include a diverse range of dietary residues such as charcoal, cracked and ground seeds, snail and mussel shell fragments, bird and reptilian egg shell, feathers, fish scales, animal hair, plant fibers, insect parts, and the bone fragments of small birds, mammals, and fish. Although many of these food residues often occur in non-human feces, it is accepted that such feces will only exhibit the diversity characteristic of a human diet in exceptionally rare instances (Bryant 1974c:5; Fry 1985:131).

A survey of the macroscopic contents identified in analyzed paleofecal samples from Danger and Hogup caves, Utah (Fry 1976); Salts and Mammoth caves, Kentucky (Yarnell 1969,1974; Marquardt 1974; Stewart 1974); rockshelter site 41VV162 in southwest Texas (Bryant 1974a); and the Haystack rockshelter (15PO47), Powell County, Kentucky (Cowan 1978) indicates that there is a substantial empirical basis for the validity of this criterion as an indicator of human fecal origin.

Unfortunately, differentiating human from non-human feces solely in terms of dietary content diversity may be misleading. Notwithstanding the circular reasoning inherent in such an approach, this caveat is especially relevant to circumstances where domestic dogs are likely contributors to the

paleofecal assemblage of an archaeological site. The differentiation of archaeological human feces from those of domesticated canids is particularly problematical because these companion animals generally subsist on food scraps scavenged from humans. Although the size and external morphology of a fecal specimen may sometimes provide a clue regarding its origin, the fortuitous occurrence of particular host specific endoparasite eggs in the feces should permit one to differentiate human from non-human feces with a reasonable degree of certainty.

Feces containing the eggs of Enterobius vermicularis (human pinworm) are, in most cases, unequivocally human based on the recognition that man is the only species which serves as definitive host for this parasite. The simplicity of this approach is complicated, however, by the fact that dogs are prone to copraphagous behavior. Therefore, it is reasonable to expect the occasional presence of human pinworm eggs in feces of canid origin. Pre-Columbian feces containing Taenidae (tapeworm) type eggs, however, are likely to be Canidae or Felidae in origin. Humans are the definitive host for only two species of tapeworms having this type of egg (Beaver et al 1984:493). Although both the beef tapeworm, Taenia saginata, and the pork tapeworm, Taenia solium, share a cosmopolitan

distribution in the modern world it is widely accepted that they were introduced in the New World following European contact.

Demonstrable changes in the color and translucency of the solution used to reconstitute archaeological feces is the most widely acknowledged indicator of human origin (Bryant 1974c:4; Fry 1985:131). In fact, the acceptance of this inferential approach is so widespread that the authors of a recent medical anthropology text noted " A chemical test helps the researches decide if a specimen is of human origin." (McElroy and Townsend 1985:167-168). Briefly, the convention accepted among researchers is that desiccated human feces rehydrated in a 0.5% solution of $NaPO_3$, turn the reagent opaque-black within 72 hours (Bryant 1974c:4; Fry 1985:131; Wilke and Hall 1975:9). Fry's experimental study of laboratory desiccated feces obtained from eleven zoo-kept animal species seemed to warrant this convention (Fry 1977: Table 4). Of all the species tested by Fry, only human feces and those of the omnivorous coatimundi (Nasua nasua) turned the reconstitution solution opaque dark brown-black (Fry 1985:132). Although the fluid of the other specimens varied from red-brown to yellow-brown, all remained translucent (Fry 1985:132). The experience of other researchers, however, provides a basis for questioning the validity of rehydration

analysis as a test for determining the origin of archaeological fecal material (Wilke and Hall 1975:9). The salient point of these studies is that the nature of the reaction obtained from immersing a desiccated fecal sample in the $NaPO_3$ solution is more likely a function of dietary content rather than the simple distinction between human versus non-human origin (Fry 1985:133).

## Rehydration Experiments and Results of the Analysis

In 1986 desiccated fecal material recovered from a prehistorically utilized dry rockshelter (40MC1) in Macon County, Tennessee was rehydrated for the combined purpose of dietary content and parasitological analysis. Although the feces were hypothesized to be of ruminate origin based on an examination of their external morphology, their spatial association with the prehistoric archaeological assemblage recovered from the shelter warranted an examination of their contents. Each of the fecal specimens was rehydrated in a 0.5% solution of NaPO3 as previously described. After 48 hours, the rehydrating fluid turned dark brown-black (Munsell color 10 yr 2/2, very dark brown) and assumed an opaque appearance which was indistinguishable from the

solution used to rehydrate a fragment of one of the Big Bone Cave fecal specimens. Subsequent examination of the contents indicated that the dietary residues were composed of finely masticated plant material and contained no identifiable seeds. These residues were consistent with the dietary contents of modern caprine fecal samples submitted to the University of Tennessee College of Veterinary Medicine (UTCVM) clinical parasitology laboratory for parasitological examination.

Based on this experience, additional experiments using oven dried sheep feces and naturally desiccated skunk and canine (probably coyote) feces were performed with the following results. The skunk feces turned the rehydrating fluid opaque dark brown-black (Munsell color 10yr 2/1) immediately following immersion. There was no appreciable change in either the color or opacity of the $NaPO_3$ solution after 72 hours. The canid feces, in contrast, turned the rehydrating fluid light yellow (Munsell color 5y 7/3) immediately following immersion. The color of the solution intensified gradually overnight and after 72 hours attained a rich brownish-yellow (Munsell color 10yr 6/8) which remained translucent. The sheep feces turned the solution a light reddish-brown (Munsell color 5 yr 3/4), characteristic of weak tea, immediately following immersion. The color of the

solution continued to intensify and after 72 hours attained a dark reddish brown (Munsell color 2.5yr 3/6) which remained translucent.

The results of the experiments described above were compared visually to changes observed in the color and opacity of the $NaPO_3$ solution used to rehydrate the Big Bone Cave paleofecal specimens. In all cases, the Big Bone Cave feces turned the rehydrating fluid opaque dark-brown black (Munsell color 10yr 2/1) immediately following immersion, with no appreciable differences in color or opacity observed after 72 hours. Demonstrable differences in the color and opacity of the $NaPO_3$ rehydrating solution were evident when the laboratory desiccated sheep feces and the naturally desiccated canid feces were visually compared with the Big Bone Cave fecal specimens. However, when the naturally desiccated skunk feces were compared with the Big Bone Cave feces there appeared to be no discernable difference in the color and opacity of the $NaPO_3$ rehydrating solution. Given the results of these experiments there appears to be no reason to accept <u>a priori</u> the prevailing view that only human feces, with the exception of the coatimundi, turn the $NaPO_3$ dark black and opaque. Moreover, this experience corroborates Fry's (1985:133) general impression that the resulting color

of the rehydrating fluid is more a function of dietary content, rather than fecal origin.

## Desiccated Feces from Big Bone Cave (40VB103): Criteria for Inferring Human Origin

The size and external morphology of each of the Big Bone Cave fecal specimens was evaluated using the illustrations of non-human feces presented in Murie (1974). The comparison was admittedly subjective as there are no well established morphological criteria for differentiating human from non-human feces, other than general size and shape. Specimens 1 and 2 were judged to be atypical of human feces based on their large size and amorphous form. Specimen 3 appeared to be a relatively complete, well formed stool, and exhibited a so-called "typical" human morphology which was evidenced in the serpentine coil of its shape. Although specimens 4, 5, 6, and 7 were too fragmentary to be of much comparative value, all were consistent with respect to their maximum diameter of approximately 2.5 to 3 cm. Specimen 8 also appeared to be a relatively complete stool. Although its size was large (see dimensions in Chapter 4, p.34), the general impression was that the size and morphology of the specimen was consistent with the variability expressed in human stool form. In summary, after consideration of all possible contributors (canidae, felidae,

mustelidae etc.) to the Big Bone Cave fecal assemblage, there was no convincing morphological evidence to suggest that animals other than humans were the most likely source of the feces recovered from the cave.

Given the ambiguous results of the rehydration experiments conducted above, additional evidence of human origin was sought in the dietary content and parasitological analyses. It was expected that the presence of human pinworm eggs in at least a portion of the feces would provide a basis for inferring that the Big Bone Cave fecal specimens were unequivocally human in origin. The identification of known prehistorically utilized plant species such as Iva annua (sumpweed), Chenopodium sp. (goosefoot) and Helianthus annuus (sunflower) in the dietary contents would unequivocally support the belief that the feces were associated with aboriginal utilization of the cave and not the products of 19th century saltpeter miners or 20th century speleologists.

# CHAPTER 6

# DIETARY CONTENT ANALYSIS

The dietary contents preserved in each of the Big Bone Cave feces were analyzed for the combined purpose of obtaining a descriptive summary of the food items consumed by the population using the cave and to derive a quantitative estimate of the relative contributions of cultivated versus gathered food items in the diet. It was expected that this information would provide an important link in elucidating the development and intensification of food production behavior between the Terminal Archaic period and the Middle Woodland period in central Tennessee. A brief discussion of the theoretical orientation underlying this analysis is presented below. The descriptive summary of the dietary contents and results of the quantitative analysis are presented in subsequent sections.

## Theoretical Orientation

The nature of prehistoric dietary behavior has been a topic of anthropological inquiry since the late 1890's when J. W. Harshberger (1896) recognized that the examination of prehistoric fecal material would permit inferences regarding the various species of plants consumed by prehistoric Amerindians

(Harshberger 1896:150). Gilmore (1931) and Jones (1936) identified most of the major prehistoric foodstuffs in their analyses of paleofeces and ethnobotanical remains recovered from the Ozark and Newt Kash Hollow shelters. They recognized the existence of a subsistence pattern based primarily on the intensive utilization and possible domestication of indigenous seed bearing annuals like sunflower (Helianthus annuus), goosefoot (Chenopodium sp.), maygrass (Phalaris caroliniana), and marshelder (Iva annua). This subsistence pattern became known as the Eastern Agricultural Complex and was postulated by Jones (1936) as tentative evidence for the independent origin of agriculture in Eastern North America.

Subsequent research in the last two decades established the temporal and spatial boundaries of the Eastern Agricultural Complex. It is well known that by 2000 years ago prehistoric human populations in the Midwest and Southeast appear to have increased their dependence and utilization of the indigenous seed bearing annuals first identified by Gilmore (1931) and Jones (1936). The increased archaeological representation of these plants has been interpreted as reflecting a greater emphasis on horticultural activities, rather than a more intensive exploitation of wild stands (Asch and Asch 1978; Smith 1985a, 1988; Yarnell and Black 1985). Yarnell (1978) and Smith

(1985a, 1985b) clarified the domesticated nature of Iva annua, Helianthus annuus and Chenopodium berlandieri ssp. jonesianum by demonstrating phenotypic changes in the morphology of the seeds. Other research has indicated that additional species such as maygrass (Phalaris carolinia), erect knotweed (Polygonum erectum) and little barley (Hordeum pusilum) were apparently cultivated without recognizable phenotypic change in the morphology of the seeds (Cowan 1985; Ford 1985).

Despite these relatively recent contributions, a number of questions regarding the nature of Woodland Period subsistence economies persist. For example, we now know which plants were domesticated, but we know comparatively little of the developmental trajectory preceding their domestication. The geographic region(s) where sumpweed, sunflower, and goosefoot were first domesticated and emerged as an archaeological assemblage remains unknown (Ford 1985). Similarly, the relative dietary importance of these prehistoric domesticates in the Early Woodland period subsistence economies of the Midwest and Southeast is difficult to establish given the nature of the evidence and the taphonomic processes affecting the representation of plant remains in the archaeological record (Gasser and Adams 1981; Yarnell 1982).

For the last decade ethnobotanical research in Tennessee has sought to address these basic issues in elucidating the nature of prehistoric subsistence through the systematic accumulation and analysis of archaeobotanical assemblages from a variety of temporal and spatial contexts. Detailed summaries of these analyses are available for the Little Tennessee River Valley in eastern Tennessee (Chapman and Shea 1981; Cridlebaugh 1984; Watson 1985) and the Upper and Middle Duck River and Elk River valleys in central Tennessee (Shea 1977; Crites 1978, 1986, 1987; Watson 1985). In central Tennessee, prehistoric plant use for the Terminal Archaic period (3500-2500 years B.P.) and the Middle Woodland period (2000-1300 years B.P.) is exceptionally well documented as a result of ethnobotanical research from the Roaring Fork River Valley and the Upper Duck and Elk river valleys (Crites 1978, 1986, 1987; Kline et al. 1982). However, few data regarding prehistoric plant use during the Early Woodland period (2500-2000 years B.P.) are available from central Tennessee. Analysis of the food plant remains preserved in the Big Bone Cave feces provided an opportunity to contribute additional information to one of the most poorly understood cultural/temporal contexts in the region.

## Descriptive Summary

The seeds of domesticated sumpweed, Iva annua, were a ubiquitous dietary item as indicated by their presence in each of the eight fecal specimens (Table 2). As demonstrated by Yarnell (1978), Asch and Asch (1978), and Cowan (1985), domesticated Iva annua has substantially larger achenes than those characteristic of modern wild populations. The mean size (length multiplied by width) of the achenes recovered from each of the eight fecal specimens range from 11.4 mm to 16.57 mm. However, the overall mean size of the Big Bone Cave Iva annua is 13.51 mm and is comparable to the size of the sumpweed achenes recovered from feces attributed to the Early Woodland utilization of Salts Cave, Kentucky (Yarnell 1978: Table 2).

The seeds of goosefoot, Chenopodium sp., were likewise present in each of the eight feces (Table 2). Examination of a sample of the comparatively more intact seeds with scanning electron microscopy indicated that many are morphologically consistent with the domesticated species Chenopodium berlandieri ssp. jonesianum described from Russell Cave, Alabama and Ash Cave, Ohio (Smith 1985a, 1985b). The Big Bone Cave specimens exhibit a prominent beak and the reticulate-alveolate dorsal pericarp pattern characteristic of species belonging to subsection

Table 2. Food items represented in Big Bone Cave feces.

| Dietary Item | Specimen Number 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Iva annua | + | + | + | + | + | + | + | + |
| Chenopodium | + | + | + | + | + | + | + | + |
| Polygonum | + | + | | | | + | | + |
| Helianthus | | + | | | | + | | + |
| Carya nutshell | + | + | + | + | + | + | + | + |
| Panicum | + | | + | + | + | | | |
| Portulaca | + | | | + | | | | + |
| Viburnum | | + | | | | | | |
| Rhus | | + | + | | | | | |
| Cerastium | | | | | | | | + |
| Feathers | | + | + | | + | | | + |
| Avian Bone | | | | | | | | + |

Cellulata of the family Chenopodiaceae and show a marked tendency towards truncate seed margins. Measurements of the testa thickness range from approximately 12 to 22 um and are comparable to the measurements obtained from the Russell Cave and Ash Cave specimens (Smith 1985a, 1985b). These data indicate that at least some of the Chenopodium represented in the Bone Cave paleofecal specimens may be tentatively assigned to the domesticated taxon Chenopodium berlandieri ssp. jonesianum.

Domesticated sunflower, Helianthus annuus, was represented in three fecal specimens by small amounts of fragmentary material (Table 2). However, 12 measurable achenes were recovered from one of the feces. The mean size (length multiplied by width) of the achenes is 23 mm and is comparable to the size of the sunflower recovered from Salts Cave, Kentucky (Yarnell 1978: Table 1).

The seeds of erect knotweed, Polygonum erectum, occurred in four fecal specimens (Table 2). The seeds are basically triangular in shape and range in size from approximately 2.6 to 3 mm by 1.8 to 2 mm. Morphologically, these seeds seem to be indistinguishable from those of modern wild populations.

The consumption of wild plant foods was evidenced by the occurrence of crushed hickory nutshell, Carya sp. in each of the eight feces (Table 2). Panicum dichotomiflorum, a fall flowering grass, was present in four specimens (Table 2). Purslane seeds, Portulaca oleracea, were found in three specimens, and Sumac seeds, Rhus sp., occurred in two samples (Table 2). The seeds of black haw, Viburnum prunifolium, were identified in a single fecal specimen along with a complete berry that had been voided without mastication (Table 2). The seeds of chickweed, Cerastium sp. were also present in a single specimen.

Interestingly, evidence of meat consumption was represented by small feather fragments in four of the eight feces and avian bone in one specimen (Table 2).

Other materials of interest recovered in the dietary contents include six fleas identified as Epitedia cavernicola, and insect remains identified to the Order Diptera in a single fecal specimen, and a weevil larva identified to the subfamily Apioninae in another (Borror et al 1976; CDC 1967; Chu 1949). The fleas are parasitic on woodrats, Neotoma floridana, and probably represent postdepositional invasion of the fecal specimen, although accidental ingestion by the defecator cannot be ruled out as a possible explanation. Although a generic level identification

was not possible for the weevil larva, members associated with the subfamily Apioninae live in the seeds of legumes and other plants and are commonly regarded as stored food pests (Harwood and James 1979). The presence of this taxon in a single fecal specimen indirectly supports an interpretation of the dietary contents as stored food commodities.

## Quantitative Analysis

A quantitative analysis of the dietary contents was done to determine the relative importance of each of the items preserved in the Big Bone Cave feces. Particular attention was directed at obtaining an estimate of the contribution of domesticated and/or cultivated plant taxa relative to wild gathered plant-foods in the subsistence economy of the population using the cave. The results of this analysis are presented below for each of the eight fecal specimens. Detailed dietary content data for each of the feces is summarized in tabular form and presented in Appendix A.

### Specimen 1

The 25% subsample of the dietary contents from this specimen totaled 3.84 grams (Table 7, Appendix A). Materials greater than 1 mm accounted for approximately 44% or 1.70 grams of the total weight of

the subsample. Unsorted materials less than 1 mm comprised approximately 56% of the total weight of the subsample. Cursory sorting of these materials failed to reveal the presence of additional taxa that were not represented in the greater than 1 mm fraction. This analysis also indicated that the materials present in the less than 1 mm fraction were represented in approximately the same proportions as those of the greater than 1 mm fraction. Of the 1.70 grams available for analysis, 26.5% or 0.45 grams was classified as residual. Sorted materials totaled 1.25 grams.

Domesticated plant species accounted for 83% of the dietary contents present in the sample. Iva annua was the most abundant taxon represented and accounted for 44% of the food items consumed. Chenopodium sp. was the second most abundant taxon identified and accounted for 35% of the sample weight. Polygonum erectum was a minor constituent of the suite of domesticated and/or cultivated plant taxa represented in the sample and accounted for only 4% of the food weight. Hickory nutshell comprised 15% of the dietary contents and was the only identifiable wild plant food species represented. Carbonized nutshell and wood charcoal accounted for the remaining 2% of the fraction weight. Other materials present in quantities insufficient for obtaining an accurate

scale weight included the fragmentary remains of plant infloresences, seeds and a single fragment of possible animal bone.

Specimen 2

The 25% subsample of the dietary contents from this specimen totaled 6.21 grams (Table 8, Appendix A). Materials greater than 1 mm accounted for approximately 53% or 3.28 grams of the total weight of the subsample. Unsorted materials less than 1 mm comprised approximately 47% of the total weight of the subsample. Cursory sorting of these materials failed to reveal the presence of additional taxa that were not represented in the greater than 1 mm fraction. This analysis also indicated that the materials present in the less than 1 mm fraction were represented in approximately the same proportions as those of the greater than 1 mm fraction. Of the 3.28 grams available for analysis, approximately 38% or 1.24 grams was classified as residual. Sorted materials totaled 2.03 grams.

Domesticated and/or cultivated plant species accounted for 54% the of the dietary contents present in the sample. Iva annua was the most abundant taxon represented and accounted for 32% of the food items consumed. Chenopodium sp. was the second most abundant taxon associated with food production and accounted

for 20% of the dietary component weight. Polygonum erectum and Helianthus annuus were minor constituents of the suite of domesticated and/or cultivated taxa represented in the sample and accounted for only 0.88% and 0.58% of the food weight, respectively.

Hickory nutshell was the most abundant wild plant food species represented and comprised 21% of the dietary content weight. Viburnum prunifolium was represented by 4 complete seeds, 12 seed fragments and associated fruit skin. This taxon was the second most abundant wild plant food species identified and accounted for 13% of the sample weight. Undifferentiated plant remains which included stems, rootlets and other fiberous materials comprised 11% of the total dietary content weight. Carbonized nutshell and wood charcoal represented less than 1% of the sample weight. Other materials present in quantities insufficient for obtaining an accurate scale weight included the fragmentary remains of plant infloresences, seeds and epidermal tissue, and a single feather fragment.

Specimen 3

The 25% subsample of the dietary contents from this specimen totaled 4.16 grams (Table 9, Appendix A). Materials greater than 1 mm accounted for approximately 69% or 2.86 grams of the total weight of

the subsample. Unsorted materials less than 1 mm comprised approximately 31% of the total weight of the subsample. Cursory sorting of these materials failed to reveal the presence of additional taxa that were not represented in the greater than 1 mm fraction. This analysis also indicated that the materials present in the less than 1 mm fraction were represented in approximately the same proportions as those of the greater than 1 mm fraction. Of the 2.86 grams available for analysis, 26% or 0.75 grams was classified as residual. Sorted materials totaled 2.11 grams.

Domesticated and/or cultivated plant species accounted for just 21% the of the dietary contents present in the greater than 1 mm fraction. Chenopodium sp. was the most abundant taxon associated with food production and accounted for 13% of the dietary component weight. The contribution of Iva annua accounted for 8% of the food items consumed. Hickory nutshell was the most abundant plant food species represented and comprised 75% of the dietary content weight. Rhus sp. was represented by a single seed which accounted for less than 1% of the food weight. Meat consumption was indicated by the presence of several small feather fragments in the dietary contents. The contribution of this material class accounted for 3% of the food weight.

Specimen 4

The 25% subsample of the dietary contents from this specimen totaled 1.53 grams (Table 10, Appendix A). Materials greater than 1 mm accounted for approximately 46% or 0.70 grams of the total weight of the subsample. Unsorted materials less than 1 mm comprised approximately 54% of the total weight of the subsample. Cursory sorting of these materials failed to reveal the presence of additional taxa and indicated that the materials present in the less than 1 mm fraction were represented in approximately the same proportions as those of the greater than 1 mm fraction. Of the 0.70 grams available for analysis, approximately 14% or 0.09 grams was classified as residual. Sorted materials totaled 0.61 grams.

Domesticated and/or cultivated plant species accounted for just 24% of the dietary contents present in the greater than 1 mm fraction. Iva annua was the most abundant taxon associated with food production, and accounted for 22% of the dietary content weight. The contribution of Chenopodium sp. accounted for 2% of the food items consumed. Hickory nutshell was the most abundant plant food species represented and comprised 76% of the dietary contents.

Specimen 5

The 25% subsample of the dietary contents from this specimen totaled 1.66 grams (Table 11, Appendix A). Materials greater than 1 mm accounted for approximately 63% or 1.05 grams of the total weight of the subsample. Unsorted materials less than 1 mm comprised approximately 37% of the total weight of the subsample. Cursory sorting of these materials failed to reveal the presence of additional taxa and indicated that the materials present in the less than 1 mm fraction were represented in approximately the same proportions as those of the greater than 1 mm fraction. Of the 1.05 grams available for analysis, approximately 16% or 0.17 grams was classified as residual. Sorted materials totaled 0.88 grams.

Domesticated and/or cultivated plant species accounted for just 4.5% of the dietary contents present in the sample. Iva annua was the most abundant taxon associated with food production and accounted for 4% of the dietary component weight. The contribution of Chenopodium sp. accounted for less than 1% of the food items consumed. Hickory nutshell was the most abundant plant food species represented and comprised 86% of the dietary content weight. The seeds of Panicum dichotomiflorum accounted for 2% of the food weight. Undifferentiated plant stems, rootlets and fiberous materials accounted for 7.5% of

the dietary content weight. Meat consumption was indicated by the presence of several small feather fragments which were insufficient for obtaining an accurate scale weight.

Specimen 6

The 25% subsample of the dietary contents from this specimen totaled 1.38 grams (Table 12, Appendix A). Materials greater than 1 mm accounted for approximately 14% or 0.18 grams of the total weight of the subsample. Unsorted materials less than 1 mm comprised approximately 86% of the total weight of the subsample. Cursory sorting of these materials failed to reveal the presence of additional taxa and indicated that the materials present in the less than 1 mm fraction were represented in approximately the same proportions as those of the greater than 1 mm fraction. Sorted materials totaled 0.18 grams.

Domesticated and/or cultivated plant species accounted for 91% of the dietary contents present in the greater than 1 mm fraction. Iva annua was the most abundant taxon associated with food production and accounted for 85% of the dietary content weight. The contribution of Chenopodium sp. accounted for approximately 6% of the food items consumed. Polygonum erectum and Helianthus annuus were minor constituents of the suite of domesticated and/or

cultivated taxa present in the specimen, and represented in quantities insufficient for accurate weight determination. Hickory nutshell was likewise represented by one fragment which was insufficient for accurate weight determination. Undifferentiated plant stems and fiberous materials accounted for 9% of the dietary contents.

Specimen 7

The 25% subsample of the dietary contents from this specimen totaled 0.90 grams (Table 13, Appendix A). Materials greater than 1 mm accounted for approximately 46% or 0.41 grams of the total weight of the subsample. Unsorted materials less than 1 mm comprised approximately 54% of the total weight of the subsample. Cursory sorting of these materials failed to reveal the presence of additional taxa and indicated that the materials present in the less than 1 mm fraction were represented in approximately the same proportions as those of the greater than 1 mm fraction. Sorted materials totaled 0.36 grams.

Domesticated and/or cultivated plant species accounted for 61% of the dietary contents present in the greater than 1 mm fraction. Chenopodium sp. was the most abundant taxon associated with food production and accounted for 43% of the dietary content weight. The contribution of Iva annua

accounted for 18% of the food items consumed. Hickory nutshell was the second most abundant plant taxon represented, and accounted for 39% of the dietary contents.

Specimen 8

The 25% subsample of the dietary contents from this specimen totaled 5.14 grams (Table 14, Appendix A). Materials greater than 1 mm accounted for approximately 62% or 3.19 grams of the total weight of the subsample. Unsorted materials less than 1 mm comprised approximately 38% of the total weight of the subsample. Cursory sorting of these materials failed to reveal the presence of additional taxa and indicated that the materials present in the less than 1 mm fraction were represented in approximately the same proportions as those of the greater than 1 mm fraction. Of the 3.19 grams available for analysis, approximately 1.06 grams or 33% was classified as residual. Sorted materials totaled 2.13 grams.

Domesticated and/or cultivated plant species accounted for 85% of the dietary contents present in the greater than 1 mm fraction. Helianthus annuus was the most abundant taxon associated with food production and accounted for 60% of the dietary component weight. Chenopodium sp. was the second most abundant plant taxon represented, and accounted for

18% of the dietary contents. The contribution of Iva annua accounted for 7% of the food items consumed. Polygonum erectum was a minor constituent of the suite of domesticated and/or cultivated food plants represented in the specimen, and accounted for 0.32% of the food weight.

The consumption of wild plant food taxa was represented by three species which accounted for less than 2% of the dietary content weight. Hickory nutshell accounted for 1.64% of the weight. Portulaca oleracea was represented by a single seed, and Cerastium sp. by three seeds. Neither species was present in sufficient quantities for accurate weight determination.

Undifferentiated plant stems and fiberous materials accounted for approximately 12% of the food weight. Meat consumption was indicated by numerous small feather and avian bone fragments which accounted for 0.48% of the identifiable dietary contents.

## Summary

The eight 25% subsamples of the dietary contents from the Big Bone Cave paleofecal specimens totaled 24.82 grams (Table 3). Domesticated and/or cultivated plant species accounted for 52% of the dietary contents present in the greater than 1 mm fraction. Iva annua was the most abundant taxon associated with

Table 3. Dietary content data for all Big Bone Cave Paleofecal Specimens

| Food Item | Gram Weight | Percent Represented |
|---|---|---|
| Iva annua | 1.92211 | 20.17 |
| Chenopodium sp. | 1.69829 | 17.82 |
| Polygonum erectum | 0.07123 | .74 |
| Helianthus annuus | 1.28909 | 13.52 |
| Carya nutshell | 3.61428 | 37.29 |
| Viburnum prunifolium | 0.27199 | 2.85 |
| Panicum dichotomiflorum | 0.01655 | .17 |
| Rhus sp. | 0.00598 | .06 |
| Portulaca oleracea | 0.00001 | ----- |
| Cerastium sp. | 0.00001 | ----- |
| Undifferentiated botanical | 0.52840 | 5.84 |
| Wood charcoal/nutshell | 0.03628 | .38 |
| Feather/ bone fragments | 0.07478 | .78 |
| Total Cultivated Plant foods | 4.98072 | 52.26 |
| Total Gathered Plant Foods | 3.90880 | 41.01 |
| Total Sorted Material | 9.52900 | 71.25 |
| Total Residual Material | 3.84398 | 27.28 |
| Total All Materials > 1mm | 13.37298 | 53.87 |
| Total All Materials < 1mm | 11.44763 | 46.11 |
| Total Sample Weight | 24.82061 | 99.98 |

food production and accounted for 20% of the dietary component weight. Chenopodium sp. was the second most abundant plant taxon represented, and accounted for 18% of the dietary contents. The contribution of Helianthus annuus accounted for approximately 14% of the food items consumed. Polygonum erectum was a minor constituent of the suite of domesticated and/or cultivated food plants represented in the eight feces, and accounted for 0.74% of the food weight.

The consumption of wild plant food taxa was represented by six species which accounted for 41% of the total dietary content weight (Table 3). Hickory nutshell was the most abundant taxon represented, and accounted for 37% of the weight. Viburnum prunifolium was represented in a single fecal specimen by several complete and fragmentary seeds and associated fruit skin. The contribution of this taxon accounted for approximately 3% of dietary content weight. The seeds of Panicum dichotomiflorum and Rhus sp. were minor constituents of the suite of wild plant taxa consumed, and accounted for 0.17% and 0.06% of the dietary content weight, respectively. Portulaca oleracea was represented by one seed, and Cerastium sp. by three seeds. Both taxa were recovered from a single fecal specimen. Neither species, however, was present in sufficient quantities for accurate weight determination. Undifferentiated plant stems, seed

fragments and fiberous materials accented for approximately 6% of the food weight.

Meat consumption was indicated in four specimens by numerous small feather and avian bone fragments which accounted for 0.78% of the identifiable dietary contents.

Carbonized nutshell, wood charcoal and inorganic grit accounted for less than 1% of the greater than 1 mm fraction weight of the eight fecal specimens.

## Statistical Analysis

A statistical analysis of the dietary contents was conducted to determine if there were any statistically significant correlations between each of the food items and their relative representation in the fecal samples. Correlation coefficients were calculated for each of the dietary items using Kendall's Tau statistic with alpha specified at $p < 0.05$. Although a number of positive and negative correlations were noted between the various dietary items identified in the feces, none of them met the criteria specified for statistical significance. The results of this exploratory analysis indicated that further statistical analyses of the dietary content data was unwarranted.

# CHAPTER 7

# PALYNOLOGICAL ANALYSIS

The pollen preserved in each of the Big Bone Cave feces was analyzed according to the procedures outlined in Chapter 4. A brief discussion of the expectations and theoretical orientation of this analysis is presented in the section below. Morphological-taxonomic descriptions and flowering biology for each of the pollen taxa identified in the feces, results of the analysis, and an assessment of seasonality for the fecal samples are presented in subsequent sections.

## Expectations and Theoretical Orientation

Analysis of the pollen preserved in the Big Bone Cave feces was undertaken in conjunction with the dietary content analysis to determine the seasonality of each of the fecal specimens. This information was expected to provide a basis for evaluating seasonal patterning in the consumption of particular dietary items represented in the feces. Additional insight regarding the consumption of various plant taxa that were not represented in the dietary contents was also anticipated by the identification of their characteristic pollen in the fecal samples (Bryant 1974a, 1974b; Schoenwetter 1974).

The presence of various pollen taxa in paleofeces may be differentiated with respect to inclusion in either an economic component or a background component (Bryant 1974c; Williams-Dean and Bryant 1975). The important distinction between pollen derived from the natural pollen rain and that derived from the economic utilization of particular plant taxa was first recognized by Martin and Sharrock (1964) and later elucidated by Schoenwetter (1974). In Schoenwetter's (1974) terms economic pollen consists of "pollen ingested as, or eaten as a portion of a food or beverage"; or "pollen which, clinging to food in storage, is transferred to another food source in the storage container and ultimately eaten". An important behavioral distinction is implicit in these two fundamentally different modes of economic pollen representation. With respect to the first condition, the pollen represents the direct consumption of flowers, flower buds, or fresh pollen-contaminated foliage (Schoenwetter 1974:53,55). Typically, pollen types ingested as a consequence of this condition are derived from various entomophilous (insect-pollinated) taxa, and characterized by the relatively high frequency of their occurrence in a fecal specimen. Ethnographic accounts which document the intentional consumption of the flowering parts of anemophilous (wind-pollinated) taxa provide an

important exception to this generality, however (Williams-Dean and Bryant 1975). In the second condition, the pollen represents the food item stored and is ingested incidental to the consumption of a particular dietary item. As a general rule of thumb, in situations where the second condition prevails, there is close correspondence between the prevalence of a taxon in the macrobotanical dietary contents and its pollen representation in a fecal specimen.

Pollen attributed to the background component is that "which rains out of the atmosphere onto food during preparation or consumption of a meal, and is ingested as part of a meal" (Schoenwetter 1974:53). Alternatively, pollen from the atmosphere may be inhaled into the upper respiratory system, swallowed with saliva and passed into the alimentary tract where it is incorporated into the feces (Schoenwetter 1974:53). Under normal circumstances, background pollen is primarily derived from anemophilous (wind-pollinated) taxa such as trees and weedy herbaceous plants, and is distinguished by the relatively low frequency of its representation in a fecal specimen. Patterned variability in the representation of particular wind-pollinated taxa may be used to infer the seasonality of paleofecal specimens (Bryant 1974a, 1974b; Schoenwetter 1974).

Iva cilliata Type

Pollen grains identified to this morpho-type are spheroidal to suboblate in shape, 19-22 um in diameter, with short, generally < 1.5 um, broad based spines distributed approximately 3.4 to 4.6 um apart (Woodhouse 1935:531,538). Pollen of this type have relatively coarse columellae (maximum diameter approximately 1 um) which result in a conspicuously granular appearance (Woodhouse 1935:531; Delcourt and Delcourt 1978). The presence of Iva cilliata type pollen in the Big Bone Cave feces is probably derived from the consumption of Iva annua achenes, and therefore attributed to the economic component.

Undifferentiated Low Spine Asteraceae

Pollen grains identified to this morpho-type are spheroidal to suboblate in shape, 17-24 um in diameter, with short, approximately 1.5 to 2 um, abruptly acuminate spines distributed approximately 2.6 to 3.4 um apart (Woodhouse 1935:538; Delcourt and Delcourt 1978). Pollen of this type is differentiated from the preceding Iva cillata type by the absence of a conspicuously granular appearance and the closer arrangement of the spines. Pollen grains that could not be confidently placed in the Iva cilliata type, but were clearly distinguishable as Low Spine

Asteraceae, have also been included. The presence of Low Spine Asteraceae type pollen in the Big Bone Cave feces is probably derived from a variety of taxa within the subtribe Ambrosiinae, which includes the genera of Ambrosia (ragweed) and Xanthium (cockelburr). Ragweed and cockelburr are extremely polliniferous plants which are well represented in the atmospheric pollen rain of the southeastern United States from June through September (Lewis et al 1983). The presence of Low Spine Asteraceae pollen in the Big Bone Cave feces has been attributed to the background component, although economic utilization (Gilmore 1931) of some of the taxa responsible for its contribution is not precluded.

High Spine Asteraceae

Pollen grains identified to this morpho-type are spheroidal to prolate-spheroidal in shape, 30-40 um in diameter, with long, 3-5 um, broad based attenuate spines distributed approximately 2.5 to 3.5 um apart (Kapp 1969:154). High spine pollen is common to several genera in the Asteraceae, some of which include Aster (daisy), Solidago (goldenrod) and Helianthus (sunflower). Many of the genera associated with this type of pollen are entomophilous and characteristically not represented in the atmospheric pollen rain (Lewis et al 1983:139). Although the

pollen of this type may represent the contributions of a variety of taxa within the Asteraceae, it is tentatively attributed to the genus Helianthus based on its association with numerous sunflower achenes in a single fecal specimen (Specimen 8).

Artemisia

The single pollen grain identified to this genus is spheroidal to trilobate in shape, depending on its orientation, 17 um in diameter, possesses three distinct furrows, each containing a well defined pore, and has a conspicuously thick stratified exine (Kapp 1969:153; McAndrews et al 1973:11). Mugwort is an extremely polliniferous plant which is well represented in the atmospheric pollen rain of the southeastern United States from September through October (Lewis et al 1983:142). Ethnographic utilization of the plant as a medicinal beverage has been documented (Yarnell 1964:68). Significant quantities of Artemisia pollen in paleofeces may warrant its assignment to the economic component. However, the incidental frequency of this pollen type in the Big Bone feces indicates that it is probably a background contaminant.

Chenopodium/Amaranthus Type

Pollen grains identified to this morpho-type are spheroidal in shape, approximately 25 um in diameter, with numerous, evenly distributed, well defined annulate pores (Kapp 1969:192). Although the pollen of this type may represent the contributions of several species within the genera Chenopodium and Amaranthus, assignment to the genus Chenopodium and the economic component is warranted based on its association with numerous chenopod seeds in each of the eight fecal specimens.

Polygonum aviculare Type

Pollen grains identified to this morpho-type are oblate-spheroidal to prolate in shape, approximately 28 to 30 um in diameter, and exhibit three distinct furrows, each containing a pore with a conspicuously thickened margin (McAndrews et al 1973:43, Figure 13c). Members of the genus Polygonum are insect pollinated and characteristically not represented in the atmospheric pollen rain (Lewis et al 1983:169. Although the pollen of this type may represent contributions of several closely related species within the genus Polygonum, it is tentatively attributed to the species P. erectum based on its association with macrobotanical evidence of knotweed consumption in a single fecal specimen (Specimen 8).

Gaura (Onagaraceae)

Pollen grains identified to this genus are subtriangular in shape, approximately 130 um in diameter, with three strongly protruding (aspidate) pores which are conspicuously muscular in appearance (Kapp 1969:174). Members of the Onagaraceae (primrose family) are insect pollinated and characteristically not represented in the atmospheric pollen rain. The species of Gaura known from Tennessee are erect, biennial and perennial herbs, common to open woods, stream banks, meadows and roadsides (Radford et al 1968:754,755). In Tennessee, flowering and concomitant pollination occurs from July through September. Given the large size of the pollen grains and its entomophilous aerobiology, significant quantities of Gaura pollen in a paleofecal sample may indicate intentional consumption of the flowers. However, the incidental occurrence of this taxon in two fecal specimens supports its assignment to the background component.

Gramineae Type

Pollen grains identified to this morpho-type are spheroidal in shape, approximately 25 to 30 um in diameter, with a single well defined annulate pore (Kapp 1969:174). Members of the Gramineae (grass family) are anemophilous and characteristically well

represented in the atmospheric pollen rain from May through July in the southeastern United States (Lewis et al 1983:111). Significant quantities of pollen associated with macrobotanical evidence of grass (seed) consumption in the dietary contents of paleofeces support an assignment of this type to the economic component (Bryant 1974b). However, the incidental occurrence of Gramineae type pollen in several of the Big Bone fecal samples probably indicates that it is a background contaminant.

Pinus

Pollen grains identified to this genus have two distinctive bladder-like appendages attached to their margins, possess no pores or furrows, and range in size from 35 to 65 um in diameter depending on their orientation. Although species separation within this genus is unreliable, differentiation between species belonging to section Haploxylon or Diploxylon is possible based on the presence or absence of distinctive verrucae (belly-warts) distributed on the distal surface of the pollen grain body (McAndrews et al 1973:5). The Pinus pollen identified in the Big Bone Cave feces belongs to the section Diploxylon which includes all species of pine reported from Tennessee, with the exception of white pine. The aerobiology of Pinus is anemophilous and the genus is

characteristically well represented in the atmospheric pollen rain from March through May in the southeastern United States (Radford et al 1968:38). Because of its anemophilous aerobiology, and incidental occurrence in the Big Bone Cave paleofecal samples Pinus pollen is considered a background contaminant.

Quercus

Pollen grains identified to this genus are subprolate to ambrounded-triangular in shape, depending on their orientation, approximately 25 to 35 um in diameter and possess three slit-like furrows (Kapp 1969:114; Lewis et al 1983:56; McAndrews et al 1973:9). The surface texture of these grains varies from finely verrucate to irregularly scabrate (Lewis et al 1983:56; McAndrews et al 1973:9). Species separation within this genus is unreliable without recourse to scanning electron microscopy. The aerobiology of Quercus is anemophilous and the genus is well represented in the atmospheric pollen rain from March through April in the southeastern United States (Lewis et al 1983:53). Significant quantities of oak pollen in paleofeces may indicate intentional consumption of the flowering catkins. However, the assignment of Quercus pollen to the background component is warranted because of its anemophilous

aerobiology, and incidental occurrence in the Big Bone Cave paleofecal samples.

Castanea

Pollen grains identified to this genus are prolate to trilobate in shape, depending on their orientation, < 16 um in diameter, exhibit a smooth (psilate) surface texture, and possess three distinct furrows, each containing a well defined equatorially elongate pore (Kapp 1969:126; Lewis et al 1983:52; McAndrews et al 1973:10). The aerobiology of Castaena is entomophilous, although the grains of this genus are easily carried aloft and represented in the atmospheric pollen rain due to their small size (Lewis et al 1983:53). Flowering and concomitant pollen shedding occurs from June through July for C. dentata (American chestnut) and September through October for C. pumila (chinquapin) in the southeastern United States (Radford et al 1968: 372). Species separation by pollen morphology is unreliable. Significant quantities of Castaena pollen in paleofeces may indicate intentional consumption of the flowering catkins. The incidental occurrence of chestnut pollen in the Big Bone Cave paleofecal samples, however, justifies its assignment to the background component.

Juglans

Pollen grains identified to this genus are oblate in shape, approximately 35 um in diameter, exhibit a psilate surface texture, and possess 12 to 18 well defined annulate pores evenly distributed on one surface (Kapp 1969:189; Lewis et al 1983:60; McAndrews et al 1973:7). The aerobiology of Juglans is anemophilous and the genus is well represented in the atmospheric pollen rain from April through May in the southeastern United States (Lewis et al 1983:58). The presence of Juglans pollen has been assigned to the background component based on its anemophilous aerobiology, and incidental occurrence in the Big Bone Cave paleofecal samples.

Carya

Pollen grains identified to this genus are oblate in shape, approximately 38 to 40 um in diameter, exhibit a psilate surface texture, and possess three well defined pores distributed slightly off the equatorial mid-line (isopolar) of the pollen grain (Kapp 1969:175; Lewis et al 1983:60; McAndrews et al 1973:7). The aerobiology of Carya (hickory) is anemophilous and the genus is represented in the atmospheric pollen rain of the southeastern United States from April through May (Lewis et al 1983:58). The assignment of Carya pollen to the background

component is warranted based on its anemophilous aerobiology, and incidental occurrence in the Big Bone Cave paleofecal samples.

Betula

The single pollen grain identified to this genus is oblate in shape, approximately 30 um in diameter, exhibits a psilate surface texture, and possesses three well defined, aspidate pores (Kapp 1969:178; Lewis et al 1983:25; McAndrews et al 1973:6). The aerobiology of Betula (birch) is anemophilous and the genus is typically represented in the atmospheric pollen rain from February through May in the southeastern United States (Lewis et al 1983:27). Significant quantities of birch pollen in paleofeces may indicate intentional consumption of the flowering catkins. However, the anemophilous aerobiology of Betula, and its incidental occurrence in the Big Bone Cave paleofecal samples indicates that it is probably a background contaminant.

Ostrya/Carpinus Type

The single pollen grain identified to this morpho-type is oblate in shape, approximately 30 um in diameter, exhibits a psilate surface texture, and possesses three well defined, aspidate pores (Kapp 1969:179; Lewis et al 1983:25; McAndrews et al 1973:6). Differentiation of this pollen type from that

of the genus Betula, described above, is based on the absence of a distinct separation in the endexine at the base of the pore (McAndrews et al 1973:6). Separation of the two genera subsumed in this type is unreliable. Ostrya (hop-hornbeam) and Carpinus (blue beech) are similar with respect to their anemophilous aerobiology, and each are characteristically well represented in the atmospheric pollen rain from April through May in the southeastern United States (Lewis et al 1983:27). Assignment of this pollen type to the background component is based on its anemophilous aerobiology, and incidental occurrence in the Big Bone Cave paleofecal samples.

Corylus

The single pollen grain identified to this genus is subtriangular in shape, approximately 25 um in diameter, exhibits a psilate surface texture, and possesses three well defined, slightly protruding pores (Kapp 1969:179; Lewis et al 1983:25; McAndrews et al 1973:7). The pollen of this genus is differentiated from that of the Ostrya/Carpinus morpho-type based on its smaller size, subtriangular shape, and scarcely protruding pores (Kapp 1969:179; McAndrews et al 1973:6). The aerobiology of Corylus (hazelnut) is anemophilous, and the genus is represented in the atmospheric pollen rain from

January through March in the southeastern United States (Lewis et al 1983:27). Given its incidental occurrence in the Big Bone Cave paleofecal samples, and anemophilous aerobiology, the representation of Corylus is attributed to the background component.

Alnus

Pollen grains identified to this genus are amb-pentagonal in shape, approximately 22 um in diameter, exhibit a psilate surface texture, and possess five well defined aspidate pores distributed on the equatorial mid-line (stephanoporate) of the pollen grain (Kapp 1969:180; Lewis et al 1983:29; McAndrews et al 1973:7). Alnus (alder) pollen is distinguished by the presence of conspicuous thickened bands (arci) connecting each of the pores (Kapp 1969:180; Lewis et al 1983:29; McAndrews et al 1973:7). The aerobiology of Alnus is anemophilous and the genus is characteristically represented in the atmospheric pollen rain from January through March in the southeastern United States (Lewis et al 1983: 58). Significant quantities of alder pollen in a paleofecal specimen may indicate intentional consumption of the flowering catkins. The assignment of Alnus pollen to the background component is based on its anemophilous aerobiology, and incidental occurrence in the Big Bone Cave paleofecal samples.

Ulmus

The single pollen grain identified to this genus is oblate in shape, approximately 35 um in diameter, exhibits a convoluted (rugulate) surface texture, and possesses five well defined pores distributed along the equatorial mid-line (Kapp 1969:181; Lewis et al 1983:25; McAndrews et al 1973:7). Species included within this genus cannot be differentiated based on pollen morphology. The aerobiology of Ulmus (elm) is anemophilous, and the genus is characteristically represented in the atmospheric pollen rain of the southeastern United States from January through March (Lewis et al 1983:27). Given its incidental occurrence in the Big Bone Cave paleofecal samples, and anemophilous aerobiology, the representation of Ulmus is attributed to the background component.

Celtis

Pollen grains identified to this genus are spheroidal in shape, approximately 29 um in diameter, exhibit a scabrate surface texture, and possess three weakly annulate pores (Kapp 1969:177; Lewis et al 1983:94; McAndrews et al 1973:7). The aerobiology of Celtis (hackberry) is anemophilous and the genus is generally represented in the atmospheric pollen rain from April through May in the southeastern United States (Lewis et al 1983:93). The assignment of Celtis

pollen to the background component is based on its anemophilous aerobiology, and incidental occurrence in the Big Bone Cave paleofecal samples.

Cornus

The pollen grains identified to this genus are prolate in shape, approximately 42.5 X 25 um in diameter, exhibit a psilate surface texture, and possess three well defined furrows, each containing an indistinct pore characterized by a constriction of the furrow margin (Kapp 1969:132; McAndrews et al 1973:11). The presence of a conspicuous transverse furrow which resembles a bow tie is a distinctive feature of these pollen grains (Lewis et al 1983:39). Although the aerobiology of Cornus (dogwood) is entomophilous, the genus is occasionally airborne and represented in the atmospheric pollen rain of the southeastern United States from March through April (Lewis et al 1983:39). Given its incidental occurrence in the Big Bone Cave paleofecal samples, the representation of Cornus is attributed to the background component.

Lirodendron

Pollen grains identified to this genus are ellipsoid in shape, approximately 47.5 X 32 um, exhibit a distinctive granular surface texture, and possess a single broad furrow (Kapp 1969:84; Lewis et

al 1983:64). Although the aerobiology of Liriodendron (tulip poplar) is entomophilous, the genus has been identified in the atmospheric pollen rain of Missouri and Oklahoma in small quantities (Lewis et al 1983:64). In Tennessee, flowering and pollination occur from April through June (Radford et al 1968:473). The assignment of Lirodendron pollen to the background component is based on its incidental occurrence in a single paleofecal sample.

## Results

The results of the palynological analysis of the Big Bone Cave paleofeces are collectively presented below. Detailed pollen data for each of the eight fecal samples analyzed are summarized in tabular form in Appendix B. Pollen associated with economically utilized plant species accounted for a significant percentage of the identifiable pollen counted from each of the eight feces (Appendix B). The Iva cillata morpho-type was the primary constituent represented in each of the specimens. The Chenopodium/Amaranthus morpho-type was also ubiquitous, and consistently accounted for at least 5% of the total pollen in seven of the eight samples. Pollen attributed to the grass family (Gramineae) and the Polygonum aviculare and High Spine Asteraceae morpho-types were sporadically associated with the economic component. The

representation of each of these pollen taxa in the fecal samples can be attributed to consumption of their macrobotanical counterparts: Iva annua, Helianthus annuus, Chenopodium sp., Polygonum erectum and Panicum dichotomiflorum. Interestingly, the relative abundance of these taxa in the economic pollen component appears to parallel the results of the dietary content analysis. This supports the view that the economic pollen represented in the feces is exclusively derived from pollen clinging to food in storage. There was no evidence to suggest that any of the economic pollen identified in the Big Bone feces is from the intentional consumption of plant inflorescences as part of a food or beverage.

Pollen associated with the background component accounted for approximately 20 to 30% of the total identifiable pollen counted from seven of the eight feces. Specimen 4 was atypical of the other samples; approximately 50% of the pollen counted was attributed to the background component (Table 18, Appendix B). The significance of this observation as a potential indicator of seasonality is discussed in the following section. The Low Spine Asteraceae morpho-type was the most abundant pollen represented. As noted in the preceding section, the primary taxonomic group associated with this morpho-type includes several species within the genera of Ambrosia and Xanthium.

These species are collectively known by their common names as ragweeds and cockelburrs. Although economic utilization of Ambrosia has been documented (Gilmore 1931), macrobotanical evidence indicating its consumption was not present in the Big Bone Cave fecal samples. Two explanations may account for the consistent representation of the Low Spine Asteraceae (LSA) morpho-type in the feces. First, the LSA is a residual category: pollen that could not be confidently identified to the Iva cilliata type was assigned to this morpho-type. Thus, the true contribution of the ragweeds and cockelburrs to the total pollen counts may actually be lower than indicated by this analysis. The second explanation derives from the association of these species with open areas and waste places, as would be characteristic of the prehistoric habitation sites during the Woodland period (Cridlebaugh 1984; Crites 1987). Because ragweed and cockelburr are extremely polliniferous plants which typically shed abundant quantities of pollen throughout the summer months, it is reasonable to expect that some of their pollen should be spuriously associated with the cultivated plant species at the time they were harvested. The incidental occurrences of Gaura, Gramineae, Artemisia

and High Spine Asteraceae pollen in the fecal samples may also be explained in this manner.

The presence of pollen associated with arboreal taxa in the Big Bone Cave feces is easier to interpret. Thirteen arboreal taxa were identified in the feces. Although the relative abundance of these taxa was variable in each of the fecal samples, none accounted for more than 2% of the total pollen count. Because all of the taxa represented are common constituents of the atmospheric pollen rain in the southeastern United States, their incidental occurrence in the feces indicates that they are background contaminants. There was no evidence to suggest that some of the pollen derived from arboreal sources could be attributed to intentional consumption of the inflorescences as part of a food or beverage.

## Assessment of Seasonality

The approximate season of deposition for the Big Bone Cave fecal samples was estimated by considering the relative representation of various taxa attributed to the background pollen component. All of the macrobotanical remains identified in the dietary contents represented fall available food items which are amenable to storage. Thus, the seasonal availability of these taxa is not necessarily indicative of the season in which they were consumed.

The identification of pollen attributed to background contamination provides an independent line of evidence for inferring seasonality. With the exception of Cowan's (1978) analysis, efforts to assess the seasonality of paleofecal specimens through palynological analysis have typically focused on the availability of spring entomophilous pollen derived from the intentional consumption of plant inflorescences (Bryant 1974a; Schoenwetter 1974). These studies attach less interpretative weight to the inclusion of minor amounts of arboreal pollen in the feces as an important indicator of seasonality. The argument for this rather conservative approach is based on the logic that pollen grains are extremely small, easily aerosolized and likely to be "recycled" for deposition and ingestion in another seasonal context (Bryant 1974a; Schoenwetter 1974). Apparently, the source of this conservatism stems from Tauber's (1967) studies of pollen transport in forested areas. Tauber (1967) reported that as much as 95% of the captured Fagus (beech) pollen, with an estimated average of 34 to 55% for all of the species in his study, was refloated from the surrounding vegetation (Faegri and Iverson 1975:64). As pointed out by Fageri and Iverson (1975:65), Tauber's research has not been generally corroborated and most research shows very little or no pollen transported in the

atmospheric pollen rain outside of the flowering period. This rather sweeping generalization is supported by detailed studies of the aerobiology of numerous North American pollen taxa (Lewis et al 1983).

The reluctance of analysts to base assessments of seasonality on arboreal pollen may also be related to its overall low representation in paleofecal specimens. Typically, arboreal pollen rarely accounts for more than 5% of the total pollen counted from given fecal sample (Bryant 1974a; Schoenwetter 1974). This overall pattern of low representation is undoubtedly related to the high frequencies with which pollen derived from economically utilized species is represented. Few studies have systematically collected data to document just how much arboreal pollen may be represented in a fecal specimen. Informal observations of the types and quantity of pollen represented in modern fecal specimens submitted to the University of Tennessee College of Veterinary Medicine (UTCVM) clinical parasitology laboratory indicate that pollen from arboreal sources is rarely abundant in feces. Moreover, there seems to be little evidence of pollen being represented outside of the flowering season with the exception of solitary grains of pine pollen in approximately one out of 20 to 30 fecal samples

submitted for analysis. Clearly, this subject warrants further research.

The presence of arboreal pollen in fecal specimens 1, 2, 3, 5, 7, and 8 indicates spring seasonality (Appendix B). In each of these specimens, the representation of arboreal pollen contributes to at least 2% of the total pollen sum. In most cases, this combined percentage reflects the contribution of three to six separate arboreal taxa whose peak periods of pollen dispersal occur between the months of February and June (Table 4). Although, the individual frequency is low, often indicated by one grain, their significance as indicators of seasonality is based on the co-representation with other spring flowering trees. A consideration of the representation of selected pollen taxa in the atmospheric pollen rain supports this assertion. For example, the frequency of Quercus pollen in the atmosphere varies from 3.3% at the onset of pollination to 35.6% during the peak month of flowering and 4.3% at the end of the flowering period (Lewis et al 1983:53). Carya pollen is represented in the atmosphere similarly. The frequency of Carya pollen captured from the atmospheric rain in the mid-latitude portion of the southeastern United States varies from 1.2% at the onset of pollination to 7.6% during the peak month of dispersal and 1% at the end of the flowering period

Table 4. Flowering periods for arboreal pollen taxa represented in Big Bone Cave feces (after Lewis et al 1983, and Radford et al 1968).

| Pollen Taxa | Flowering Period |
|---|---|
| Pinus sp. | March through May |
| Quercus sp. | March through May |
| Castaena sp. | June through July |
| Juglans sp. | April through May |
| Carya sp. | April through May |
| Betula sp. | March through April |
| Ostrya/Carpinus | March through May |
| Corylus sp. | January through March |
| Alnus sp. | February through March |
| Ulmus sp. | January through April |
| Celtis sp. | April through May |
| Cornus sp. | March through May |
| Liriodendron | April through May |

(Lewis et al 1983:64). In the Big Bone Cave feces, the representation of Quercus pollen relative to the other arboreal taxa varies from 16% to as much as 50% of the total arboreal pollen counted for each of the specimens in which it occurred (Table 5). Carya pollen is represented in similar fashion, and consistently accounted for 11% to 16% of the total arboreal pollen count (Table 5).

The observed differences in the relative representation of the arboreal taxa in the feces can be attributed to such factors as differential pollen production, dispersal modes, and local vegetational abundance (Fageri and Iverson 1975). The proximity of pollen shedding trees to water sources and residential areas may also have a significant effect on the representation of particular taxa in fecal samples by distributing abundant quantities of pollen to localities and food sources where incidental ingestion is inevitable. Given these recognized sources of taphonomic bias, the pollen data support the view that the arboreal taxa present in the Big Bone Cave feces are represented approximately proportional to their occurrence in the regional pollen rain. Thus, it is argued that as few as five arboreal pollen grains can be regarded as a significant indicator of spring seasonality provided that they represent different taxa sharing the same period of pollen dispersal.

Table 5. Relative percentages of arboreal pollen represented in Big Bone Cave feces.

| Pollen Taxa | Specimen Number 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Pinus sp. | 16 | 11 | 16 | 100 | 29 | 33 | 50 | 50 |
| Quercus sp. | 50 | 33 | 33 | -- | 17 | 16 | 33 | 50 |
| Castaena sp. | -- | -- | -- | -- | 11 | -- | -- | -- |
| Juglans sp. | 16 | 11 | -- | -- | 23 | -- | -- | -- |
| Carya sp. | 16 | 11 | 16 | -- | -- | -- | -- | -- |
| Betula sp. | -- | 11 | -- | -- | -- | -- | -- | -- |
| Ostrya/ Carpinus | -- | -- | -- | -- | -- | 16 | -- | -- |
| Corylus sp. | -- | -- | 16 | -- | -- | -- | -- | -- |
| Alnus sp. | -- | -- | -- | -- | -- | 33 | -- | -- |
| Ulmus sp. | -- | -- | -- | -- | -- | 6 | -- | -- |
| Celtis sp. | -- | 11 | 16 | -- | -- | -- | -- | -- |
| Cornus sp. | -- | 11 | -- | -- | -- | -- | 16 | -- |
| Liriodendron | -- | -- | -- | -- | 11 | -- | -- | -- |
| Total Arboreal Pollen Counted | 6 | 9 | 6 | 1 | 17 | 6 | 6 | 4 |

The pollen data available for Specimen 4 support an assessment of late summer or early fall seasonality for this sample (Table 18, Appendix B). The inordinately high representation of the Low Spine Asteraceae morpho-type, coupled with the near absence of background pollen derived from arboreal sources is atypical of the pattern observed in the other fecal specimens. The single grain of pine pollen is probably indicative of "pollen recycling" and spuriously associated with the sample. As noted previously, solitary pine pollen grains are a common, although infrequent, constituent of fecal samples submitted to the UTCVM clinical parasitology laboratory for analysis during the late summer and fall months of the year. The presence of nearly 2% grass pollen warrants its recognition as a background contaminant based on the near absence of macrobotanical evidence indicating kernel consumption. The single grain of Artemisia pollen likewise reinforces the interpretation that this is a late-summer or early-fall fecal sample.

# CHAPTER 8

## PARASITOLOGICAL ANALYSIS

The examination of desiccated human fecal material for evidence of parasitic infection has increasingly become a routine aspect of paleofecal research in the last decade. Such studies are relevant to understanding the community health and hygiene of prehistoric populations, and the antiquity and geographic distribution of specific organisms that infect humans. Parasitic diseases are also implicated as agents of natural selection with the potential to affect the work capacity, mortality, fertility, and growth patterns of prehistoric groups (Cohen 1977; Dunn 1968; McElroy and Townsend 1985; Rathbun et al 1980). The expectation of this research was that the trend toward increased sedentary behavior during the Woodland Period would be reflected in the prevalence of parasitic infections, particularly those associated with sedentism, poor sanitation and crowded living conditions. Each of the eight Big Bone Cave feces was examined for helminth eggs and larvae, coccidian oocysts, and protozoan cysts with the techniques described in Chapter 4. The results of this analysis are summarized below. Following the results, a brief discussion of the life cycle, mode of transmission, and pathogenesis associated with each of

the endoparasitic species identified in the paleofecal samples is presented.

## Results

Five of the eight feces examined contained the eggs of the human pinworm, Enterobius vermicularis (Table 6). The eggs ranged in size from 57.5 to 60 um by 27 to 30 um, were characteristically flattened on one side, and contained a well differentiated larva with a distinctly pointed tail.

Eggs resembling the intestinal roundworm, Ascaris lumbricoides were found in two paleofecal specimens (Table 6). The eggs were 55 um in diameter, basically round with relatively thick shells, and exhibited the remmants of an outer mammilated layer.

Several first-stage rhabditiform larvae were collected from two specimens, and a single thin-shelled egg containing an unhatched larvae was also observed in one of these (Table 6). The apparent absence of internal diagnostic structures prevented definitive identification of the larvae. The size (65 um X 37.5 um) and morphology of the egg, however, was consistent with parasitic species in the order Strongylida. These eggs are tentatively identified to the superfamily Ancylostomoidea which includes the human hookworms, Ancylostoma duodenale and Necator americanus.

Table 6. Endoparasitic species identified in Big Bone Cave feces

| Species | Specimen Number 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Enterobius vermicularis | + | + | | + | | | + | + |
| Ascaris lumbricoides | | | | | + | | + | |
| Rhabditform larvae | | | + | | | + | | |
| Ancylostomoid egg | | | + | | | | | |
| Giardia intestinalis | + | | | | | | | |

Protozoan-like cysts similar to Giardia intestinalis were observed in paleofecal specimen 1 (Table 6). Each of the cysts exhibited the ellipsoidal morphology characteristic of Giardia and consistently measured between 10 to 12 um in length and 7 to 9 um in width. The cysts were confirmed as Giardia using the indirect immunofluorescent antibody (IFA) test described in Chapter 4. Ten wells containing feces from Specimen 1 were examined on four occasions using the IFA procedure. At least one cyst in each of the ten wells containing feces from the positive specimen was observed to exhibit a vibrant apple-green fluorescence of the cyst wall identical to that of the Giardia cysts in the positive control wells. Thus, the IFA procedure supports the identification of the archaeological cysts as Giardia.

## Life Cycles, Epidemiology, and Pathogenesis

### Enterobius vermicularis

Infection with Enterobius vermicularis results from ingestion of the eggs containing infective stage $L_3$ larvae. The eggs are swallowed and hatch in the small intestine. The larvae develop into adults and live primarily in the lower portion of the small intestine, between the ileum and the cecum, where they attach to the intestinal mucosa and feed on epithelial cells and bacteria (Beaver et al 1984:302; Schmidt and

Roberts 1977:467). Copulation occurs in the ileocecal region. Following copulation, the gravid females migrate in the lumen of the colon, emerge from the host and oviposit on the perianal folds surrounding the anus. The life cycle is direct and the eggs are infective within a few hours following deposition (Beaver et al 1984:303). Under cool, moist conditions, the eggs may remain viable for up to 13 days (Beaver et al 1984:303).

Transmission of the infective eggs to the definitive host by anus-mouth contact via a contaminated finger completes the life cycle (Beaver et al 1984:304). The eggs may also be dislodged from contaminated clothing, or bed linens, aerosolized and swallowed or inhaled by other persons sharing the sleeping quarters or residence of an infected individual (Beaver et al 1984:304). This second mode of transmission accounts for the high prevalence of infection among members of the same household (Beaver et al 1984:304; Schmidt and Roberts 1977:469).

The common pathological conditions associated with pinworm infection result from the crawling sensation and puritis produced by the gravid females as they emerge from the host to oviposit (Beaver et al 1984:304). This condition elicits a scratching response which often results in scarification and secondary

infection of the perianal tissues (Beaver et al 1984:304; Schmidt and Roberts 1977:469). Nervousness, irritability, anorexia, insomnia, and nightmares in children have also been associated with enterobiasis (Beaver et al 1984:304; Schmidt and Roberts 1977:469). These secondary responses to pinworm infection can be viewed as a "stress component" which may have debilitating effects on the overall health of an infected individual (McElroy and Townsend 1985).

Ascaris lumbricoides

Infection with Ascaris lumbricoides results from ingestion of embryonated eggs containing infective stage $L_3$ larvae (Beaver et al 1984:310). Once swallowed, the eggs hatch in the stomach and small intestine (Beaver et al 1984:310). The hatched larvae penetrate the wall of the small intestine and enter the portal circulation passing through the liver, the right heart, and into the pulmonary vessels to the interalveolar tissues of the lungs (Beaver et al 1984:310). Following growth and continued development in the lungs, the larvae migrate or are carried in the mucous flow, through the bronchi, up the trachea to the throat where they are swallowed and enter the alimentary tract (Beaver et al 1984:310). In the intestine, the larvae molt to the $L_4$ stage and live free in the lumen pending a final molt when they become

adult male and female worms (Beaver et al 1984:310). Copulation occurs in the small intestine and the female begins laying eggs approximately 8 to 9 weeks postinfection (Beaver et al 1984:310). The fertilized eggs are passed in the feces of the infected host, where they require a minimum incubation period of 18 days at 28$^{o}$ C before becoming infective (Beaver et al 1984:309). Transmission of the embryonated egg to the definitive or final host completes the life cycle.

Infections with A. lumbricoides are acquired by ingesting embryonated eggs derived from fecally contaminated soil (Beaver et al 1984:311). Typically, the eggs are swallowed during the consumption of unwashed fruits or vegetables (Beaver et al 1984:311). The copraphagous behavior of domestic animals, particularly dogs, also plays an important role in transmission (Beaver et al 1984:312). Because Ascaris eggs are able to pass unaffected through the intestine of these animals, they may be transferred to a more socially acceptable location where they may be accidentally ingested via unwashed hands or suspended in aerosolized dust particles and inhaled (Beaver et al 1984:312).

The maintenance of A. lumbricoides in a host population is dependent on the presence of (1) infected individuals in the population, (2) continuous inoculation of the soil with viable eggs, and (3)

suitable environmental conditions for the development of the eggs to infective stage. Because the life span of the parasite is relatively short, approximately 1 year, the maintenance of A. lumbricoides in a population is dependent on a pattern of chronic reinfection of the host. Promiscuous defecation habits and the use of human excreta to enhance soil fertility contribute to the endemicity of ascariasis in human populations by providing exceptional opportunities for the continuous inoculation of the soil with viable eggs (Beaver et al 1984:312). Moist shady locations with temperatures between 22 and 30$^{o}$ facilitate the development of viable eggs to the infective stage (Beaver et al 1984:309). The eggs are highly resistant to desiccation and frost and remain dormant under such conditions. With the return of favorable conditions, the eggs may undergo accelerated development to infective stage. In temperate regions, the seasonal distribution of rainfall and temperature are important environmental constraints which affect the development of infective eggs (Beaver et al 1984:312). The transmission of ascariasis in a semi-sedentary population like that postulated for the Woodland period is enhanced if social aggregation takes place when these environmental conditions are met.

The pathological consequences of infection with Ascaris may be severe. Adverse effects result from

immune reactions in the tissues elicited by the migrating larvae, as well as mechanical damage and significant nutritional impairment of the host by the adult worms (Beaver et al 1984). During the initial infection, the migration of the larvae produces no major pathological changes in the liver and lung of the host, unless the number of larvae is overwhelming (Beaver et al 1984:313). However, subsequent migrations, resulting from reinfection elicit intense tissue reactions in both the liver and the lungs (Beaver et al 1984:313). In essence, these reactions are a manifestation of the host's cellular immune mechanism and attempt to mitigate the adverse effects of the larval migration (Beaver et al 1984:313). Typical pathological changes associated with the host's immune response consist of eosinophilic infiltration and accompanying granuloma formation around and in the path of the migrating larvae (Beaver et al 1984:313). The presence of ascarid larvae in the lungs stimulates a pathologic process known as Ascaris pneumonitis which includes the cellular responses described above coupled with an allergic reaction (Beaver et al 1984:313). The clinical picture of Ascaris pneumonitis is generally characterized by shortness of breath, associated with a dry or productive cough, coarse or wheezing rales and moderate fever (Beaver et al 1984:313). Pulmonary ascariasis is common and occasionally fatal in regions

where the infection follows a seasonal pattern of transmission (Beaver et al 1984:314).

The presence of adult ascarids in the intestine of the host is generally well tolerated unless the infection is heavy or the nutrition intake is inadequate (Beaver et al 1984:314). Massive infections can cause intestinal blockage, often with fatal consequences. Fever in the host may stimulate an outward migration of the adults (Beaver et al 1984:315; Schmidt and Roberts 1977:459). Wandering adults may probe and force their way into various tissues and ducts causing acute blockage. Liver abscess frequently result from the forced entry of the adults into the parenchymal tissue (Beaver et al 1984:315). Although A. lumbricoides occasionally takes blood from the intestinal wall of the host, its primary food source is the liquid contents of the intestinal lumen (Schmidt and Roberts 1977:459). Nutritional impairment resulting from intestinal ascariasis may have pronounced adverse effects on the overall health of the infected individual. One of the measurable consequences of ascariasis is impaired carbohydrate absorption (Beaver et al 1984:314). In cultures where carbohydrates (i.e. starchy seed crops) are a primary constituent of the subsistence economy, ascariasis may be a significant contributory cause of malnutrition in the population. The long term effect of such malnutrition is impaired

growth in individuals, and reproductive insufficiency through decreased natality and increased infant mortality in the population at large (McElroy and Townsend 1985).

Superfamily Ancylostomoidea

The superfamily Ancylostomoidea includes the human hookworms Ancylostoma duodenale and Necator americanus. Although the eggs produced by these parasites are morphologically indistinguishable, each of these species represent distinct families that differ markedly with respect to their morphology and life cycle. For the purpose of this section the life cycle, epidemiology and pathogenesis of A. duodenale will be discussed exclusive of N. americanus. Current evidence suggests that N. americanus was not indigenous in the Amerindian population, but introduced from Africa via the slave trade (Horne 1985; Schmidt and Roberts 1977:441).

The life cycle of Ancylostoma duodenale involves both a free living phase and a parasitic phase. Fertilized eggs are passed in the feces of the host and hatch into first stage rhabditiform larvae within 24 to 48 hours under favorable conditions. The rhabditiform larvae feed on organic matter in the feces and the surrounding soil matrix. After two molts, the larvae develop to infective stage ($L_3$) filariform larvae. The

infective larvae live in the humus layer of the soil, remaining in the capillary layer of water surrounding the individual soil particles (Schmidt and Roberts 1977:440). Depending on the time of day or the weather conditions the larvae often migrate vertically in response to the moisture content of the soil (Schmidt and Roberts 1977:440). When the ground surface is wet from rain or morning dew the larvae move to the surface vegetation and assume an extended posture that provides maximum opportunity for contact with a suitable host (Schmidt and Roberts 1977:440). Under favorable environmental conditions the larvae may remain viable in the soil for several weeks (Beaver et al 1984:273; Schmidt and Roberts 1977:440).

The parasitic phase of the life cycle of A. duodenale is typically initiated when the infective stage larvae contact and penetrate the skin of a human host (Beaver et al 1984:273; Schmidt and Roberts 1977:440). Following penetration, the larvae enter the pulmonary circulation and are carried through the right heart to the lungs where they break out of the capillaries and enter the air sacs (Beaver et al 1984:273). The larvae migrate, without essential development, or are carried in the mucous flow through the bronchi, up the trachea to the throat where they are swallowed, enter the alimentary tract and continue to the small intestine (Beaver et al 1984:273). In the

small intestine, the larvae molt to the $L_4$ stage and develop a temporary buccal capsule which is used for attachment to the intestinal mucosa. The larvae continue to grow in size and become sexually differentiated. In time, a definitive buccal capsule is developed. The larvae molt to adult stage and reproduce (Beaver et al 1984:273). The life cycle is completed when the fertilized eggs are passed in the feces of the host. The elapsed time for the completion of the life cycle, from the first exposure of the host to infective larvae until the female worms begin to oviposit is at least five weeks (Beaver et al 1984:273).

Infections with A. duodenale are acquired by contact with infective stage larvae derived from soil contaminated with feces. Typically, the larvae penetrate the skin of the human host and complete the life cycle. Infective larvae may also be swallowed during the consumption of unwashed fruits or vegetables. When ingested, the infective larvae penetrate the mucous membranes of the mouth and pharnyx to enter the pulmonary passages and complete the tracheal migration phase of the life cycle. The pulmonary passage of the larvae is facultative in A. duodenale and the larvae are capable of developing to maturity immediately upon arrival in the small intestine (Beaver et al 1984:269). However, this mode of infection is thought to be rare (Schmidt and Roberts

1977:443). Transmammary passage of infective stage larvae sequestered in the muscle tissues of canines is well documented for A. caninum, the hookworm of dogs, and other members of the Ancylostomoidea (Beaver et al 1984:274; Olsen and Lyons 1961). Although efforts to demonstrate lactogenic transmission in A. duodenale have been unsuccessful, the high incidence of neonatal infections suggests the possibility of transmammary passage despite the failure to recover larvae in the milk of nursing mothers (Nwosu 1978).

The maintenance of A. duodenale in a host population is dependent on the presence of (1) infected individuals in the population, (2) continuous inoculation of the soil with viable eggs, and (3) suitable environmental conditions conducive to hatching the eggs and development of the larvae to infective stage. Because the worms are relatively short lived (approximately 2 years), the maintenance of A. duodenale in a population is dependent on chronic reinfection of the host. Promiscuous defecation habits and the use of human excreta to enhance soil fertility contribute to the endemicy of ancylostomiasis in human populations by providing exceptional opportunities for the continuous inoculation of the soil with viable eggs and exposure of the population to infective larvae (Beaver et al 1984:280). Given the importance of the subcutaneous route of transmission, going barefoot

enhances the likelihood of infection (Schmidt and Roberts 1977:444). The endemicy of ancylostomiasis in a region is particularly dependent on the seasonal distribution of rainfall, temperature, and soil substrate (Beaver et al 1984:280; Schmidt and Roberts 1977:443). Each of these factors are important environmental constraints which affect hatching of the eggs and development of the larvae to infective stage. Because the eggs and the larvae are highly susceptible to desiccation and frost, moist shady locations with temperatures between 23 and 30$^{o}$ C provide optimal conditions for hatching of the eggs and subsequent development of the hatched larvae to infective stage (Schmidt and Roberts 1977:443). The survival of Ancylostoma is also affected by soil substrate. Because their metabolism is aerobic, oxygen is necessary for hatching the eggs and development of the larvae to infective stage (Schmidt and Roberts 1977:443). Undiluted feces, water-logged soil and heavy clay substrates are typically inhospitable to the parasite because of their anaerobic conditions (Schmidt and Roberts 1977:443). Thus, loose humus enriched soils with adequate aeration and drainage favor the development of the larvae to infectivity (Schmidt and Roberts 1977:443). Given this rather narrow suite of environmental constraints, the maintenance of A. duodenale in a semi-sedentary population, similar to

that postulated for the Woodland period, is dependent on a cultural pattern of social aggregation which coincides with seasonally favorable temperature and moisture conditions. Well aerated humus enriched substrates such as those characteristic of village middens would have provided exceptional conditions for the development and exposure of the people to infective stage larvae.

The pathogenic consequences of infection with A. duodenale are manifested in the cutaneous or invasion phase, the pulmonary or migratory phase, and the intestinal phase (Schmidt and Roberts 1977:444). In the invasion phase, the infective larvae penetrate the skin of the host wherever they make contact. Mechanical damage to the host at the point of invasion is slight because the larvae seem to enter through minute cracks in the skin or penetrate through hair follicles (Schmidt and Roberts 1977:444). Once in the skin, however, the larvae induce an itching sensation which is related to the immune response of the subcutaneous tissues to the invading larvae. Within hours, an allergic reaction, to the worms and their products is seen as a puritic, erythematous rash that may become vesicular (Beaver et al 1984:281). This reaction is popularly known as "ground itch" (Beaver et al 1984:281). Secondary bacterial infections are common

when the lesions are abraded by scratching (Beaver et al 1984:281). The pulmonary migration of hookworm larvae produces minute focal hemorrhages in the capillaries as they break out into the alveoli (Beaver et al 1984:283). This phase of the infection is generally asymptomatic, although a dry cough and sore throat may occur (Schmidt and Roberts 1977:445). The severe pneumonitis typically associated with pulmonary ascariasis, is generally nonexistent except in the rare instances of a massive simultaneous migration of the larvae (Beaver et al 1984:283; Schmidt and Roberts 1977:445).

The ingestion of A. duodenale infective larvae results in a different clinical picture. Although some larvae pass directly to the small intestine, others penetrate the mucous membranes of the mouth and pharynx to carry out a lung migration (Beaver et al 1984:283). The clinical signs associated with this mode of transmission include nausea, vomiting, excessive salivation, itching of the pharynx, and hoarseness (Beaver et al 1984:283). These initial symptoms are followed by an illness of several days duration which includes coughing, dyspnea, hypereosinophillia, nausea and vomiting (Beaver et al 1984:283). These rather severe symptoms may be the result of an allergic reaction to the invading larvae (Beaver et al 1984:283). The intestinal phase of hookworm infection

has the most serious consequence to the health of the host. The arrival of the worms in the small intestine is marked by their attachment to the mucosa of the intestinal wall. Once attached, the worms digest portions of the villi, and suck blood from the tissues in great amounts. Although it has been estimated that a single A. duodenale is capable of sucking approximately 0.15 ml of blood per day, the actual blood loss may be higher because of superfluous bleeding at the attachment site (Beaver et al 1984:284; Schmidt and Roberts 1977:445). Acute infections with Ancylostoma typically result in fatigue, nausea, vomiting, followed by intense burning and abdominal cramping. Stools are generally diarrheic and vary in color from black to red depending on the amount and rate of blood loss. Heavy hookworm infections, especially in infants, are often characterized by massive intestinal hemorrhage and may result in death due to shock.

Chronic ancylostomiasis may be manifested in particular individuals as "hookworm disease". The severity of the disease is directly proportional to the worm burden and the overall nutritional health of the affected individual (Schmidt and Roberts 1977:443). The pivotal point to the distinction between "hookworm infection" and "hookworm disease" is that far more people are infected with the worm than those who

exhibit symptoms of the disease (Schmidt and Roberts 1977:443). Hookworm disease is typically characterized by a profound iron deficiency anemia with varying degrees of pallor, facial and pedal edema, listlessness and apathy. The adverse effects of hookworm disease are exacerbated by poor nutrition and concurrent infections with other parasitic helminths such as Ascaris lumbricoides and Trichuris trichura (human whipworm) (Beaver et al 1984:316; Schmidt and Roberts 1977:445). Populations subsisting on high carbohydrate diets are particularly susceptible to iron deficiency anemia due to the synergistic effect of blood loss by the worms and the presence of iron binding phytates in many starchy plant foods which reduce the availability of dietary iron. Children raised under these circumstances generally exhibit retarded physical and mental development and impaired antibody production to various infectious diseases (Schmidt and Roberts 1977:445). From a population perspective, the long term consequences of chronic ancylostomiasis may be deleterious to the overall fitness of a cultural group by adversely affecting its work capacity, immunological resistance and reproductive sufficiency through increased infant mortality.

Giardia intestinalis

Giardia intestinalis is a protozoan parasite that resides in the intestinal tract of a wide variety of mammalian, avian, and reptillian hosts (Beaver et al 1984:44; Kulda and Nohynkova 1978: Table 8). Giardia has a two stage life cycle that includes both a trophozoite and cyst stage. The life cycle is direct and does not require an intermediate host prior to infecting the definitive or final host. The trophozoite is the motile, feeding stage of the organism which attaches to the villi of the small intestine in the infected host by means of an adhesive sucking disk (Kirkpatrick 1987). The cyst is the dormant stage of the life cycle and is typically passed in the feces of the infected host (Kirkpatrick 1987). In contrast to the trophozoites that die soon after passage from the host, the cysts are relatively resistant to deterioration and may remain viable for several weeks in cold (but not frozen) wet environmental conditions (Kirkpatrick 1987). Infection with the parasite is the result of accidental ingestion of the cyst stage of the organism. Contact with cyst contaminated water is the most frequently documented mode of transmission. Giardiasis has been reported among hikers and campers who drank from contaminated mountain streams (Beaver et al 1984:46). In remote areas, where fecal contamination of the water by people is unlikely, wild animals have

been implicated as reservoir hosts for the infection (Beaver et al 1984:46).

Many cases of infection with Giardia are asymptomatic. Available evidence suggests that some individuals residing in hyper-endemic localities are capable of acquiring protective immunity to infection with the parasite (Istre et al 1984). Other individuals, however, are more sensitive to infection and experience increased mucous production, severe and transitory diarrhea, dehydration, intestinal pain, flatulence, and weight loss (Beaver et al 1984:46; Kulda and Nohynkova 1978:95). In heavy infections, the absorption of dietary fats and nutrients may be impaired because of the dense coating of trophozoites on the intestinal epithelium (Beaver et al 1984:46; Kulda and Nohynkova 1978:95). Children in traditional non-westernized cultures are particularly vulnerable to the adverse effects of giardiasis. In rural Guatemala, for example, it was found that the death rate resulting from diarrhea was 519 times greater than that in the United States for preschool age children per 1,000 population (Logan 1978:183). This high mortality rate can be attributed, in part, to traditional medical practices such as dietary restrictions on food and liquids which serves to exacerbate harmful dehydration resulting from the diarrhea (Logan 1978:184). Thus, while giardiasis is generally not fatal in

immunocompetent individuals, the presence of the infection in a traditional non-westernized setting may have a profound impact on the overall health and well being of a cultural group.

# CHAPTER 9

# DISCUSSION AND CONCLUSIONS

The interdisciplinary orientation of the Big Bone Cave paleofecal research has resulted in a wealth of information regarding the dietary behavior and prevalence of parasitic infection among the population using the cave. These data provide a potentially useful context for interpreting the settlement and subsistence patterns manifested in the Early Woodland period in central Tennessee. A brief discussion of the analyses undertaken in this study is presented in the section below. The general conclusions of the research are presented in the subsequent section.

## Discussion

The first problem addressed in this study was to determine that each of the feces was human in origin, and unequivocally associated with aboriginal utilization of the cave. Evidence to substantiate these inferences was sought in the parasitological and dietary content analyses because of the subjective nature of the attempt to determine human origin by the external morphology of the specimens, and the ambiguous results generated in the experimental rehydration analysis.

The recovery of Enterobius vermicularis (human pinworm) eggs in five of the eight feces provides the best evidence for unequivocally attributing the Big Bone Cave paleofeces to human defecation behavior because humans are the only known definitive host for this intestinal parasite. The recovery of the feces from various locations associated with prehistoric mining activity in excess of 1.5 km from the cave entrance further suggests that domestic dogs or other copraphagous mammals were not potential sources for the fecal samples analyzed in this study. The identification of prehistorically domesticated plant taxa in the dietary contents indicates that the feces are associated with aboriginal utilization of the cave and not the products of the 19th century saltpeter miners or 20th century speleologists. The radiocarbon determination (2550 +/- 80 B. P., Beta-32546) from Specimen 1 provides unequivocal support for the antiquity of the feces and their dietary contents.

The results of the Big Bone Cave dietary content analysis represent a significant contribution toward an understanding of the subsistence economy for the Early Woodland period in central Tennessee. The radiocarbon age of 2220 +/- 135 B. P. for the utilization of Big Bone Cave supports the inference that the record of plant food utilization represented in the feces is intermediary between the

ethnobotanical records obtained from Terminal Archaic and Middle Woodland Period archaeological contexts in central Tennessee. Ethnobotanical remains from the Chapman site (40JK102), a Terminal Archaic Period mortuary/ habitation site, indicated a subsistence economy based primarily on arboreal seed crops, supplemented by the gathering of herbaceous annuals like maygrass (Crites 1985:102). Evidence of small scale horticultural activities was indicated by the recovery of squash remains, a single sunflower achene and three Chenopodium berlandieri seeds (Crites 1985:105). Plant remains from Middle Woodland period contexts in the Eastern Highland Rim, in contrast, suggest a pattern of utilization characterized by increased reliance on and cultivation of a narrow suite of indigenous weedy annual plant species (Crites 1987:729). The primary plant taxa implicated in Crites's (1987) agroecology are Chenopodium berlandieri, C. missouriense and Phalaris caroliniana (maygrass). These taxa account for 80 to 95% of the plant remains recovered from early and late Middle Woodland period contexts in central Tennessee (Crites 1987: Table 1). This dramatic increase in the representation of cultivated plant taxa has been interpreted as a reflection of increasing population density and demands on plant resource potential during the Middle Woodland period (Crites 1987:733).

The Big Bone Cave ethnobotanical assemblage is consistent with the expectation that it is intermediary between the assemblages documented from Terminal Archaic and Middle Woodland period contexts in central Tennessee. These data indicate that a substantial portion (52%) of the dietary contents represented in the feces are derived from horticultural activities (Figure 2). In order of decreasing abundance, the primary plant taxa represented in the feces include Iva annua, Chenopodium sp., and Helianthus annuus. Each of these taxa are both numerically abundant and ubiquitous in the fecal samples. The measurements of the Iva annua achenes preserved in the feces are comparable with the domesticated sumpweed attributed to the Early Woodland utilization of Salts Cave, Kentucky. Additionally, the SEM analysis of a sample of the Chenopodium seeds suggests that some of the goosefoot represented in the Big Bone Cave feces may be tentatively attributed to the domesticated taxon C. berlandieri ssp. jonesianum. Additional research is necessary, however, to fully determine the potential contribution of this taxon in the dietary remains. Interestingly, both Iva annua and Helianthus annuus are well represented in the Big Bone Cave ethnobotanical assemblage, while evidence of their utilization is comparatively scarce from Middle Woodland period sites in central

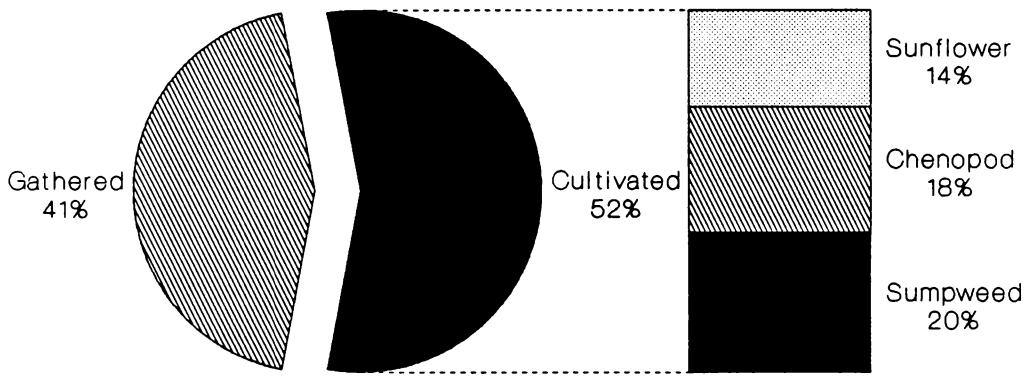



**Figure 2. Relative Percentages of Principal Food Plants Represented in Big Bone Cave Dietary Contents.**

Tennessee. This discrepancy may be an indication that the ethnobotanical assemblage from the Middle Woodland period sites in central Tennessee is incomplete, and therefore biased toward taxa which require parching as part of their preparation for storage (Gasser and Adams 1981; Yarnell 1982). It is worth noting that none of the sumpweed and sunflower preserved in the Big Bone feces exhibited any evidence of parching or contact with fire. This may well indicate that these taxa were processed differently prior to storage and consumption.

Although wild plant food species comprised approximately 41% of the food weight (Figure 2), hickory nutshell accounted for 37% of this weight. Most of the hickory nutshell, however, was recovered from a single specimen. The dominance of hickory nutshell in the feces is not surprising because the relative percentages were computed based on the weight of the taxa recovered. Hickory nutshell may be overrepresented. Nevertheless, the ubiquity of hickory nut in each of the eight feces suggests that it was at least as important as Iva annua and Chenopodium sp. in the diet of the Big Bone cavers. The consumption of Viburnum prunifolium berries was indicated in a single specimen by numerous seeds and an intact berry that was voided without mastication. The relative contribution of this taxon accounted for approximately

3% of the total food weight. Evidence of meat consumption accounted for less than 1% of the total weight of the identifiable dietary contents.

In general, the dietary pattern reconstructed from the Big Bone Cave feces is comparable to Yarnell's (1974: Table 16.5) quantified estimates of the Salts Cave dietary contents where approximately 72% of the identifiable subsistence remains can be associated with horticultural activities. It is important to point out that Yarnell's (1974) percentages are based on well founded estimates of the relative abundance of the plant foods consumed. Nevertheless, his results are essentially comparable to those obtained from the Big Bone Cave analysis.

The most striking difference between the Salts and Mammoth Cave and Big Bone Cave dietary patterns is the diversity and comparative lack of diversity in the plant foods represented between them. The Salts and Mammoth Cave samples contained evidence of maygrass, strawberry, blackberry, blueberry, and grape consumption (Marquardt 1974: Table 24.1; Stewart 1974: Table 5.1, Table 5.2; Yarnell 1974: Table 16.5). Evidence of these taxa, as indicated by their seeds, was lacking in the Big Bone Cave feces. The recovery of the extremely small seeds of Portulaca oleracea (purslane) Cerastium sp. (chickweed) and Panicum dichotomiflorum (panic grass) substantiates the belief

that these taxa were not overlooked due to their small size. The most parsimonious explanation for the non-representation of these taxa in the Big Bone Cave feces may be a function of the sample size. Because only eight feces were analyzed from Big Bone Cave compared to the 165 feces analyzed from Salts and Mammoth caves, it is reasonable to expect that the Big Bone Cave sample should exhibit less diversity. The lack of maygrass in the Big Bone feces is problematical, however, especially in light of the apparent importance of this plant in the earlier Terminal Archaic and later Middle Woodland ethnobotanical assemblages from central Tennessee. Until additional paleofecal material has been examined, the inference that maygrass was not among the plant taxa consumed by the population utilizing Big Bone Cave is unwarranted.

The results of the palynological analysis indicated that the majority of pollen represented in the Big Bone Cave fecal samples was derived from the economic utilization of Iva annua and Chenopodium. As noted in Chapter 7, the representation of these taxa in the economic pollen component parallels their importance in the dietary contents. There was no palynological evidence of the intentional consumption of plant inflorescences in any of the feces examined.

A consideration of the pollen attributed to background contamination indicated that seven of the eight fecal specimens are referable to the spring months of the year. The consistent occurrence of several spring flowering arboreal taxa in each of the feces supports this assessment. Although the individual representation of these taxa was low, it has been argued that their significance as indicators of seasonality is justified based on the pattern of co-representation with other spring flowering trees.

In general, the palynological record from the Big Bone Cave feces is comparable with the evidence obtained from analysis of the Salts and Mammoth Cave samples. The pollen spectra from Salts and Mammoth caves were dominated primarily by pollen derived from the economic utilization of particular plant taxa (Schoenwetter 1974: Table 6.1; Bryant 1974b: Table 25.1). The most secure assessments of seasonality from those feces was based on the identification of abundant quantities of pollen derived from intentional consumption of the flowers of spring flowering herbaceous perennials (Bryant 1974b:208; Schoenwetter 1974:55). Pollen derived from arboreal sources, accounted for between 3.5 and 6.5% of the total pollen count (Schoenwetter 1974: Table 6.1).

Inordinately high counts of pollen derived from arboreal sources may be atypical of the usual pattern

of background representation in fecal samples. This contention is supported by informal observations of arboreal pollen representation in modern fecal samples submitted to the UTCVM clinical parasitology laboratory for parasitological analysis. The proximity of pollen shedding trees to residential areas and water sources may have a significant effect on the representation of arboreal taxa in fecal samples by distributing abundant quantities of pollen to localities and food sources where incidental ingestion is inevitable. The results of Cowan's (1978) palynological analysis of five paleofecal specimens from the Haystack rockshelter (15PO47), Powell County, Kentucky, is a striking example of this point. The predominance of arboreal pollen in these samples may be a function of the close proximity of pollen shedding trees to the rockshelter and/or the water sources used by the occupants of this site. Additional research is necessary to fully elucidate the factors affecting the representation and concentration of arboreal pollen in paleofecal samples.

The parasitological data from the Big Bone Cave fecal samples is consistent with the expectation that increased sedentary behavior during the Woodland period is reflected in the prevalence of parasitic infections typically associated with sedentism, poor sanitation and crowded living conditions.

Enterobius vermicularis occurred in five of the eight feces examined. The ubiquity of this parasite among the population using Big Bone Cave is not surprising given its ease of transmission and the crowded living conditions commonly attributed to prehistoric societies. The prevalence of E. vermicularis in approximately 62% of the feces is sufficient to infer that a large portion of the population using the cave was infected because pinworm is generally diagnosed by fecal examination in only 5% of the cases identified with the superior scotch tape technique (Beaver et al 1984:305). Although E. vermicularis is the most frequently encountered endoparasite preserved in fecal samples attributed to Anasazi occupations of the Colorado Plateau, evidence of the organism has not been reported previously from Eastern North America (Samuels 1965; Reinhard et al 1987; Reinhard 1988).

Eggs resembling those of the intestinal roundworm Ascaris lumbricoides were found in two specimens. The occurrence of Ascaris in the Big Bone feces is indicative of the living conditions which prevailed during the Early Woodland time period. Minimally these data indicate contact with fecally contaminated soil and lack of adequate sanitation in the habitation site of the defecator. A semi-sedentary or transhumant lifestyle is also implied by the life cycle of this

parasite because the eggs require a minimum incubation period of 18 days to become infective (Beaver et al 1984:309).

A single Ancylostomoid egg and several first-stage rhabditiform larvae were identified in two of the eight fecal samples examined. The recovery of these parasite products in the Big Bone Cave feces further attests to the lack of adequate sanitation among the population using the cave. In cultures where hookworm infection is endemic, promiscuous defecation habits and the use of night soil for fertilizer provide exceptionally good opportunities for continuous inoculation of the soil with eggs, and exposure of the people to the infective larvae (Beaver et al 1984:280). The relationship of ascariasis and ancylostomiasis with sedentism is substantiated by epidemiological studies of parasitic infection among relatively unacculturated hunting-gathering populations and sedentary fishing-farming populations (Cockburn 1971; Chernela and Thatcher 1989; Tobias 1966). Interestingly, these studies have shown that infections with roundworm or hookworm are comparatively scarce or altogether lacking among mobile hunting and gathering populations (Cockburn 1971; Tobias 1966). This striking difference in the prevalence of parasitic infection is presumably attributed to the frequent relocation of

hunter-gatherer foraging bases which effectively preclude transmission by minimizing exposure of the people to infective eggs and larvae (Cockburn 1971; Truswell and Hansen 1976).

Protozoan cysts identified as Giardia intestinalis were observed in one specimen. Because infection with this parasite is simply the result of drinking contaminated water, correlating the presence of the cysts in the Big Bone Cave feces with poor sanitation among the population using the cave is unwarranted. Giardiasis has been diagnosed among hunting and gathering populations as well as sedentary village dwellers (Cockburn 1971; Chernela and Thatcher 1989). The only report of Giardia in a prehistoric context, however, is the identification of the cysts in two 1800 year-old paleofecal specimens recovered from a cave in Israel (Witenburg 1961). Evidence of the organism has not been reported previously from paleofeces in the New World.

Surprisingly, there was no evidence of Trichuris trichura (human whipworm) infection found in any of the Big Bone Cave fecal samples. The prevalence of this parasite has been widely documented as a human health concern throughout the southeastern United States in areas where poor sanitation and appropriate environmental conditions coincide (Beaver et al 1984:242; Schmidt and Roberts 1977:421). The

identification of Ascaris lumbricoides and tentative identification of Ancylostoma duodenale among the population using the cave indirectly indicates that these conditions were characteristic of prehistoric habitation sites during the Woodland period. Trichuris eggs have only been reported from prehistoric age deposits in North America once, despite the vast quantity of paleofecal material examined from the southwestern United States (Horne 1985). The overall scarcity of this parasite in the arid southwest has been attributed to the absence of dense shade and moisture retaining soil (Horne 1985). Certainly, these environmental conditions do not pertain to the humid southeast where the climate, vegetation and substrate are favorable to its survival. The absence of Trichuris eggs in the Big Bone Cave feces is probably not an artifact of preservation. The thick-shelled eggs are extremely resistant to weathering and the sheltered nature of the cave environment should be ideal for their preservation. Examination of additional material is necessary to infer that Trichuris trichura was not one of the parasitic infections among the population using the cave.

## Conclusions

The comparatively small sample of paleofeces from Big Bone Cave precludes all but the most general conclusions regarding the dietary behavior and the prevalence of parasitic infection during the Early Woodland period in central Tennessee. The ethnobotanical assemblage preserved in the dietary contents indicates substantial utilization of Iva annua, Chenopodium sp., and Helianthus annuus. These indigenous weedy plant species are intimately associated with human horticultural activities. The relative representation of the dietary items identified in the feces suggests that domesticated and/or cultivated foods are at least as important as those obtained from food gathering. This dietary pattern is intermediary between the subsistence patterns documented from Terminal Archaic and Middle Woodland period contexts in central Tennessee. Palynological evidence from the feces supports the interpretation that the primary focus of cave utilization occurred during the spring months of the year. Given that the dietary items identified in the feces are exclusively fall-available plant species, their consumption during the spring implies that they were stored food commodities. The recovery of a weevil

larva from a single fecal specimen indirectly supports this contention.

The prevalence of endoparasitic infections typically associated with sedentism, poor sanitation, and crowded living conditions supports the conclusion that the settlement pattern of the population using the cave was characterized by decreased residential mobility, and probably entailed the occupation of multi-seasonal nucleated habitation sites during the warmer months of the year.

Continued research of the paleofeces preserved in Big Bone Cave is warranted by the conclusions offered in this study. The plant species represented in the dietary contents are among the earliest prehistoric domesticates in Tennessee. This information is potentially significant to understanding the development and origins of prehistoric food production in Eastern North America. The evidence of endoparasitic infection preserved in the Big Bone Cave fecal sample is the most complete record available in Eastern North America. This information is a new contribution to the development of an understanding of the relative health status and living conditions which prevailed in the emergent horticultural societies of prehistoric Eastern North America. Two of the helminths, Enterobius vermicularis, and the

Ancylostomoid species, have never been reported from prehistoric context in Eastern North America. The identification of Giardia cysts in a single specimen is the earliest evidence of the organism in the New World and represents the first successful attempt to apply immunological techniques to the identification of parasite products recovered from archaeological context. The collection of a larger sample of fecal material from Big Bone Cave will be necessary for evaluating the non-representation of particular plant species like maygrass and endoparasitic species such as Trichuris trichura in the specimens examined by this study. The acquisition of additional samples with stricter contextual control will allow future investigations to focus on delineating potentially meaningful diachronic trends manifested in the dietary behavior and prevalence of parasitic infections among the prehistoric population(s) utilizing the cave.

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# APPENDIXES

# APPENDIX A

## DIETARY CONTENT DATA

Table 7. Dietary content data for Big Bone Cave Paleofecal Specimen 1

| Food Item | Gram Weight | Percent Represented |
|---|---|---|
| *Iva annua* | 0.54486 | 43.85 |
| *Chenopodium* sp. | 0.43848 | 35.07 |
| *Polygonum erectum* | 0.04620 | 3.69 |
| *Carya* nutshell | 0.19303 | 15.44 |
| Wood charcoal/nutshell | 0.02748 | 2.19 |
| Undifferentiated botanical | 0.00003 | ---- |
| Total Cultivated Plant foods | 1.02954 | 82.61 |
| Total Gathered Plant Foods | 0.19303 | 15.44 |
| Total Sorted Material | 1.25008 | 73.44 |
| Total Residual Material | 0.45204 | 26.55 |
| Total All Materials > 1mm | 1.70212 | 44.21 |
| Total All Materials < 1mm | 2.14718 | 55.78 |
| Total Sample Weight | 3.84930 | 99.99 |
| Total Dried Weight | 16.59000 | |

Table 8. Dietary content data for Big Bone Cave Paleofecal Specimen 2

| Food Item | Gram Weight | Percent Represented |
|---|---|---|
| Iva annua | 0.65890 | 32.37 |
| Chenopodium sp. | 0.40907 | 20.09 |
| Polygonum erectum | 0.01802 | .88 |
| Helianthus annuus | 0.01190 | .58 |
| Carya nutshell | 0.42580 | 20.92 |
| Viburnum prunifolium | 0.23273 | 11.43 |
| Fruit skin | 0.03926 | 1.92 |
| Undifferentiated botanical | 0.23376 | 11.48 |
| Wood charcoal/nutshell | 0.00580 | .28 |
| Feather fragment | 0.00001 | ----- |
| Total Cultivated Plant foods | 1.09789 | 53.94 |
| Total Gathered Plant Foods | 0.69779 | 34.28 |
| Total Sorted Material | 2.03525 | 62.02 |
| Total Residual Material | 1.24625 | 37.97 |
| Total All Materials > 1mm | 3.28149 | 52.76 |
| Total All Materials < 1mm | 2.93800 | 47.23 |
| Total Sample Weight | 6.21950 | 99.99 |
| Total Dried Weight | 21.93000 | |

Table 9. Dietary content data for Big Bone Cave Paleofecal Specimen 3

| Food Item | Gram Weight | Percent Represented |
|---|---|---|
| Iva annua | 0.16855 | 7.95 |
| Chenopodium sp. | 0.28105 | 13.27 |
| Carya nutshell | 1.59755 | 75.44 |
| Rhus sp. | 0.00598 | .28 |
| Undifferentiated botanical | 0.00003 | ----- |
| Wood charcoal/nutshell | 0.00001 | ----- |
| Feather fragment | 0.06431 | 3.03 |
| Total Cultivated Plant foods | 0.44969 | 21.23 |
| Total Gathered Plant Foods | 1.60353 | 75.72 |
| Total Sorted Material | 2.11744 | 73.82 |
| Total Residual Material | 0.75094 | 26.17 |
| Total All Materials > 1mm | 2.86842 | 68.79 |
| Total All Materials < 1mm | 1.30121 | 31.20 |
| Total Sample Weight | 4.16963 | 99.99 |
| Total Dried Weight | 14.97000 | |

Table 10. Dietary content data for Big Bone Cave Paleofecal Specimen 4

| Food Item | Gram Weight | Percent Represented |
|---|---|---|
| Iva annua | 0.13284 | 21.74 |
| Chenopodium sp. | 0.01451 | 2.37 |
| Carya nutshell | 0.46364 | 75.88 |
| Undifferentiated botanical | 0.00003 | ----- |
| Wood charcoal/nutshell | 0.00001 | ----- |
| Total Cultivated Plant foods | 0.14735 | 24.11 |
| Total Gathered Plant Foods | 0.46364 | 75.88 |
| Total Sorted Material | 0.61103 | 86.39 |
| Total Residual Material | 0.09619 | 13.60 |
| Total All Materials > 1mm | 0.70722 | 46.20 |
| Total All Materials < 1mm | 0.82343 | 53.79 |
| Total Sample Weight | 1.53065 | 99.99 |
| Total Dried Weight | 5.92000 | |

Table 11. Dietary content data for Big Bone Cave Paleofecal Specimen 5

| Food Item | Gram Weight | Percent Represented |
|---|---|---|
| Iva annua | 0.03332 | 3.77 |
| Chenopodium sp. | 0.00668 | .75 |
| Carya nutshell | 0.75907 | 86.03 |
| Panicum dichotomiflorum | 0.01656 | 1.87 |
| Undifferentiated botanical | 0.06663 | 7.54 |
| Feather fragments | 0.00001 | ----- |
| Total Cultivated Plant foods | 0.04000 | 4.52 |
| Total Gathered Plant Foods | 0.77563 | 87.91 |
| Total Sorted Material | 0.88227 | 83.62 |
| Total Residual Material | 0.17270 | 16.37 |
| Total All Materials > 1mm | 1.05497 | 63.25 |
| Total All Materials < 1mm | 0.61290 | 36.74 |
| Total Sample Weight | 1.66787 | 99.99 |
| Total Dried Weight | 6.55000 | |

Table 12. Dietary content data for Big Bone Cave Paleofecal Specimen 6

| Food Item | Gram Weight | Percent Represented |
|---|---|---|
| Iva annua | 0.16108 | 85.01 |
| Chenopodium sp. | 0.01168 | 6.16 |
| Polygonum erectum | 0.00001 | ----- |
| Helianthus annuus | 0.00001 | ----- |
| Carya nutshell | 0.00001 | ----- |
| Undifferentiated botanical | 0.01668 | 8.80 |
| Wood charcoal/nutshell | 0.00001 | ----- |
| Total Cultivated Plant foods | 0.17278 | 91.19 |
| Total Gathered Plant Foods | 0.00000 | 00.00 |
| Total Sorted Material | 0.18948 | 99.99 |
| Total Residual Material | 0.00000 | ----- |
| Total All Materials > 1mm | 0.18948 | 13.71 |
| Total All Materials < 1mm | 1.19211 | 86.28 |
| Total Sample Weight | 1.38154 | 99.99 |
| Total Dried Weight | 5.86000 | |

Table 13. Dietary content data for Big Bone Cave Paleofecal Specimen 7

| Food Item | Gram Weight | Percent Represented |
|---|---|---|
| Iva annua | 0.06458 | 17.85 |
| Chenopodium sp. | 0.15700 | 43.40 |
| Carya nutshell | 0.14010 | 38.70 |
| Wood charcoal/nutshell | 0.00001 | ----- |
| Total Cultivated Plant foods | 0.22158 | 61.25 |
| Total Gathered Plant Foods | 0.14010 | 38.70 |
| Total Sorted Material | 0.36169 | 86.28 |
| Total Residual Material | 0.05754 | 13.71 |
| Total All Materials > 1mm | 0.41923 | 46.26 |
| Total All Materials < 1mm | 0.48699 | 53.73 |
| Total Sample Weight | 0.90622 | 99.99 |
| Total Dried Weight | 3.88000 | |

Table 14. Dietary content data for Big Bone Cave Paleofecal Specimen 8

| Food Item | Gram Weight | Percent Represented |
|---|---|---|
| Iva annua | 0.15798 | 7.41 |
| Chenopodium sp. | 0.37982 | 17.82 |
| Polygonum erectum | 0.00700 | .32 |
| Helianthus annuus | 1.27718 | 59.94 |
| Carya nutshell | 0.03508 | 1.64 |
| Portulaca oleracea | 0.00001 | ----- |
| Cerastium sp. | 0.00001 | ----- |
| Undifferentiated botanical | 0.25674 | 12.05 |
| Wood charcoal/nutshell | 0.00296 | .13 |
| Feather fragments | 0.00219 | .10 |
| Avian bone | 0.00825 | .38 |
| Inorganic (mineral) | 0.00327 | .15 |
| Total Cultivated Plant foods | 1.82198 | 85.49 |
| Total Gathered Plant Foods | 0.03508 | 1.64 |
| Total Sorted Material | 2.13049 | 66.60 |
| Total Residual Material | 1.06829 | 33.39 |
| Total All Materials > 1mm | 3.19878 | 62.17 |
| Total All Materials < 1mm | 1.94581 | 37.82 |
| Total Sample Weight | 5.14457 | 99.99 |
| Total Dried Weight | 18.36000 | |

# APPENDIX B

## POLLEN DATA

Table 15. Pollen data for Big Bone Cave Paleofecal Specimen 1

| Pollen Type | Grains Counted | Percent Represented |
|---|---|---|
| *Iva cillata* type * | 192 | 63.36 |
| Low Spine Asteraceae type | 76 | 25.08 |
| High Spine Asteraceae type | 1 | .33 |
| *Chenopodium/Amaranthus* type* | 20 | 6.60 |
| *Polygonum aviculare* type* | 7 | 2.31 |
| Gramineae | 1 | .33 |
| *Pinus* sp. | 1 | .33 |
| *Carya* sp. | 1 | .33 |
| *Juglans* sp. | 1 | .33 |
| *Quercus* sp. | 3 | .99 |
| Total Economic Pollen | 219 | 72.27 |
| Total Background Pollen | 84 | 27.72 |
| Total Pollen Counted | 303 | 99.99 |

* Inclusion in the economic pollen component

Table 16. Pollen data for Big Bone Cave Paleofecal Specimen 2

| Pollen Type | Grains Counted | Percent Represented |
|---|---|---|
| *Iva cillata* type* | 215 | 71.19 |
| Low Spine Asteraceae | 47 | 15.56 |
| High Spine Asteraceae* | 3 | .99 |
| *Chenopodium/Amaranthus* type* | 27 | 8.94 |
| *Polygonum aviculare* type* | 1 | .33 |
| *Pinus* sp. | 1 | .33 |
| *Betula* sp. | 1 | .33 |
| *Carya* sp. | 1 | .33 |
| *Juglans* sp. | 1 | .33 |
| *Celtis* sp. | 1 | .33 |
| *Quercus* sp. | 3 | .99 |
| *Cornus* sp. | 1 | .33 |
| Total Economic Pollen | 246 | 81.45 |
| Total Background Pollen | 56 | 18.54 |
| Total Pollen Counted | 302 | 99.99 |

* Inclusion in economic pollen component

Table 17. Pollen data for Big Bone Cave Paleofecal Specimen 3

| Pollen Type | Grains Counted | Percent Represented |
|---|---|---|
| *Iva cillata* type* | 125 | 41.39 |
| Low Spine Asteraceae type | 69 | 22.84 |
| High Spine Asteraceae type | 5 | 1.65 |
| *Chenopodium/Amaranthus* type* | 97 | 32.11 |
| *Pinus* sp. | 1 | .33 |
| *Corylus* sp. | 1 | .33 |
| *Carya* sp. | 1 | .33 |
| *Celtis* sp. | 1 | .33 |
| *Quercus* sp. | 2 | .66 |
| Total Economic Pollen | 222 | 73.50 |
| Total Background Pollen | 80 | 26.49 |
| Total Pollen Counted | 302 | 99.99 |

* Inclusion in economic pollen component

Table 18. Pollen data for Big Bone Cave Paleofecal Specimen 4

| Pollen Type | Grains Counted | Percent Represented |
|---|---|---|
| *Iva cillata* type* | 164 | 50.77 |
| Low Spine Asteraceae type | 148 | 45.82 |
| *Chenopodium/Amaranthus* type* | 4 | 1.23 |
| Gramineae | 5 | 1.54 |
| *Pinus* sp. | 1 | .30 |
| *Artemisia* sp. | 1 | .30 |
| Total Economic Pollen | 168 | 52.17 |
| Total Background Pollen | 155 | 47.82 |
| Total Pollen Counted | 323 | 99.96 |

* Inclusion in economic pollen component

Table 19. Pollen data for Big Bone Cave Paleofecal Specimen 5

| Pollen Type | Grains Counted | Percent Represented |
|---|---|---|
| *Iva cillata* type* | 173 | 57.47 |
| Low Spine Asteraceae type | 83 | 27.57 |
| High Spine Asteraceae type | 2 | .66 |
| *Chenopodium/Amaranthus* type* | 15 | 4.98 |
| Gramineae* | 10 | 3.32 |
| *Gaura* sp. | 1 | .33 |
| *Pinus* sp. | 5 | 1.66 |
| *Juglans* sp. | 4 | 1.32 |
| *Ulmus* sp. | 1 | .33 |
| *Castanea* sp. | 2 | .66 |
| *Quercus* sp. | 3 | .99 |
| *Liriodendron* sp. | 2 | .66 |
| Total Economic Pollen | 198 | 65.78 |
| Total Background Pollen | 103 | 34.21 |
| Total Pollen Counted | 301 | 99.95 |

* Inclusion in economic pollen component

Table 20. Pollen data for Big Bone Cave Paleofecal Specimen 6

| Pollen Type | Grains Counted | Percent Represented |
|---|---|---|
| *Iva cillata* type* | 202 | 63.92 |
| Low Spine Asteraceae type | 88 | 27.84 |
| High Spine Asteraceae type* | 2 | .63 |
| *Chenopodium/Amaranthus* type* | 18 | 5.69 |
| *Pinus* sp. | 2 | .63 |
| *Alnus* sp. | 2 | .63 |
| *Ostrya/Carpinus* type | 1 | .31 |
| *Quercus* sp. | 1 | .31 |
| Total Economic Pollen | 222 | 70.25 |
| Total Background Pollen | 94 | 29.74 |
| Total Pollen Counted | 316 | 99.99 |

* Inclusion in economic pollen component

Table 21. Pollen data for Big Bone Cave Paleofecal Specimen 7

| Pollen Type | Grains Counted | Percent Represented |
|---|---|---|
| *Iva cillata* type* | 216 | 66.46 |
| Low Spine Asteraceae | 77 | 23.69 |
| High Spine Asteraceae type | 1 | .30 |
| *Chenopodium/Amaranthus* type* | 16 | 4.92 |
| *Polygonum aviculare* type | 1 | .30 |
| Gramineae | 7 | 2.15 |
| *Gaura* sp. | 1 | .30 |
| *Pinus* sp. | 3 | .90 |
| *Quercus* sp. | 2 | .60 |
| *Cornus* sp. | 1 | .30 |
| Total Economic Pollen | 232 | 71.38 |
| Total Background Pollen | 93 | 28.61 |
| Total Pollen Counted | 325 | 99.99 |

* Inclusion in economic pollen component

Table 22. Pollen data for Big Bone Cave Paleofecal Specimen 8

| Pollen Type | Grains Counted | Percent Represented |
|---|---|---|
| *Iva cillata* type* | 158 | 49.68 |
| Low Spine Asteraceae type | 74 | 23.27 |
| High Spine Asteraceae type* | 19 | 5.97 |
| *Chenopodium/Amaranthus* type* | 50 | 15.72 |
| *Polygonum aviculare* type* | 10 | 3.14 |
| Gramineae | 3 | .94 |
| *Pinus* sp. | 2 | .62 |
| *Quercus* sp. | 2 | .62 |
| Total Economic Pollen | 237 | 74.52 |
| Total Background Pollen | 82 | 25.47 |
| Total Pollen Counted | 319 | 99.99 |

* Inclusion economic pollen component

## APPENDIX C

## PROJECT BENCHMARKS

The following benchmarks have been achieved during the course of this research:

PUBLICATIONS:

Prehistoric Parasitism in Tennessee: Evidence from Paleofecal Samples Collected from Big Bone Cave, Van Buren County, Tennessee. Charles T. Faulkner, Sharon Patton, and Sandra Strawbridge Johnson. Journal of Parasitology **75:** 461-463.

Desiccated Human Paleofeces from Big Bone Cave (40VB103), Van Buren County, Tennessee. Charles T. Faulkner. Tennessee Anthropological Association Newsletter **14** (2): 1-7.

AWARDS AND HONORS:

First Prize in the Social Sciences Category. 1988 Sigma-Xi Student Paper Competition, University of Tennessee, Knoxville TN. Analysis of Paleofecal Samples from Big Bone Cave, Van Buren County, Tennessee: An Overview of the Research.

Elon E. Byrd Award for the best student presentation at the 1987 Annual Meeting of the Southeastern Society of Parasitologists, University of Georgia, Athens GA. Analysis of Paleofecal Samples from Big Bone Cave, Van Buren County, Tennessee.

GRANTS RECEIVED:

University of Tennessee Faculty Development Grant. Dr. Sharon Patton, Charles T. Faulkner, Sandra Johnson, Dr. Robert Edwards. Identification of Protozoan Cysts Isolated from Paleofecal Samples Collected from Big Bone Cave, Van Buren County, Tennessee. $700.

PAPERS PRESENTED AT PROFESSIONAL MEETINGS:

Desiccated Human Paleofeces from Big Bone Cave (40VB103), Van Buren County, Tennessee. **Program and Abstracts of the 1989 National Speleological Society Convention,** University of the South. Sewanee, Tennessee.

Prehistoric Disease and Dietary Behavior: Evidence from Paleofecal Samples Collected from Big Bone Cave, Van Buren County, Tennessee. Coauthored with Dr. Sharon Patton and Sandra Johnson, Dept of Pathobiology, College of Veterinary Medicine, University of Tennessee, Knoxville. **Program and Abstracts of the 50th Anniversary Meeting of the Southeastern Archaeological Conference.** New Orleans, Louisiana.

Prehistoric Parasitism in Tennessee: Evidence from Paleofecal Samples Collected from Big Bone Cave, Van Buren County, Tennessee. Coauthored with Dr. Sharon Patton and Sandra Johnson, Dept of Pathobiology, College of Veterinary Medicine, University of Tennessee, Knoxville. **Program and Abstracts of the 1988 Annual Meeting of the American Society of Parasitologists,** Wake Forest University. Winston Salem, North Carolina.

Identification of Protozoan Cysts Isolated from Paleofecal Samples Collected from Big Bone Cave, Van Buren County, Tennessee. Coauthored with Dr. Sharon Patton, Sandra Johnson, Dr. Robert Edwards, Dept of Pathobiology, College of Veterinary Medicine, University of Tennessee, Knoxville, and Dept of Parasitology and Laboratory Practice University of North Carolina, Chapel Hill. **Program and Abstracts of the 1988 Annual Meeting of the Southeastern Society of Parasitologists,** Clemson University. Clemson, South Carolina.

Analysis of Paleofecal Samples from Big Bone Cave, Van Buren County, Tennessee. Coauthored with Dr. Sharon Patton, Dept of Pathobiology, College of Veterinary Medicine, University of Tennessee, Knoxville. **Program and Abstracts of the 1987 Annual Meeting of the Southeastern Society of Parasitologists and Association of Southeastern Biologists,** University of Georgia. Athens, Georgia.

# VITA

Charles Thomas Faulkner was born in Paris, France on August 10, 1954. Because his father was a member of the United States Navy, he attended various public and private schools in the United States and Japan, and was graduated from High School in 1973. After a two-year tour of duty with the United States Navy, he entered St. Mary's College of Maryland and transferred to the University of Tennessee, Knoxville. He received a Bachelor of Arts degree in Anthropology in 1982. In the fall of 1982, he began work toward a Master's degree at the University of Tennessee, Knoxville. This degree was awarded in December 1989.

During the course of his education, Mr. Faulkner has been affiliated with various archaeological research projects and been employed as a Naturalist with the Tennessee Department of Conservation, Division of State Parks. He is presently employed as a Senior Laboratory Technician with the Department of Pathobiology at the University of Tennessee College of Veterinary Medicine in Knoxville, Tennessee.

Mr. Faulkner is a member of the Society for American Archaeology, American Society of Parasitologists, Southeastern Archaeological Conference, and the Society of Southeastern Parasitologists.