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Diet, Parasitism, and Anemia in the Prehistoric Southwest

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DIET, PARASITISM, AND ANEMIA IN THE PREHISTORIC SOUTHWEST

A Dissertation

by

KARL JAN REINHARD

Submitted to the College of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

December 1988

Major Subject: Anthropology

DIET, PARASITISM, AND ANEMIA IN THE PREHISTORIC SOUTHWEST

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KARL JAN REINHARD

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December 1988

ABSTRACT

Diet, Parasitism and Anemia in the
Prehistoric Southwest. (December 1988)

Karl Jan Reinhard, B.A., University of Arizona;
M.S., Northern Arizona University
Chair of Advisory Committee: Dr. Vaughn M. Bryant, Jr.

The primary goal of this study is the demonstration of the utility of parasitological data retrieved from coprolites in documenting prehistoric infectious disease. The study focuses on levels of infection of two subsistence types, hunting-gathering and agriculture. Analysis of differences between the two types, and of variation of parasitism between sites of the same type, are presented. It is demonstrated that parasitism was more common among hunter-gatherers than agricultural populations. Parasitism is shown to have been mediated by ecology and human behavior among agricultural sites. A second goal is the integration of parasitological data with evidence of pathology derived from skeletal analysis. The parasitological data correlate well with skeletal data relating to anemia and suggest that parasitological analysis can complement osteological analysis when approaching questions of prehistoric health. The study demonstrates the value of parasitological data in the general rubric of bioarchaeology. Dietary data are evaluated with respect to the maize dependency hypothesis of iron deficiency anemia. A long tradition of dietary specialization among Archaic hunter-gatherers is documented which led to dietary specialization on cultivated crops in agricultural times. However, dependence on agricultural foods is highly variable and can not account for prehistoric anemia alone. The various analyses demonstrate the power of incorporating dietary, parasitological and osseous pathology data in assessing health of prehistoric peoples. Specific contributions of the study are the elucidation of parasitism among dilute hunter-gatherer bands and concentrated populations of agricultural people. It is shown that zoonotic infection was common among both groups, but that the advent of agriculture resulted in an increase of human specific parasitism. The increase in human specific parasitism resulted from poor hygienic conditions, sedentism and population aggregation. However, it is clear that local ecology, excreta disposal systems, and foraging behavior at certain agricultural sites reduced the level of parasitism. Thus, both ecology and social adaptation are documented as lowering the impact of parasitism.

ACKNOWLEDGEMENTS

Working with feces, no matter how old, is a tough business. In the laboratory one must contend with the tedium. Outside of the laboratory one must content with the jokes. It is my advice to anyone entering the maligned field of coprology to develop a strong stomach, thick skin and most importantly, a sense of humor.

The burdens of research and writing of this dissertation have been shouldered by several individuals. Two people have been most helpful through the four years I have worked on the project. Throughout the process, my wife, Debra K. Meier, has been a source of support and encouragement. She has also helped in writing the dissertation and in producing many figures for intriguing presentations that were generated by the research. During the last few years she has helped me select samples for study, both for this dissertation and for my thesis. Besides Debbie, John G. Jones has been my closest friend and colleague since the first day I arrived at Texas A&M. The analysis of Turkey Pen Cave and Hinds Cave I did jointly with him. The Results and Methodology chapters are derived in part from papers he and I wrote together. Of the people with whom I have worked during my entire tenure at Texas A&M, John has been my most dependable colleague and friend. Through periods of trauma, pressure, and most of all tedium, John kept me smiling. Without Debbie and John, it is doubtful that I would have persisted in obtaining my Ph.D.

Several close friends contributed materially to the production of this dissertation. Maria Jacobsen and Eri Weinstein read through and edited the second and final drafts. This is quite a chore for people who have little interest in ancient parasitism, and I will long appreciate their help. The logic, organization and wording of the final draft was hammered out with their help and encouragement. Thus the glory, or the blame, must be shared with them. The first draft was written on Maria's computer which she loaned to me for this purpose. Peter Warnock also helped by allowing me access to his computer when no other computer was up to the task of generating graphs from spread sheets. Pollen analyses of Salmon Ruin and Antelope House were done jointly with Bob Murry and Sherrian Edwards. The coprolites studied from Baker Cave were generously supplied by Kristin Sobolik.

Outside of the Anthropology Department, Texas A&M University, several individuals participated in the study. My father, Karl R. Reinhard, and my Master's major professor, Richard Hevly (Department of Biological Sciences, Northern Arizona University), critiqued the first draft of the dissertation. John Holmes (Department of Zoology, University of Alberta) reviewed the final draft. T. Michael Fink would have helped in editing the final draft, had he the time. Mike did have the time to help with the analysis of the Antelope House coprolites, and even became interested. Tammy McLean formatted and printed the final dissertation, thereby substantially contributing to the fruition of the research.

The coprolites were selected for analysis by myself and Debbie Meier. The selection was facilitated by Harry Shafer and Gloria Fenner (Western Archaeological and Conservation Center, Tucson).

One of my main goals in my studies at Texas A&M has been to hone my parasitological expertise. I am deeply grateful to Norm Dronen (Department of Wildlife and Fisheries) for spending two semesters in teaching to me acanthocephalan and nematode taxonomy and morphology. Tom Craig (Department of Veterinary Parasitology and Microbiology) instructed me in helminthology, parasitic protozoa, and helminth ecology. I greatly appreciated the help provided by these professors and their students: John Melon, Kathy Wade, Tariq Quersteri and Dan Miller.

Many friends and colleagues have provided encouragement and support for this dissertation and my research in general. At the risk of ruffling feelings, I list them in the order in which they come to mind rather than in cold, objective, alphabetical order. These include Debra Meier, John Jones, Maria Jacobsen, Eri Weinstein, T. Michael Fink, Aleydis Van der Moortel, Mike Pendleton, Peter Warnock, Steve Weinman, Merrill Sweet, Chuck Merbs, Bob Murry, Sherrian Edwards, Lain Ellis, Nina Caris, Norman Dronen, John Melon, Bruce Dickson, Kathy Dettwyler, Dora Lopez, Karen Taylor, Norm Thomas, Beth Miller, Richard Hevly, Dave Breternitz, Jesse Jennings, Bill Rathje, Emil Haury, Dick Ambler, Peter Price, Karl Aufderheide, and last but not least my parents, Karl and Janet Reinhard. I am grateful to these people, and others who were wittingly or unwittingly helpful to me, or meant to be helpful to me, during the research and writing phase of this project.

As for my Committee, I first of all appreciate their cumulative efforts and intensive participation in the "final hour" of the fall semester, 1988. Individually, I have found Vaughn M. Bryant, Jr. to be genuinely interested in my career's progress during the past four years. That career has progressed with his support and concern.

Gentry Steele has also been as source of academic and personal support during the past four years. I especially appreciate our talks, debates and arguments over aspects of paleopathology and bioarchaeology and most importantly, iron deficiency anemia. I have no doubt that some day we will find a point on which we agree without "discussion".

Despite the fact that my research is on one of the farthest fringes of parasitology, Tom Craig has been consistently interested in my research. It takes an open mind and broad background to deal with prehistoric parasitism. Craig is blessed with both of these qualities and has been the source of much learned advice and parasitological council over the years.

I greatly appreciate the efforts of Harry Shafer in introducing me to the archaeology of the lower Pecos and guiding my study of the area. With luck we will continue to work together with aspects of hunter-gatherer adaptation in the Southwest.

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CHAPTER I

INTRODUCTION

Theoretical Background

It has become axiomatic that hunter-gatherers enjoyed better health and diet than agricultural and industrial peoples. This idea began with the revelation that modern hunter-gatherers spend less time collecting food reserves, have more leisure time, and have an adequate diet in comparison to agricultural and modern urban peoples (Lee 1972). Prevalence of infectious disease among hunter-gatherer peoples is also relatively low (Dunn 1972). At the same time it was recognized that modern hunter-gatherer peoples are becoming rare and that future research into hunter-gatherer morbidity and mortality should focus in part on the study of archaeological remains, specifically coprolites (Cockburn 1971; Dunn 1972). However, not until 1985 was a comparative study of disease prevalence as evidenced by helminth remains undertaken through coprolite studies (Reinhard 1985a). This limited study of coprolites from hunter-gatherer and agricultural contexts was not conclusive due to the small sample size.

Dietary change resulting from agriculture was thoroughly addressed by Cohen (1977). Cohen views population increase and resulting stress on subsistence base as a main factor leading to agriculture. At some point

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human populations were forced from a subsistence strategy of collecting a wide variety of foods to labor intensive production of a limited range of cultigens. With this change, Cohen postulates that quality of diet declined. This notion is currently in vogue in both the scientific literature (Cohen and Armelagos 1984; Eaton and Konner 1985) and the popular literature (Desowitz 1981; Diamond 1987; Karlen 1984). Because of increased sedentism and population aggregation, infectious disease became more prevalent (Cohen 1977; Cohen and Armelagos 1984).

This latter aspect has been more fully discussed by several other authors (Black 1975; Boyden 1970; Cockburn 1971; Fenner 1970; May 1983; McKeown 1976; McNiell 1976: Nelson 1972). Their works are either based on studies of current cultures, or on historical documentation. Several central points are common to many of the works. In general, it is believed that population increase accompanied the subsistence shift from hunting-gathering to agriculture. Growing populations reached thresholds that promoted infection with new pathogens. Furthermore, aggregations of people resulted in many more human to human contacts and intensified the spread of infectious disease. These factors led to increased levels of disease through out the history of agriculture which was also promoted by accumulations of trash and excreta contamination from the ever-growing agricultural populations. A point emphasized by McNiell is that trade between sedentary populations resulted in the spread of infectious organisms. Cockburn emphasizes the role of domestic animals in the spread of infectious disease of zoonotic origin.

Role of Bioarchaeology

In the absence of direct studies of disease by coprolite studies, the comparative health of hunter-gatherers and agriculturalists has been evaluated by examination of skeletal remains. Several pathological conditions relevant to general health have been investigated (Martin et al. 1985). Dental disease is considered to indicate general levels of "stress". These include conditions that result from metabolic disruptions such as enamel hypoplasia (Rose et al. 1985), carious lesions and tooth attrition (Moore and Corbett 1983; Powell 1985). Metabolic disorders evidenced in bone are also used as a comparative gauge of stress. Most important among these are porotic hyperostosis and cribra orbitalia in the cranium (El-Najjar et al. 1976), and growth resumption lines (Harris lines) in the longs bones. Rickets and osteomalacia are also evidenced in the long bones. Infectious disease is documented by periostitis, osteomyelitis, and specific osseous changes associated with tuberculosis, syphilis, and leprosy. Degenerative conditions such as osteoarthritis and osteophytosis are sometimes considered in the evaluation of prehistoric "stress". Skeletal studies also relate to diet as indirectly studied through chemical analysis of bone including analysis of nitrogen isotopes, carbon isotopes and strontium isotope formation (Gilbert 1985). Stature is considered to also reflect general health conditions.

Using these indicators, several interesting papers have been generated concerning relative health and or diet of hunter-gatherers and agricultural peoples (Cohen and Armelagos 1984). Cassidy (1980) finds that in the Ohio River Valley, osseous indicators of stress increase among agriculturalists in comparison to hunter-gatherers. Using osseous indicators of stress, Angel (1984) documents changing health status in the Mediterranean and concludes that although poor health did not accompany the introduction of agriculture into the area, but as agriculture progressed and populations grew, health did decline. Smith et al. (1984) focus their study on the time period in Palestine during which agriculture was adopted. Like Angel, they find that health status did not decrease immediately when agriculture began. From south Asia, Kennedy (1984) reports that the period of transition from gathering agriculture resulted in food shortages, a conclusion that contrasts with those of Angel (1984) and Smith et al. (1984). In Nubia, the transition to agriculture was not sharply defined (Martin et al. 1984). In the early stages of agriculture, Nubian populations apparently supplanted their diet with gathered foods. However, osseous lesions indicate a lowered health status among Nubian agriculturalists in contrast with earlier hunter-gatherer populations. Evidence for a decline in health status is also present in skeletal evidence from Georgia (Larsen 1984).

Rose et al. (1984) find that ecology is critical in determining the health status of both hunter-gatherers and agriculturalists. Thus local ecology of prehistoric settlements has a pronounced effect on health. This theme is repeated in the American Southwest where local ecology of habitations is thought to have had a pronounced effect on the health status of agricultural peoples (El-Najjar et al. 1976; Palkovich 1984).

Cook (1984) finds that the introduction of agriculture in the Mississippi Valley did not lower the nutritional status of peoples there.

She finds, however, that an increased population resulting from agriculture led to increased prevalence of infectious disease.

As noted above, some studies have revealed the importance of local ecology in determining health status. This aspect of prehistoric health goes beyond the general correlation of subsistence change and declining health. One can focus on differences in the incidence of skeletal pathology between populations practicing the same general subsistence strategy (El-Najjar et al. 1976). In comparison to the change in health status from hunter-gatherers to agriculturalists, the effect of local ecology has not been researched.

Role of Coprolite Analysis

The study of prehistoric parasitism as evidenced by helminth remains in coprolites can be viewed potentially as another method of determining prehistoric health status or "stress". In comparison to skeletal analyses, ambiguity in diagnosis is lessened in coprolite analysis. Coprolites contain the reproductive products of infective organisms themselves. Skeletal analysis presents signs of disease, but usually can not implicate specific disease organisms.

As important as parasite evidence, coprolites provide direct evidence of diet. Therefore, the changes noted in parasitism can be correlated with dietary adaptation. Thus the development of the field of "paleoparasitology" has direct applications to bioarchaeological research.

History of Paleoparasitology

Paleoparasitology as a distinct field is only ten years old although the field has roots that date back to the early 1900's. Until the initiation of broad geographical studies of parasitism exemplified by Fry (1977) and Fouant (1981), prehistoric parasitism was largely a topic of scholarly speculation, especially with respect to the New World (Stewart 1960; Cockburn 1971; Desowitz 1981). There are essentially two historical phases to parasitological analysis. The first includes pioneering efforts spanning the time from 1910 to 1980. The second period includes problem oriented research dating from 1980 to present.

The first discovery of helminth remains in archaeological context is attributed to Ruffer (1910) by Ubelaker (1982). Ruffer discovered the eggs of _Schistosoma_ _haemotobium_ in tissues of a Egyptian mummy. After this discovery, there is a long period during which almost no parasitological research was done. Two important reports were published in the 1950's. The first was of _Trichuris_ _trichiura_ eggs and possible _Entamoeba_ spp. cysts found in the intestine of a Incan mummy (Pizzi and Schenone 1954). The second was Taylor's (1955) description of _Trichura_ spp., _Ascaris_ spp., and _Dicrocoelium_ _dendriticum_ eggs found in an English, Medieval latrine deposit. This latter publication initiated European research which from then until the present continued to focus primarily on latrine deposits.

Callen and Cameron (1960) published a landmark paper in which _Diphyllobothrium_ was identified from Peruvian coprolites. This paper initiated New World analysis which focussed primarily on coprolites. Techniques for recovery of helminth eggs and larvae were refined by Samuels (1965) working with coprolites from the Mesa Verde region in his attempt to document parasitic disease in the Southwest. The rapid application of parasitological analysis to coprolites in the southwestern United States led to an explosion of research in the late 1960's (Dunn and Watkins 1970; Heizer 1967; Heizer and Napton 1969; Fry and Hall 1969; Fry and Moore 1969; Moore et al. 1969) which was to continue into the early 1970's (Fry 1977; Fry and Hall 1975; Hall 1972, 1977; Moore et al. 1974).

In the Old World, parasitological studies of latrine deposits continued in England and northern Europe (Pike 1967). By the 1970's, emphasis in Europe shifted from description of parasite finds to interpretation of parasites in archaeological contexts (Pike 1975).

The end of the 1970's and beginning of the 1980's saw intensification of parasitological research in the Americas and in Europe. At this time the field was recognized as a unique interdisciplinary entity derived from parasitology and anthropology. Araújo et al. (1981) applied the term "paleoparasitology" to the growing field. Introduced by Araújo et al. (1981), paleoparasitology is defined as an extension of paleopathology which is the study of ancient disease. The term is gaining acceptance among North America researchers (Reinhard et al. 1987).

Archaeoparasitology

As a matter of opinion, some might object to the term paleoparasitology. In strict definition, "paleo" refers to ancient forms or conditions. In this context, Kliks (1983) applied the term paleoparasitology to examination of the origins of hominid parasitism. With respect to New World archaeology, "paleo" has specific time and cultural meanings and refers to ancient big game hunting cultures. In North America, the examination of parasitological evidence from archaeological sites includes ancient materials (Fry and Moore 1969; Moore et al. 1969), and recent materials dating into historic times (Reinhard et al. 1986). For the historical material, "paleoparasitology" is a misnomer, falling out of the range of what is normally considered ancient, especially in the perspective of Kliks' application. Perhaps "archaeoparasitology" is a more appropriate term for the study of parasitological remains from archaeological contexts and this term will be used for the purposes of this work.

Archaeoparasitology in the 1980's is distinct from previous research in that parasitological data derived from archaeological contexts are used to address specific biological and anthropological questions. During the late 1970's and early 1980's, several foci for archaeoparasitological research were established in the Americas and in Europe. The establishment of these occurred independently and consequently resulted in distinct theoretical orientations as well as the innovation of several analytical techniques (Reinhard et al. 1988). The four most important are those established by Ferreira, Araújo, and Confalonieri in Rio de Janeiro; Ambler, Anderson, Hevly, Reinhard and Price at Northern Arizona University; Jones at the University of York; and Herrmann, Krüger and Schultz at the Institut für Anthropologie, Universität Göttingen.

The concurrent, independent development of major archaeoparasitological research foci in four geographical areas has been of benefit in archaeoparasitology in the 1980's. Each offers different insights into past parasitism. Thus the research groups serve to compliment each other.

The Brazilian team is composed solely of parasitologists who solicit participation of archaeologists. Their goals are oriented towards the empirical identification of both human parasites and non-human parasites from archaeological material (Confalonieri et al. 1985; 1988). This has led to a biogeographical orientation in tracing the distribution of parasitic infections in prehistoric populations. Most important to the Brazilian team is tracing the introduction of whipworm (Trichuris trichiura) and hookworm (Ancylostomidae) into the prehistoric New World. Latrine soils, coprolites and mummy intestinal contents are all under study by this group.

In Britain, archaeoparasitology has developed from a long history of parasitological studies of Medieval latrine deposits (Gooch 1983; Moore 1981; Pike 1967; Taylor 1955). The most recent theoretical developments have come from the incorporation of archaeoparasitological studies in "Environmental Archaeology" which is itself a development of British archaeology (Jones 1985). British archaeoparasitological research is oriented towards the identification of the nature of archaeological deposits. In theory, parasite remains are seen as clues to depositional processes that create archaeological sites. Beyond archaeological applications, coprolites and mummies have been studied to assess the severity of Medieval parasite infection (Jones et al. 1988; Jones and Hall 1983).

Some of the most insightful archaeoparasitological research is being conducted in Germany (Herrmann 1986, 1987; Herrmann and Schultz 1987). There a great variety of factors relevant to comparative parasite epidemiology are studied. These factors include comparative egg production between species and worm burden in the accumulation of parasite eggs in latrine deposits; the effects of soil chemistry and decay organisms on helminth remains; and the role of human behavior in shaping human parasitism. Of the four major research groups, the Germans are the most holistic in their theoretical approach to archaeoparasitology. German archaeoparasitological research, with its focus on comparative epidemiology, is clearly a development of paleopathology. However, the Germans also interpret the data within a cultural framework and therefore have a distinct anthropological orientation.

The research initiated at Northern Arizona University attempts to relate human parasitism to cultural development (Hevly et al. 1979; Reinhard 1985a; Reinhard et al. 1985, 1987). The theoretical framework involves concepts from both parasite ecology and human ecology and thus involves parasitologists and anthropologists. Coprolite analysis focusses on the parasitological changes concurrent with the introduction of agriculture. The role of human behavior in shaping parasitism (Reinhard 1985a; Reinhard et al. 1985, 1987) and the impact of parasitism on prehistoric health (Hevly et al. 1979; Reinhard 1985b, 1985c) are specific areas of interest.

Through out the history of the field, parasitological remains from archaeological sites have always been the subject of interdisciplinary study. As we have seen, the impetus for study of parasitism in North America has come from archaeology and physical anthropology. In short, the parasitological study of archaeological remains is jointly derived from the fields of anthropology and parasitology with sponsorship by archaeology. In early work, relatively more research was carried out by pathologists or medical personnel than later research which is largely in the field of anthropology. However, interdisciplinary cooperation typifies modern work. For example, research done in Peru involves cooperative participation from anthropological and medical realms. In England, early research was conducted by veterinary or medical parasitologists (Taylor 1955; Pike 1967, 1975; Gooch 1983) but is now primarily in realm of anthropology (Jones 1985, 1986; Jones and Hall 1983; Jones et al. 1988). The actual examination of archaeological specimens such as coprolites (desiccated feces), latrine soils, and mummies is often done by parasitologists or pathologists (Allison et al. 1974; Dusseau and Porter 1974; Horne 1985; Zimmerman and Aufderheide 1984; Zimmerman 1980), or by anthropologists with training in parasitology (Fry 1970, 1974, 1977, 1980, 1985; Fry and Hall 1986; Hall 1977).

In the New World most archaeoparasitological study falls into the realm of coprolite analysis which is largely a development of North American archaeology (Fry 1985; Bryant 1974a, 1974b; Bryant and Williams-Dean 1975; Shafer and Bryant 1977). Consequently, parasitological studies are typically integrated with dietary data (for example Fry 1977; Fry and Hall 1986; Hall 1977; Reinhard et al. 1985). Funding and basic support for such studies comes from interested archaeologists who often see to the publication of parasitological data.

Coprolite analysis is historically aimed at the recovery of dietary and ecological data as reviewed by Bryant (1974a, 1974b, 1986) and Fry (1980). The techniques of coprolite analysis were first devised by Callen (1963, 1967) and Callen and Cameron (1960). Since then, coprolite analysis techniques have been refined by researchers in the Great Basin (Fry 1977), on the Colorado Plateau (Reinhard 1985a) and in western Texas (Bryant 1974a, 1974b; Bryant and Williams-Dean 1975; Shafer and Bryant 1977; Stock 1983; Williams-Dean 1978). For specific application to coprolites, archaeoparasitological analytical techniques are derived from the work of Callen and Cameron (1960), Samuels (1965), Hall (1972), Fry (1977, 1980) and Araújo et al. (1980) as reviewed by Horne (1985) and Reinhard et al. (1988). Refinement of technique as applied to coprolites continues in both North America and South America as well as in England, Germany and Denmark (Araújo et al. 1981; Confalonieri et al. 1985; Ferreira et al. 1983a; Reinhard 1985b, 1985c; Reinhard et al. 1987, 1988).

The same is true of latrine soils, although latrines have provided both prehistoric (Hevly et al. 1979) and historic (Reinhard et al. 1986) evidence of parasitism. Rarely, skeletal analysis reveals evidence of parasitic disease. These occur exclusively in the form of calcified hydatid cysts (Ortner and Putschar 1985; Weiss and Moller-Christensen 1971; Williams 1985).

Preservation of remains varies. Coprolites from caves provide the best conditions of preservation for helminth eggs and larvae (Fry 1974;

Coprolites from open sites are less well preserved and parasite eggs within such coprolites can be partially decomposed. The poor preservation of Enterobius vermicularis eggs is specifically noted for fecal remains excavated from open sites (Reinhard and Clary 1986). Latrine sites provide suitable conditions for preservation of more durable eggs, but fragile eggs, especially oxyurid eggs, are susceptible to decomposition in latrine sites.

Mummies are an important source of archaeoparasitological data and provide suitable conditions for helminth preservation, especially if frozen in prehistory (Zimmerman 1980) or rapidly desiccated (El-Najjar and Molinski 1980). Mummies have not been studied as intensively in North America as in South America, Europe, or Egypt (Cockburn and Cockburn 1980; Ferreira et al. 1983a).

Definitions and Concepts

Before proceeding to applications of archaeoparasitology to archaeology, it is necessary to present basic parasitological concepts and definitions.

Parasitism, mutualism, commensalism and symbiosis result from the interaction of at least two organisms (parasite and host) under environmental influences. The parasite gains nutrition and protection by living in or on another organism. The organism housing the parasite is called a host. Hosts are classified according to what stage of the parasite life cycle occurs in or on them. Parasite sexual reproduction occurs in the definitive host. Asexual reproduction or larval development occurs in the intermediate host, of which there may be more than one in some parasite life cycles. Paratenic hosts harbor larval stages of parasites that do not undergo development. The parasite migrates to somatic tissue of the paratenic host which may eventually be eaten by a definitive host. Incidental hosts are animals that are not typically infected with a given species of parasite. Zoonosis refers to human infection with a parasite species derived from an another animal. When humans become infected with a parasite not usually found in humans, or act as definitive, paratenic, or intermediate host, the infection is zoonotic. A zoonosis is an animal disease transmissible to humans.

Parasites can be classified into two major groups; obligate and facultative. Obligate parasites are those that must infect animals in order to complete their life cycles. Facultative parasites can either complete their life cycles as parasites or as free living animals.

Parasites often show a high degree of specificity. For example, pinworm (Enterobius vermicularis), the human whipworm (Trichuris trichiura), and the beef and pork tapeworms (Taenia saginata and T. solium) can only complete their sexual reproduction in a human hosts. There are other parasites, however, that can exists in a wide range of hosts.

Several environmental factors effect parasite infection. Most important of these are temperature and moisture. In general, cold temperatures and dry conditions are less conducive to parasite transmission than warm temperatures and moist conditions. For this reason, a large portion of human parasites are limited to tropical and subtropical areas where environmental factors effect the extracorporal stages of the parasite life cycles.

In a few species, such an intimate relationship is evolved between parasite and host that environmental factors have little effect on parasitism. For example, pinworm has such an intimate relationship with its host that human infections can occur without an extracorporal period. Parasites with close relationships to their host can be found in virtually any ecological setting.

Most other parasites have an extracorporal period in the life cycle during which eggs, larval stages, or both are exposed to the environment. Thus infection is limited to circumscribed areas in which the environment is suitable to extracorporal development and survival. The limits of this area are increased or decreased by the hardiness of the extracorporal stages. For example *Ascaris lumbricoides* (giant round worm or maw worm) has a very durable egg which can survive in a variety of environments. Conversely, hookworm (*Ancylostoma duodenale* and *Necator americanus*) larvae hatch from the egg outside of the body and the larvae are dependent on moist, warm conditions for survival. Consequently, *A. lumbricoides* is found in a variety of boreal, temperate, and sub-tropical habitats whereas hookworms are limited largely to the tropics and subtropics.

Those parasites that utilize intermediate hosts are limited to those regions where the intermediate host occurs. Thus many species of fluke are limited to locations where snail intermediate hosts are present. Similarly, tapeworms are limited to areas where their intermediate hosts are found.

Some parasites elude the limitations of environment by dispensing with extracorporal life cycle stages. For example, *Trichinella spiralis*, the causative organism of trichinosis, usually has no extracorporal cycle. It is transmitted by carnivory (including scavenging) and the larvae, produced by reproductive adults in the intestine, migrate to somatic tissue. Others, such as *Toxocara canis*, which may be zoonotic in humans, exhibits transplacental or transmammary infection in dogs leading to early parasitism in puppies which produce eggs which are infective to man.

A variety of nematode parasites evade the rigors of extracorporal survival by delaying reproduction until environmental conditions are suitable. Hypobiosis (suspended development) allows many species to survive in their host in larval form. Several parasites of veterinary importance utilize hypobiosis, for example *Haemonchus contortus* and *Ostertagia ostertagi* of ruminants. A few human parasites may also become hypobiotic such as *Ancylostoma duodenale* which coincides its activity with that of the monsoons.

False parasitism is a phenomenon that is characterized by the presence of parasite eggs in human feces of species not infective to humans. This results from the consumption of an infected animal. The eggs in that animal's digestive tract are liberated in the human digestive tract and pass harmlessly through the system.

In the study of archaeoparasitology, all of these factors must be considered. All of the above have direct application to the archaeological interpretation of parasite finds.

Archaeological Applications

Diet

Parasites that utilize intermediate hosts often show a high specificity for species of intermediate host. Thus, the finding of certain parasite eggs in human remains and coprolites provides direct evidence of the types of animals eaten. Because sexual stages of the parasites often are active for several months to several years, the eggs produced provide evidence of the consumption of certain animals even though direct evidence of those animals in archaeological context may be lacking.

Coprolites recovered from the Pacific coast of Chile (Araújo et al. 1983; Ferreira et al. 1984) and Peru (Callen and Cameron 1960; Patrucco et al. 1983) contained the eggs of *Diphyllobothrium pacificum*. *D. pacificum* uses fish as intermediate hosts and diphyllobothriasis results from the consumption of fish which are uncooked or incompletely cured. Thus finding the eggs of these species indicates that fish were consumed along the western coast of South America.

Parasite remains can bring archaeological and coprolite data into closer agreement. For example with the Peruvian finds of Callen and Cameron (1960), the presence of the eggs support archaeological reconstruction of the diet based on artifacts. Net sinkers were a common artifact found in the excavation and provided evidence of fishing. The animal residues in the coprolites (muscle fiber from mollusks) suggested that mollusks were more important in the diet than fish.

Anther group of tapeworms, the hymenolepidid worms, typically use rodents as definitive hosts and grain beetles as intermediate hosts. This cycle usually is associated with grain storage. Humans become accidental hosts by consuming grain beetles. Eggs of hymenolepidid worms have been found in coprolites and latrine soils from the prehistoric southwestern U.S. (Hevly et al. 1979; Reinhard 1985b; Reinhard et al. 1987). This indicates prehistoric grain storage.

The thorny-headed worms in terrestrial environments use insects as intermediate hosts and a variety of mammals as definitive host. Acanthocephalan eggs have been found in coprolites from the Great Basin and from the southwestern U.S. (Fry 1977; Fry and Hall 1969; Moore et al. 1969). The species implicated is Moniliformis clarki which uses camel crickets as intermediate hosts. Finding parasite eggs in human feces demonstrates that insects were consumed, even though dietary insect remains are not frequently found (Fry 1977).

The presence of taeniid tapeworm eggs in the intestine of an Egyptian mummy shows that poorly cooked beef or pork was eaten (Cockburn and Cockburn 1980). The only taeniid tapeworms that use humans as definitive hosts are Taenia saginata (beef tapeworm) and T. solium (pork tapeworm).

False parasitism can provide dietary information. In an analysis of an Eskimo mummy from St. Lawrence Island, Zimmerman (1980) discovered the eggs of the fluke Cryptocotyl lingua. This fluke uses fish as definitive hosts. The consumption of fish by humans results in the introduction of the eggs into the human digestive tract. Thus, in the case of the St. Lawrence Island mummy, the eggs provide evidence of fish consumption immediately prior to death.

Transhumance

Unlike parasites species which are often geographically limited in range due to environmental parameters and extracorporal requirements, human populations can move on a seasonal basis through a variety of ecological conditions. In residing seasonally in a specific habitat, a human population may pick up the parasite infections circumscribed in that habitat. When the human population moves to a second seasonal habitat, it carries with it the sexually reproducing parasites of the first habitat. Consequently, eggs will be passed in feces and even though the parasites within those eggs cannot complete their life cycles in the second habitat, the eggs will become incorporated into the archaeological record. In archaeological interpretation, the eggs provide a marker of that first seasonal habitat.

This is perhaps exemplified by the finding of *Trichuris trichiura* eggs in latrine soils at the prehistoric site of Elden Pueblo near Flagstaff, Arizona (Hevly et al. 1979; Reinhard et al. 1987). *T. trichiura* eggs require 21 days in warm, moist, densely shaded soils to become infective. Such conditions are not present today in the dry, cinder soils of the Flagstaff area, yet *T. trichiura* eggs were the most common eggs found in the latrines. Ecological reconstruction of the region through palynology (Hevly et al. 1979) indicates that in prehistory the region was drier than today, making the possibility of *T. trichiura* life cycle completion even more remote.

It is most probable that at the inhabitants of Elden Pueblo were infected somewhere else than the Flagstaff area. The Verde River valley immediately south of the Flagstaff region would have provided the necessary conditions for _Trichuris_ infection. Zooarchaeological evidence of turtle and fish species found in the Verde River in the Elden Pueblo trash deposits indicates that some hunting and fishing was done along the Verde River (Hevly et al. 1979). It is very likely that seasonal movement from the Flagstaff region to the Verde Valley resulted in the infection of the human population. The eggs found in the latrines at Elden Pueblo are therefore probable markers of seasonal transhumance.

Environment

Because certain parasites are restricted to specific ecological conditions, the parasite evidence provides general data regarding the environments in which the human population lives. They also reflect ecological change between modern and prehistoric times.

For example, among modern Native Americans on the Colorado Plateau, _Enterobius vermicularis_ is the only intestinal worm reported. In prehistory, eight intestinal parasites have been recorded, some of which are dependent on moist conditions for survival. Most important of these is _Strongyloides_ spp. _Strongyloides_ has been reported from Antelope House, Arizona (Reinhard 1985c), and Clyde's Cavern, Utah (Hall 1972). The presence of this parasite indicates that the prehistoric conditions were moister than present, at least in the confines of the pueblos and caves. The evidence of rapid desiccation of coprolites indicates that environmental conditions of the latrines themselves were quite dry.

Hevly (1986) suggests that a combination of a generally moister environment and the utilization of irrigation resulted in conditions suitable for the survival of moisture dependent parasites. Irrigation on a local level created an environment suitable for the survival of moisture dependent parasites just as water works projects in many parts of the modern world create conditions suitable for parasitic infection (Desowitz 1981).

Fluke eggs have been found in coprolites from the southwest U.S. Flukes are, in general, dependent on moist conditions for survival. The finding of fluke eggs in Lovelock Cave coprolites is not surprising considering the lacustrine environment of the cave. The presence of a fluke eggs in a human coprolite from Glen Canyon is unusual for it indicates that the environments in which humans ranged in that arid region included mesic habitats.

Warm temperatures and moist condition are prerequisites for hookworm infection. Hookworm eggs and adults have been found in coprolites from coprolites and mummies in Brazil (Araújo et al. 1981; Ferreira et al. 1980, 1983a) and Peru (Allison et al. 1974). These finds indicate that the peoples represented by these remains lived in moist, warm conditions.

Health and Disease

The most obvious implication of parasitological finds relates to health of archaeological peoples. Inferences regarding health are based not only on the pathogenicity of the specific parasite found, but also its life cycle. The finding of parasites that are transmitted through fecal contamination are evidence that the human host population was at risk from other fecal borne diseases such as amoebic dysentery.

The most intimate of the human helminth parasites, pinworm, is transmitted in conditions of poor personal hygiene and cramped living conditions. Similar conditions allow for the transmission of the louse *Pediculus humanus*. Therefore the find of pinworm signals suitable conditions for louse parasitism.

Some parasitic helminths cause disease outright. Hookworm, for example, causes severe anemia and where it occurs in the archaeological record, the cranial lesions of cribra orbitalia and porotic hyperostosis may result from hookworm induced anemia. Hookworm remains have been recovered from mummies and coprolites from Peru and Brazil (Allison et al. 1974; Araújo et al. 1981; Ferreira et al. 1980, 1983a, 1983b). The environmental conditions in many parts of Mesoamerica are suitable for hookworm parasitism. Therefore, it is likely that hookworm parasitism was a cause of anemia in these areas.

The fish tapeworm (*Diphyllobothrium*) is another helminth that is responsible for anemia. Evidence of fish tapeworm parasitism of human populations comes from Chile and Brazil as noted above. It is probable that these parasites contributed to disease on the coast of western South America.

Hydatid cyst disease and trichinosis are two of the most severe diseases caused in humans by helminth parasites. Hydatid cyst disease is caused by species of the genus *Echinococcus*. Trichinosis is caused by *Trichinella spiralis*. Williams (1985) reports a case of hydatid cyst disease from a prehistoric skeleton in South Dakota. Only 2% of hydatid cysts cases show osseous involvement. Therefore, the find of a single skeleton with cysts probably indicates that many others in the population were also infected. Zimmerman and Aufderheide (1985) report possible *Trichinella* cysts in muscle from an Inuit mummy from the north coast of Alaska. This find suggests that this population may have suffered from some debilitation due to trichinosis.

Other parasites that cause disease which are described and discussed in the anthropological literature from the New World include acanthocephalans in the Great Basin (Fry 1977) and *Strongyloides stercoralis* at Antelope House, Arizona (Reinhard 1985c). Both of these parasites cause moderate to severe intestinal damage.

Archaeological Soil Analysis

One of the most direct applications of parasitological data to archaeology is the use of parasitological data in determine the nature of archaeological soils. This development has come primarily from examination of archaeological deposits in England (Jones 1985; Jones et al. 1988).

It was originally thought that parasite egg preservation was dependent on moist soil conditions (Pike 1967; Reinhard et al. 1988). Recently Jones et al. (1988) have shown that a variety of soil types, some containing little or no obvious organic debris, contained parasite eggs. Jones (1985) used the concentration of eggs, as determined by the Stolls technique, to determine fecal from non-fecal deposits in Medieval sites and more recently, Bronze Age material.

The most obvious application of this work is in the identification of soil strata conducive to dietary study. Since parasite eggs are deposited with feces, dietary remains in the form of seeds and pollen found in soils containing high numbers of eggs are probably of dietary origin.

This work is currently applied to latrine analyses (Reinhard unpublished) to determine which stratigraphic levels in latrines contain fecal debris. In the analysis of latrines from Newport, Rhode Island, the concentration of parasite eggs is used to determine what levels are fecal and what levels are trash deposits. Once the fecal levels are isolated, they are submitted to dietary analysis through palynology and flotation.

Since parasite eggs in low frequency are typical of the "urban background fauna" (Jones 1985), the identification of parasite eggs in strata from urban context indicate that those strata are probably associated with human occupation. Thus occupational horizons may be identifiable through soil analysis for parasite eggs.

Certainly not all sites are suitable for such analysis. Sites in environments not conducive to parasitism, or non-urban sites, will probably exhibit low concentrations of parasite eggs or perhaps no parasite eggs at all. Interpreting the nature of soils based on analysis of soils for parasite eggs is probably best applied to urban sites.

Animal Domestication

Parasites of domestic animals are occasionally found in archaeological soils. The find of *Toxascaris* in feces from an Anasazi site is indicative of the presence of dogs (Gardner and Clary n.d.).

In an examination of latrine soils from the historic site of Lowell, Massachusetts, eggs of the horse pinworm *Oxyuris equi* were found which demonstrates that horses were present at the site. Jones et al. (1988) have found eggs of this species at a Roman fort dating to AD 80-90 in England which demonstrates the horses were used at the fort.

In terp soils from the Netherlands, a variety of domestic animal parasites have been found, including Toxocara canis and O. equi indicating the presence of both horses and dogs (Pike 1967).

Host-Parasite Evolution

Human parasitism is strongly affected by human behavior. Behavior includes aspects of hygiene, sedentism, food preferences, food storage and other practices. Archaeoparasitological research in the Southwestern United States focusses on these aspects of human ecology and parasite ecology (Hevly et al. 1979; Reinhard 1985a: Reinhard et al. 1987). Archaeoparasitological data are fit into the framework of cultural evolution in with the goal of demonstrating the impact of changing behavior concurrent with agriculture on the parasitology of Anasazi agriculturalists in contrast with earlier Archaic hunter-gatherers.

Goals

The goals of this study are largely derived from previous research in the Southwestern United States parasite cultural ecology. The goals of this study are threefold. First, archaeoparasitological data will be used to assess the impact of the transition from hunting-gathering to agriculture on parasite prevalence, a goal that fits into classic bioarchaeological research (Cohen and Armelagos 1984). Secondly, the roles of local ecology and behavior in mediating agricultural parasitism and bioarchaeology will be explored through comparative study of Anasazi sites. Thirdly, the role of parasitism as causative agent for anemia will be examined and contrasted with the current hypothesis that agricultural diet led to higher prevalence of anemia. This is another major theme in bioarchaeology. These goals will be address by the examination of coprolites recovered from Southwestern archaeological contexts.

The first goal will be met by the examination of nearly 1,000 coprolites from hunter-gatherer and agricultural sites in the Southwest. The second goal will be met by an detailed study of parasite ecology between two Anasazi agricultural villages. The final goal will be addressed by evaluating prevalence of coprolites containing helminth remains in comparison to one common skeletal indicator of stress, porotic hyperostosis.

These three goals will evaluate three measures of prehistoric health stress. The first addresses the classical stress consideration relating to changing subsistence base. The second evaluates the parameters of human behavior and ecology in causing stress. Finally, the third goal relates to a specific osseous measure of stress in relating anemia to diet and parasitism.

Beyond these specific goals, the value of archaeoparasitology as a bioarchaeological approach will be assessed with respect to the evaluation of prehistoric health. Directions of current and future research in the field will also be discussed.

The following two chapters highlight hunter-gatherer and agriculturalist subsistence behavior in the prehistoric southwestern U.S. They also serve as a data base for analysis in the last chapters. These studies emphasize the role of diet and lifestyle on helminth parasitism. The data presented in chapters 2 and 3 are derived from both original research related to this dissertation and from previous published and unpublished studies.

CHAPTER II

STUDY SITES

Data Set

To answer the research goals presented in the Introduction, a diverse sample of archaeological sites are studied. These include hunter-gatherer sites and agricultural sites in diverse ecological settings. These include corpolite analyses completed by myself in addition to previous studies by other researchers.

Palynological analyses have been completed on samples from Turkey Pen Cave, Bighorn Cave and Hinds Cave. Macrofossil analysis was done on coprolites from Dust Devil Cave, Bighorn Cave, Turkey Pen Cave and Hinds Cave. Parasitological analyses were completed for Bighorn Cave, Turkey Pen Cave, Hinds Cave, Chaco Canyon, Baker Cave and Antelope House.

These data are augmented by previous analysis of several sites (Fig. 1). These include Elden Pueblo (Hevly et al. 1979), Step House (Samuels 1965; Stiger 1977) Hoy House (Stiger 1977), Inscription House (Fry and Hall 1986), Antelope House (Fry and Hall 1986; Williams-Dean 1986), Glen Canyon (Fry 1977), Clyde's Cavern (Hall 1972), Chaco Canyon (Clary 1984), Lovelock Cave (Dunn and Watkins 1970; Heizer and Napton 1969), Hogup Cave (Fry 1977), Danger Cave (Fry 1977), Hinds Cave (Williams-Dean 1978) and Baker Cave (Sobolik 1988).

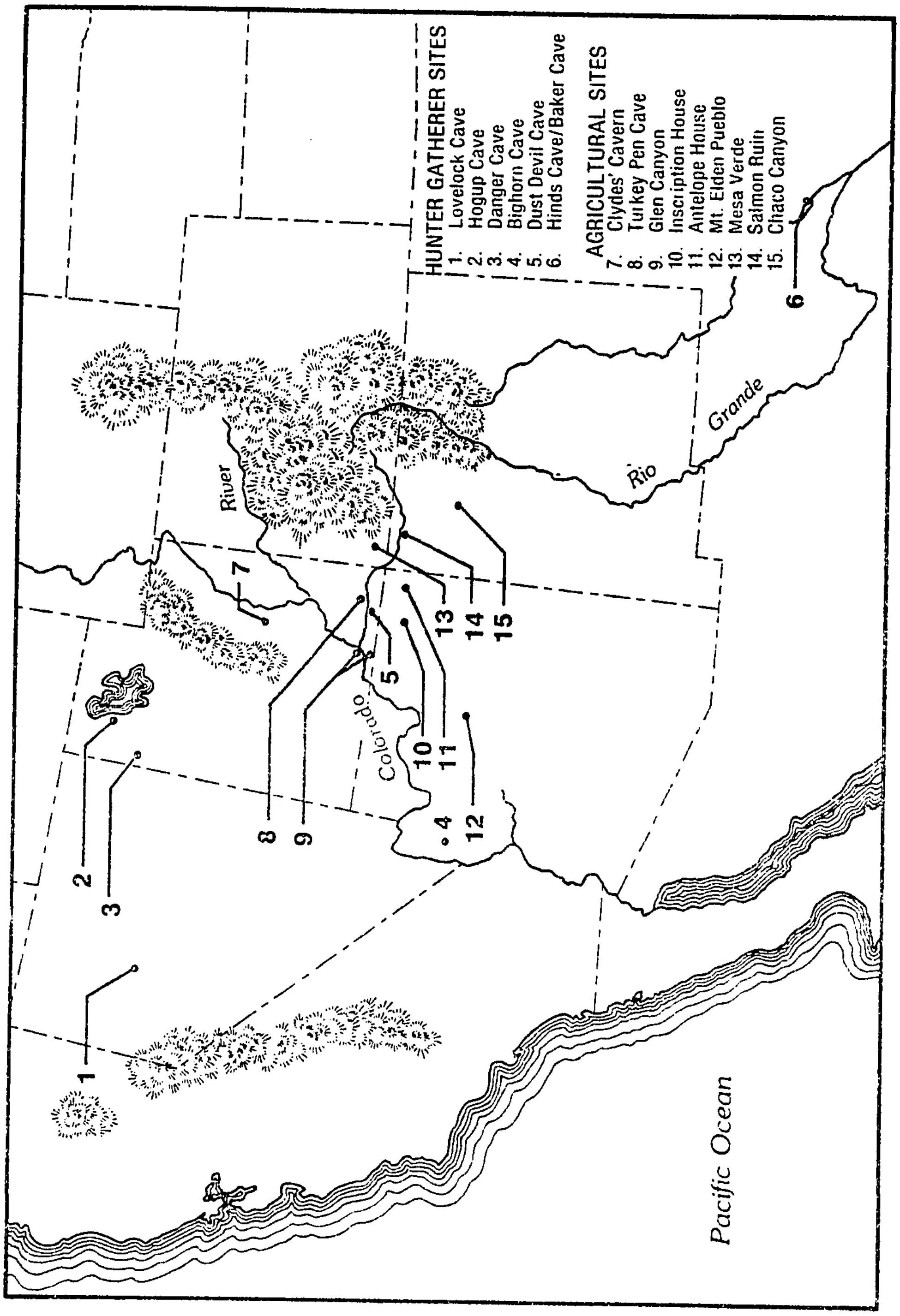

FIGURE 1

Study sites.

Hunter-gatherer Study Sites

Lovelock was occupied from 2,000 B.C. to A.D. 1805. It is located in the area of Humbolt Sink and Carson Sink on the shore of a permanent lake in Nevada. Non-dietary vegetal remains from the site include a variety of artifacts made of aquatic reed such as mats, boats and duck decoys. Dietary remains not associated with coprolites include *Scirpus* seeds, fish and a wide variety of water fowl. Identified avian remains include *Pelecanus erythorhynchos* (white pelican), *Chen hyperboreus* (lesser snow goose), *Branta canadensis* (Canada goose), *Aechmophorus occidentalis* (horned grebe), *Ardea herodias* (great blue heron), *Anser albifrons* (white-fronted goose), *Anas platyrhynchos* (mallard) and *Fulica americana* (American coot). Decoy heads of *Mergus merganser* (American merganser), *Dafila acuta* (spring pintail duck) and *Nyroca* spp. (ring-necked duck) were found which indicates that these birds were also hunted. Non-avian animal foods are represented by *Lepus americanus* (jackrabbit) bone.

Danger and Hogup Caves are located in the area of the Great Salt lake in Utah. Together they have a combined occupation span of nearly 10,000 years. Coprolites dating between 8,000 B.C. and 600 A.D. are affiliated with the Western Archaic cultural tradition (Jennings 1968). Those dating after A.D. 600 but before historic times are associated with the Fremont Culture. Historic Shoshone coprolites have also been excavated from the caves. Cordage and other artifacts of *Ascepias* (milkweed), *Juniperus*, and *Artemisisa* have been recovered from these caves as well as various artifacts made of *Artemisia*, reed, and *Scirpus*. Animal skins were worked as evidenced by numerous artifacts of rawhide, and also by the find of rabbit fur robes. Faunal analysis indicates that artiodactyls constituted the largest share of consumed meat followed in turn by lagomorphs, rodents, and carnivores. *Antilocapra americanus* (pronghorn), *Odocoileus hemionus* (mule deer), *Bison bison*, and *Ovis canadensis* (mountain sheep) constitute the artiodactyl group. *Lepus californicus* (jack rabbit), and *Sylvilagus* spp. (cottontail) constitute the lagomorph group. *Citellus* spp. (ground squirrels), *Dipodomys* spp. (kangaroo rats), *Thomomys* spp. (pocket gophers), *Neotoma* spp. (pack rats), *Microtus* (voles and meadow mice), *Peromyscus* spp. (deer mice), *Marmota flaviventris* (marmot), *Cynomys parvidens* (prairie dog) and *Erithizon dorsatum* (porcupine) are included in the rodent food category. Carnivores that were eaten include *Canis latrans* (coyote), *Canis* spp. (dog or wolf), *Lynx rufus* (lynx), *Taxidea taxus* (badger), *Vulpes macrotis* (kit fox), *Urocyon cinereoargenteus* (gray fox) and *Mustela frenata* (long tail weasel) (Aikens 1970). Plant foods from the caves include prickly pear pads, wild rye, pickleweed, pinyon pine, and bulrush.

One Archaic site containing coprolites has been excavated from the Mojave Desert. This site, Bighorn Cave, is located on the eastern margin of the desert near the town of Bullhead City, Arizona in a canyon in the Black Mountains. The local environment of the canyon differs from that of the general region in being dominated by blue oak, although palo verde and willow are also common in the area. The site was occupied from 200 B.C. to 600 A.D. The cave was formed by water erosion of the surrounding limestone which formed a tunnel emptying into the canyon. Eventually the tunnel filled with sediment, except for the portion emptying into the canyon which became a dry cave. Currently, there is no major water course in the area. A small, intermittent stream flows through the canyon. Permanent water is located in pools which collect in the bottom of the canyon and probably was a prehistoric water source. These pools support a localized, mesic plant community typified by aquatic plants such as *Typha* (cattail) and *Phragmites*. Analyses of faunal and floral remains from the midden within the cave are not yet completed.

Two archaic hunter-gatherer sites containing coprolites have been excavated from on the Colorado Plateau; Dust Devil Cave (Ambler 1984; Lindsay et al. 1968; Reinhard 1985a; Reinhard et al. 1985) and Cowboy Cave (Jennings 1980). Of these two sites, Dust Devil Cave is best studied and will be discussed at greater length. Dust Devil Cave is located in a canyon between Navajo Mountain and the San Juan River near the southern border of Utah. It is a deep but narrow cave and its small size precludes habitation by more than two dozen people. A permanent stream runs in the canyon near the cave. Three archaic strata are present in the cave. Coprolites, sandals and other organic artifacts from these strata have been radiocarbon dated. The occupation of the cave dates between 6800 and 4800 B.C. Cowboy cave is another small shelter located 70 km. north of Dust Devil Cave. The artifacts from the caves have formed the base for the definition of the Desha Complex, a Archaic hunter-gatherer adaption to the Colorado Plateau.

Plant foods recovered from the midden of Dust Devil Cave include the dry fruits or seeds of *Juniperus*, *Ephedra* (mormon tea), *Pinus edulis* (pinyon pine), grass, *Chenopodium* (goosefoot), *Quercus* (oak), and *Opuntia* (prickly pear). Fleshy fruits recovered from the cave midden include *Cucurbita* (non-cultivated squash), *Shepherdia* (buffalo berry), *Astragalus*, *Amelanchier*, *Celtis* (hackberry), and *Yucca*. Pot herbs and stems from the midden include *Allium* (wild onion), and *Eriogonum* (wild buckwheat) and Apiaceae (parsley family) (Richard H. Hevly, unpublished data). Large numbers of *Syvilagus* bones were recovered. *Odocoileus hemionus* (mule deer), *Canis latrans* (coyote) and *Ovis canadensis* (mountain sheep) bones were also found in the midden.

Two caves in the lower Pecos region have been studied: Baker Cave and Hinds Cave. Of the two, more information is available from the Hinds Cave excavations. It is located approximately 2 km from the Pecos River in Still Canyon. Occupation of the site lasted from about 7,000 B.C. to A.D. 1000. Midden material from the site contains fragments of *Agave*, *Opuntia*, *Dasylirion* vegetative tissue, fruit fragments of *Opuntia*, and fruits or seeds of *Celtis*, *Prosopis*, *Juglans*, *Quercus* and *Diospyros*. A large variety of animal taxa are represented by bones recovered from the cave. Osteological analysis indicates that lagomorphs were eaten, as well as rodents such as *Neotoma*. In addition, bird, reptiles and fish were consumed at the cave (Lord 1984). The zooarchaeology of the cave is too extensive to detail here. However, the general conclusions of the analysis are that deer provided the majority of meat consumed at the cave. Fish were commonly consumed during the entire occupation of the cave except at the earliets occupation levels. In the earlier occupations of the cave, lagomorphs, rodents, carnivores and birds were more commonly eaten. Reptiles were consumed throughout the occupation at essentially the same frequency (Lord 1984).

Baker Cave is located on a dry tributary of the Devil's River called Phillips Creek. Excavations have been carried out by Hester (1986). Analysis of animal bone by Lord (1984) indicates that deer, woodrats, cottontail rabbits, jackrabbits and fish were commonly eaten at the site.

Agricultural Study Sites

The Anasazi agricultural sites under study include early agricultural sites and late agricultural sites. The earliest agricultural phase on the Colorado Plateau is known as Basket Maker II. The Basketmaker II (ca. A.D. 200-500) phase is followed sequentially by Basketmaker III (ca. A.D. 500-700), Pueblo I (ca. A.D. 700-900), Pueblo II (ca. A.D. 900-1100), Pueblo III (ca. A.D. 1100-1300), Pueblo IV (ca. A.D. 1300-1500) and Pueblo V (ca. A.D. 1500-present) phases.

Turkey Pen Cave was occupied during the Basketmaker II phase. It is located in the Grand Gulch of southeastern Utah. The Grand Gulch is a deep, winding canyon. Turkey Pen Cave is located near the confluence of the Grand Gulch and Cane Gulch. The area is relatively high and cold in comparison to other parts of the Colorado Plateau. The vegetation of the area varies from pinyon-juniper woodland to sage parkland. Unfortunately, macrofossil and zooarchaeological data are not available from the cave as yet.

Antelope House was occupied from Basketmaker III times through Pueblo III times. The coprolites analyzed below all date to the late Pueblo II or Pueblo III occupations. The site is located in a cave in Canyon del Muerto in Canyon de Chelly National Monument near the canyon bottom. Today, immediately in front of the cave is a large sandy wash lined with riparian vegetation. Vegetal analysis of materials recovered from the cave show that in prehistory the inhabitants utilized plants in the vicinity of the cave, but emphasized riparian species as described in Chapter 5. Osteological analysis for the site demonstrates that a wide variety of animals were eaten. These include *Odocoileus hemionus* (mule deer), *Antilocapra americana* (pronghorn), *Ovis canadensis* (bighorn sheep), *Lynx rufus* (bobcat), *Ursus americanus* (black bear), *Urocyon cinereoarenteus* (gray fox), *Canis familiaris* (dog), *Canis* spp. (coyote or dog), *Erethizon dorsatum* (porcupine), *Ondatra zibethicus* (muskrat), *Microtus* spp. (voles), *Neotoma* spp. (woodrats), *Peromyscus* spp. (mice), *Castor canadensis* (beaver), *Perognathus* spp. (pocket mice), *Sciurus aberti* (abert's squirrel), *Cynomys gunnisoni* (Gunnison's prairie dog), *Citellus* spp. (ground squirrels), *Sylvilagus* spp. (cottontail), *Lepus californicus* (jackrabbit), *Crotalus* c.f. *cerastes* (sidewinder), *Thamnophis* spp. (garter snakes), *Cnemidophorus velox* (plateau whiptail lizard) and *Meleagris gallopavo* (common turkey) (Hamblin et al. 1978).

Salmon Ruin was built as a mass construction effort at A.D. 1088. During the 1100's it was abandoned but was reoccupied in the 1200's. The village was burned before A.D. 1300. The coprolites studied from this site date to the later occupation. It is located on the first terrace above the flood plain of the San Juan River. Although zooarchaeological information is not available from the site, vegetal analyses have been completed and are summarized in Chapter 5.

Inscription House is another Pueblo III village. It was built in a cave in Navajo National Monument. Its environmental setting is similar to that of Antelope House although large permanent water sources are not immediately in the cave vicinity. There is, however, a stream within a mile of the site supporting a riparian plant community. Unfortunately, only coprolite data are available from the site.

Three large ruins from Chaco Canyon have produced coprolites. These are Kin Kletzo, Pueblo Bonito and Pueblo Alto. The coprolites from these sites date to Pueblo III occupations. Toll's (1981) floral analysis demonstrates that *Amaranthus* (pigweed), *Cleome* (beeweed), *Chenopodium* (goosefoot), *Corispermum*, *Cycloloma*, *Helianthis* (sunflower), *Descuranea* (tansy mustard), *Mentzelia* (stickleaf), *Sphaeralcea* (mallow), *Portulaca* (purslane), *Nicotiana*, *Physalis* (groundcherry), *Solanum*, *Juniperus*, *Pinus edulis* (pinyon pine), *Scirpus* (rush), *Oryzopsis* (rice grass), *Sporobolus* (dropseed), *Yucca*, *Rhus* (sumac), *Echinocereus*, *Opuntia* (prickly pear), *Atriplex* (saltbush), *Zea*, *Phaseolus*, and *Cucurbita* were all likely to have been a part of Chacoan diet. Akins' (1984) analysis of faunal remains from Chacoan sites indicates that *Sylvilagus* spp. (cottontail), *Lepus californicus* (jackrabbit), *Cynomys gunnisoni* (Gunnison's prairie dog), *Odocoileus hemionus* (mule deer), *Antilocapra americana* (pronghorn), *Ovis canadensis* (bighorn sheep) and *Meleagris gallopavo* (common turkey) were commonly consumed.

Another area that has provided opportunities for coprolite research is Glen Canyon. Several sites were excavated as part of a salvage operation in conjunction with the building of Glen Canyon Dam. Faunal and floral data from the specific sites from which the coprolites are analyzed are not described in the published literature (Fry 1977).

Two sites on the Mesa Verde in Colorado have been studied: Step House and Hoy house. This is a high elevation area in a pinyon pine forest with some ponderosa pine. The occupations of the sites include Basket Maker III (Step House) and Pueblo III (Step House and Hoy House) phases. Unfortunately, macrofloral data nor zooarchaeological data are not available from these specific sites (Stiger 1977).

The Fremont Culture describes a wide variety of archaeological manifestations in Utah. There are five branches of the Fremont Culture, each associated with a specific environmental/cultural regime. The San Raphael branch is located in the canyon country in southeastern Utah adjacent to the Kayenta Anasazi. The San Raphael Fremont seem to have been influenced by the Anasazi with respect to ceramic decoration and maize cultivation (Jennings 1980). Coprolites have been studied from Fremont sites in Glen Canyon and also from a site known as Clyde's Cavern. Published descriptions of material culture from these sites are not available. Consequently, the reconstruction of prehistoric lifestyle from these areas is largely derived from fecal analysis.

CHAPTER III

METHODOLOGY

Sampling

In selecting a coprolite sample for analysis, it is ideal to diversify the sample so that many defecations by as many different individuals as possible are analyzed. Sampling strategy of the archaeological sites under study optimizes diversification. Obviously, sites with several latrines and with great time depth offer better conditions for diversification that single latrine sites with short occupations. Both types of site were included in this study. Salmon Ruin, for example, contains only one latrine suitable for study, while Antelope House contains several hundred separate latrine deposits.

The sample from Salmon Ruin comes from a single large latrine deposit. In order to optimize diversity the sample, coprolites from alternate levels in alternate grid squares were taken. From a latrine area in which I estimate at least 4,000 coprolites were excavated, 112 coprolites were selected.

Turkey Pen Cave was excavated in natural levels. The archaeologists furnished me with one coprolite selected from each distinct stratum. In this way, diversification of the sample was achieved.

Bighorn Cave contained only two distinct strata (Phil Geib, Mark Hovezak, Department of Anthropology, Northern Arizona University, personal communication). During the excavation, individual fecal concentrations were found. These were discrete vertically and horizantally and were assigned specific Field Specimen (F.S.) numbers. Several coprolites from each F.S. were provided for analysis. The archaeologists also selected samples that appeared distinct from one another to avoid sampling one defecation twice.

In the case of Baker Cave, the coprolites reached me through a second analyst (Kristin Sobolik) who in turn was supplied the coprolites from the archaeologist who excavated the site (Thomas Hester). Consequently, the sampling strategy followed is unknown.

The nineteen coprolites from Chaco Canyon were recovered from three different sites (Pueblo Bonito, Pueblo Alto and Kin Kletso) and from nine separate fecal deposits.

From Antelope House, 180 coprolites were selected for study by myself and Debra Meier. These came from 34 separate latrine areas. Differences in texture, coloration, and size were considered to avoid sampling the same defecation twice.

Sample Size

Sample size is an important consideration with respect to dietary reconstruction. The fact that diet is specialized at most sites lessens the number of coprolites that must be studied to identify the major plant components. However, the diversity of minor constituents that often occurs necessitates the study of large numbers of coprolites to evaluate the total range of plant foods. A factor that usually limits the number of coprolites studied is the time commitment involved in coprolite analysis. My approach to dietary study is to document the consumption of major food items. In this general characterization, documentation of foods that are only occasionally eaten embellish the dietary picture but are not necessary to gain an understanding of the basic diet at any given site.

For dietary analysis, it is important to analyze a representative sized fragment to make sure that the maximum number of dietary components are found. Usually, it is sufficient to simply cut the sample in half and rehydrate one half of the coprolite. For parasite analysis, a one gram fragment is sufficient for analysis.

Component Increments

In the determination of suitable sample sizes, I have considered the number of components that accumulate with each coprolite during the course of analysis. From a hypothetical site, I might find eight components in the first coprolite, five different components in the second, three different components in the third, and continue recording the number of accumulating components through the rest of the analysis.

Usually, 80%-90% of identifiable plant components are found after 15-20 coprolites have been examined. For example, in the analysis of Bighorn Cave, 20 coprolites were quantified by weight and an additional 15 coprolites were surveyed for components not found in the first 20. A total of 11 different identifiable plant components were found. After 15 coprolites were studied, 10 of these components were found and after the study of 17 coprolites, 11 components were found. Continued analysis of the remaining 18 coprolites revealed no additional dietary components. I conclude that 91% of the components were found in the study of only 10 coprolites.

In the case of the 30 Glen Canyon Anasazi coprolites, 90% of the components (19 of 21) were found in the study of 20 coprolites. In the case of 56 coprolites from Hoy House and 50 coprolites from Dust Devil cave, all components had been found by the time the 20th coprolite was analyzed. Twenty of 25 components (80%) were found in the study of 20 of 92 coprolites from Antelope House.

In general, most components are documented after the study of 20 coprolites. This trend is even more obvious when those components that occur in only one coprolite are excluded. Component increment curves are depicted in Figure 2 for sites that have 40 or more coprolites studied. Only in the case of Hinds Cave (Fig. 3) did the curve not reach a plateau by the analysis of the 20th coprolite.

Based on these cases and others, I feel that analysis of 20 coprolites is sufficient for the recovery of most identifiable plant components and to trace trends in dietary specialization, providing that the sample is diversified such that the samples do not all come from the same locus in a site. Certainly no less than 15 coprolites should be studied to characterize a diet.

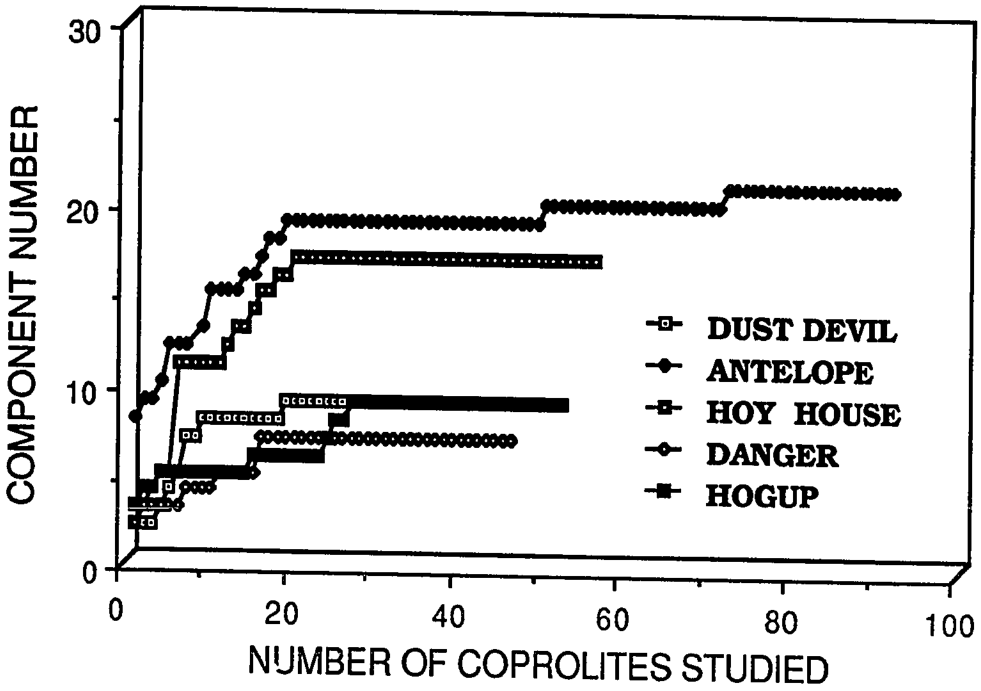

FIGURE 2

Component increment diagrams for specified sites.

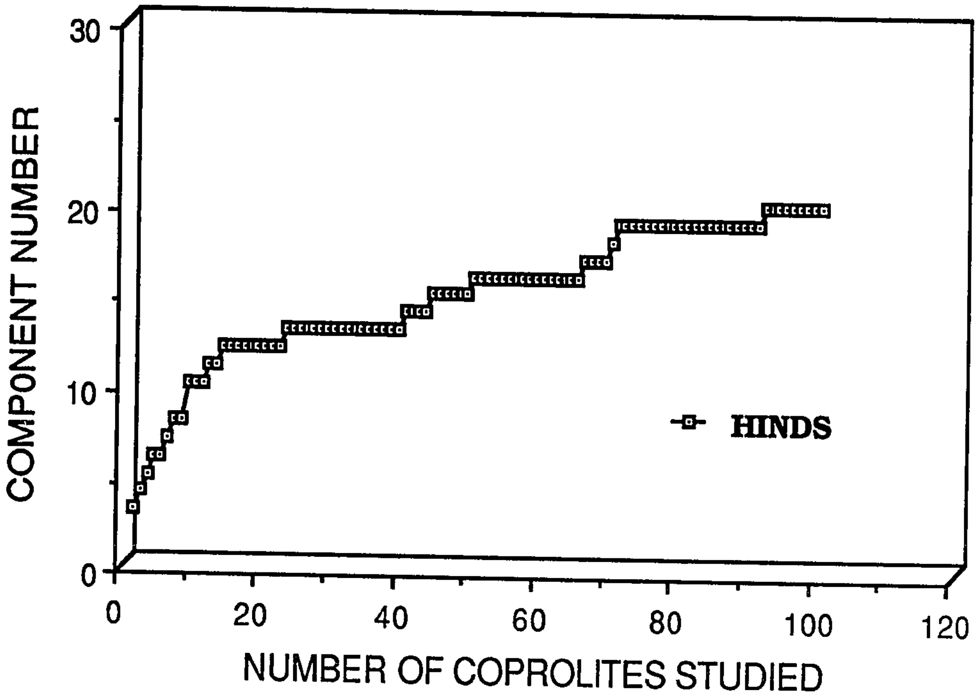

FIGURE 3

Component increment diagram for Hinds Cave.

Processing: Turkey Pen Cave

The macrofossil analysis of the Turkey Pen Alcove feces was carried out utilizing a procedure outlined by Fry (1977). The specimens were initially cleaned of all extraneous dirt, and then photographed in color and black and white. The samples were then sketched and measured in terms of length, width, thickness and weight and described in terms of surface morphology and visible inclusions. The samples were then split in half longitudinally. One half was used for analysis. It was weighed and then placed in a 0.5% weight to volume solution of trisodium phosphate (Na_3PO_4) for a minimum of 72 hours, or until the sample had largely disaggregated. Prior to screening, Munsell color readings of the trisodium phosphate solution were taken. The samples were then screened through a series of geologic sieves in mesh openings of 1.0mm and 0.5mm, labelled the coarse and fine fraction respectively. Materials smaller than 0.5mm were retained in a catch pan and were employed for pollen and parasite analysis. Macrofossils retained in the screens were transferred to filter paper and placed in a drying oven at 50° C until the samples were desiccated.

When completely dry, the materials were transferred to petri dishes for component analysis. As a general procedure, the entire coarse fraction was separated into individual components which were weighed. The fine fraction was subsampled, with approximately one third being separated into components. The remainder of the fine fraction was scanned for unique items, such as seeds and ectoparasites, and was saved. Identifications were taken to the finest taxonomic division possible (i.e. genus, species) and were based on morphological similarities to modern comparative materials housed in the Paleoethnobotany Laboratory at Texas A&M University.

The microscopic fraction was then examined for parasite remains after Reinhard (1985a, 1985b). The microscopic remains were sedimented by gravity in acetic formalin alcohol. A sample of the uppermost sediments was pipetted onto a microscope slide, mixed with glycerol, and then covered with a cover slip and sealed. When parasitological analyses were completed, the microscopic sediments were processed for pollen through sequential baths in hydrochloric acid, hydrofluoric acid, glacial acetic acid, acetolysis mixture (9 parts acetic anhydride to one part sulfuric acid), glacial acetic acid and 5% potassium hydroxide. This process sequentially dissolves carbonates, silicates, cellulose and hemicellulose, and humics (Bryant 1974B; Clary 1984; Martin and Sharrock 1964). Once processing was complete, a minimum of 200 pollen grains was counted for each specimen. A 200 grain count is considered adequate for statistical representation of pollen types (Barkley 1934). Percentages of pollen present in each sample were then derived. Dietary interpretation of the pollen data are based on these percentages.

Processing: Bighorn Cave

Each coprolite was photographed in color and black and white before processing. At this time, laboratory numbers were assigned to the coprolites.

Pollen concentration was applied to the coprolites. This technique enables one to determine the actual number of pollen grains per gram of coprolite by comparing the number of pollen grains counted to a known number of introduced, exotic spores. A one gram fragment of each coprolite was broken up into small fragments and rehydrated for 24 hours in trisodium phosphate with two tablets of Lycopodium spores (each containing approximately 11,200 spores). This softens the desiccated fecal matrix of the coprolite. After rehydration, each sample was treated for one hour in 10% potassium hydroxide and then disaggregated with a magnetic stirrer. The potassium hydroxide softens plant tissue in the coprolites and the magnetic stirrer releases pollen that might otherwise be trapped in the plant remains. The samples were then screened through a 300 micrometer mesh. The fluid passing through the screen was collected in a larger glass beaker and then centrifuged in 100 ml. centrifugation tubes. After the solid microscopic remains were concentrated by centrifugation, they were transferred to 50 ml. tubes for chemical extraction.

The extraction of the pollen involved several stages. The sediments were first treated with hydrochloric acid (70%) and then rinsed with water. Then hydrofluoric acid (30%) was added to the tubes and the tubes were placed in a boiling water bath for an hour. After the hot hydrofluoric acid treatment, the samples were rinsed with water and then rinsed twice with glacial acetic acid preparatory to acetolysis. The acetolysis mixture of 1 part sulfuric acid and 9 part acetic anhydride was added to each tube at which point the tube was placed in a boiling water bath for 40 minutes. Finally, the samples were washed with acetic acid and then several times with water (until the supernatant was clear).

When the chemical extraction was finished, the sediments were washed with 95% alcohol and transferred to small vials in alcohol. Microscope slide preparations were made by pippetting a drop of sediment onto a microscope slide. After most of the alcohol had evaporated, a drop of glycerol was mixed with the sediments. Then a cover glass was placed on top and sealed with fingernail polish. The microscope preparations were examined under 400x magnification and a minimum of 200 pollen grains was counted for each slide.

Pollen identification of the Bighorn Cave samples was based largely on the pollen comparative reference collection on file with the Palynology Laboratory, Texas A&M University. Unknown types were compared to this collection of vouchered, modern pollen to determine the type.

Macroscopic remains were recovered by rehydrating a 5 gram fragment from each coprolite in trisodium phosphate for 48 hours. After rehydration, each coprolite fragment was disaggregated with a magnetic stirrer. The solution containing the disaggregated coprolite fragment was screened through a 500 micrometer mesh. The material remaining on top of the mesh was dried on blotter paper. Once dry, the sediments were screened through 1.0 and 0.5 mm. meshes to facilitate analysis.

Parasitological examination followed that described for Turkey Pen Cave.

Processing: Hinds Cave

The procedures utilized in this analysis are essentially the same as applied to Bighorn Cave coprolites. Pollen concentration was applied in the palynological analysis. Pollen concentration involves the addition of a known number of exotic grains to the samples (in this case Lycopodium spores) so than the pollen extracted from the coprolites can be quantified in terms of the number of grains per gram. This process allows for more nearly accurate determination of dietary pollen types.

Instead of dry screening the extracted macrofossils as described for Bighorn Cave, the macrofossils were screened while wet through graduated screens. This allows for more nearly efficient separation of components. It is important to point out that only small portions of the coprolites were used in this analysis since the major goal was parasitological analysis. Only five grams from each coprolites were rehydrated. When smaller amounts are used in coprolite analysis, the chances of recovering a representative sample of dietary constituents is lessened. Consequently, weight quantification of macroscopic remains is inappropriate for this study. Macroscopic remains were quantified in terms of presence/absence.

The macroscopic analysis is designed to augment the more nearly extensive analysis completed on Hinds Cave coprolites by Williams-Dean (1978). However, because we were analyzing coprolites which date more recently then those studied by Williams-Dean, (3,000 B.C. as opposed to 5,000 B.C.), our analysis revealed a slightly different spectrum of food plants. In this analysis, 25 feces were studied macroscopically. Because of time constraints, pollen concentration was then applied to 20 of the samples. Thirty-nine coprolites from Hinds Cave were examined for parasites as described for Turkey Pen Cave.

Processing: Antelope House

The major goal of the Antelope House analysis was the recovery of helminth eggs and larvae. One gram fragments of 180 coprolites were rehydrated and sedimented for parasite eggs as described for Turkey Pen Cave.

CHAPTER IV

PROCESSING RESULTS

Bighorn Cave

The pollen counts and macroscopic results are presented below F.S. (field specimen) numbers. Many coprolites reflect only the environmental pollen rain which is dominated by Poaceae, low spine Asteraceae, and Quercus. Other specimens, however, are dominated by pollen types that certainly had a dietary origin. It is important to note that no cultivated plants are indicated by the pollen analysis.

F.S. 177

Three of the four specimens in F.S. 177 show an abundance of dietary pollen while the fourth contains what is probably environmental pollen.

Sample 1 contains mostly environmental pollen. Macroscopically, the sample is dominated by Prosopis pubescens (screwbean mesquite) fiber derived from mesquite pods. Unidentifiable bone fragments were also present as well as unidentifiable fiber.

Sample 1 contained approximately 14,300 pollen grains per gram. These grains were in a poor state of preservation. The count reflects a natural spectrum of predominantly windborne pollen types such as Quercus, Low Spine Asteraceae, Poaceae, and Cheno Am. The poor preservation suggests that the pollen types were in the environment for a period of time prior to human consumption. I feel that these grains may have been consumed with drinking water.

Mustard family pollen (Brassicaceae) dominates sample 19 to the near exclusion of all other types. Pollen concentration shows that in excess of 5,000,000 pollen grains per gram are present in sample 19 and indicates that either mustard family flowers were consumed or mustard tea was drunk. Macroscopically, Opuntia (prickly pear) epidermis was common with fiber probably derived from Opuntia. Also present were large druse phytoliths, leaf fragments, Prosopis pubescens seeds, and unidentifiable plant stems.

Ephedra pollen dominates samples 20 (74.5%) and 21 (81.3%). In ecosystems dominated by Ephedra, between 8% and 45% of the pollen rain is from Ephedra (Reinhard, unpublished counts of modern ecosystems). The variation in count depends on whether the sample was collected in an area devoid of small forbs where high Ephedra counts occur or in areas where forbs are abundant. Clearly the amount of Ephedra pollen in these two coprolite samples exceeds that expected in natural pollen rain. Pollen concentration shows that samples 20 and 21 contained quantities in the millions of pollen grains per gram. Such high quantities of pollen could have been ingested with tea brewed from Ephedra.

The macroscopic remains from sample numbers 20 and 21 consisted primarily of unidentifiable plant debris. Bone fragments, Opuntia epidermis and Opuntia fiber were present.

F.S. 229

Both samples from F.S. 229 have high percentages of Poaceae pollen. Although this is a windborne type and is consequently easily ingested by inhalation, drinking, and eating, the high percentages of samples 17 and 18 indicate that it was a dietary type in these cases. The average Poaceae percentage for all human coprolites from Bighorn Cave is 13.8%. Sample 17 contains 40.7% and sample 18 contains 47.9% Poaceae. This is strongly suggestive that grass in these instances is dietary.

Another dietary type, Brassicaceae, is represented by 14.2% in sample 18. This is a high percentage for an insect pollinated species and consequently this percentage probably indicates a dietary origin. Both sample 17 and sample 18 contain large amounts of fine charcoal in the pollen preparations. This is similar to coprolites from Dust Devil Cave that I have examined in which high grass pollen percentages occurred with large amounts of charcoal. I suspect that parching grass seeds or inflorescences accounts for the co-occurrence. Pollen concentration indicates that 17,000 and 129,000 grains per gram were present in sample 17 and sample 18 respectively.

The macroscopic remains from sample 17 include Prosopis pubescens fiber, Opuntia epidermis, unknown grass seeds, Descurania (tansy mustard) seeds, and a Juniperus (juniper) seed. In the case of sample 18, all of the rehydrated coprolite passed through the screen and consequently no microscopic remains were present for study.

F.S. 266

Only one coprolite from this provenience was submitted for analysis. Pollen concentration indicates that the coprolite contained about 150,000 pollen grains per gram. The pollen counts are dominated by Quercus (50%). The relatively high percentage of unidentifiable pollen (17%) is composed of spindled or crushed grains that are probably Quercus. In post oak savanah in eastern Texas dominated by Quercus, up to 45% of the natural pollen rain is derived from Quercus (Reinhard, unpublished pollen counts of modern ecological zones). The average Quercus percentage for all human coprolites from Bighorn Cave is 10.1%. The high percentage in sample 8 could be due to dietary reasons. However, Quercus is a prolific pollen producer and is wind pollinated. Therefore, it is possible that the high percentage is due to consumption of contaminated food or drink.

The macroscopic remains were dominated by a finely ground meal of unknown origin.

F.S. 279

The single coprolite from this provenience is from a non-human carnivore. Before rehydration, it was composed of a hard, dark, crust surrounding a core of bone and hair. It contained about 20,500 pollen grains per gram of coprolite. The dominant types are windborne. The pollen content of this coprolite no doubt mirrors the environmental pollen rain present at the time of defecation. Only bone and hair were recovered from the macroscopic screening.

F.S. 321

Four coprolites (sample's 10, 11, 12, and 13) were processed from this provenience. No pollen was recovered from sample 12. The pollen analysis from sample 10 did not demonstrate any clear examples of dietary types. However, sample 11 was dominated by Salix (willow) and sample 13 contained a relatively large percentage of Opuntia pollen. Salix is a windborne type that is especially common in spring. However, it is improbable that Salix would normally make up 86% of the pollen rain. The presence of 86% Salix pollen in sample 11 is undoubtedly due to dietary use of the plant. Opuntia never accounts for more than 0-2% of the normal pollen rain, even in a prickly-pear patches in southern Texas (Reinhard, unpublished pollen counts of modern ecological zones), a finding similar to pollen counts by Bryant in west Texas (1974a). The presence of 26.5% Opuntia pollen in sample 13 is clearly a result of dietary use of the plant. In sample 10, 36,300 pollen grains per gram are present and 53,300 grains per gram are present in sample 13. The relatively high pollen concentration value of 224,000 grains per gram was obtained from sample 12.

Unidentifiable fiber with fish bone and Opuntia epidermis were found in sample 10. Sample 11 contained Opuntia fiber, epidermis and druse phytoliths. Opuntia epidermis, fiber and fish bone was also present in sample 12. Prosopis pubescens fiber and seed were present in sample 13 as well as unidentifiable plant cuticle, leaf fragments, an unknown seed, and Opuntia epidermis.

F.S. 345

Six coprolites from this provenience were analyzed. Two of these (sample's 2 and 6) were different from the other four in having poorly preserved pollen similar to sample 1 of F.S. 177. Both of these samples probably reflect the natural pollen rain of the area in prehistory. The relatively high Poaceae count of sample 3 suggests that Poaceae pollen was introduced into the intestine through dietary means, but this can not be said with certainty. Yucca pollen in sample's 5 (32%) and 6 (23%) clearly indicate a dietary use of this plant since Yucca pollen does not normally turn up in pollen rain in such high percentages.

Sample 2 consisted mostly of Prosopis pubescens fiber and seed with small amounts of Opuntia epidermis, grass seed, and Chenopodium seed. The Poaceae pollen in this sample may relate to the presence of grass seed.

Prosopis pubescens fiber and seeds dominated Sample 3 with unidentifiable fiber and Opuntia epidermis occurring in small quantities.

Sample 4 contained mostly unidentifiable plant material, perhaps the remnants of Yucca flowers as the presence of Yucca pollen would suggest. Some Prosopis pubescens fiber and seeds, Opuntia epidermis, and unidentifiable fiber were also present.

Sample 5 was dominated by Opuntia epidermis, fiber, and glochids. Druse phytoliths were very common as well.

Sample 7 was composed almost entirely of Prosopis pubescens fiber and seeds. Descurania seeds and unknown leaf fragments were also present.

F.S. 382

Two coprolites were submitted from this provenience. Very high pollen per gram values were obtained from samples 15 and 16 (4,972,800 and 1,136,800 respectively). A large amount of fine charcoal was present in sample 16. Both samples contained large percentages of Salix pollen that certainly indicate consumption of this plant. In sample 15, the large numbers of Salix pollen grains exclude all other types.

Macroscopically, Prosopis pubescens fiber and seed was most common in sample 15. A few druse phytoliths were also present, probably derived from Opuntia. Sample 16 was composed predominantly of cucurbit seed fragments of an unknown species. Present in trace amounts were Prosopis pubescens fiber and Opuntia epidermis.

F.S. 390

The single sample from this provenience, sample 9, contained badly degraded pollen that again reflects dietary use of *Salix*. Of the pollen grains counted, 14.5% are of *Salix*. Degraded grains that are probably *Salix* constitute 10.5%. Pollen concentration indicates 29,300 grains per gram of coprolite.

Unidentifiable plant material predominated in this sample. Fiber derived from perhaps *Yucca* or *Agave* was also present as were traces of *Opuntia* epidermis, unknown leaf fragments, and bone.

Hinds Cave

This study was undertaken to evaluate coprolites from Hinds Cave for parasitological remains. In conjunction with the parasitological analysis, pollen and macrofossil analyses were also undertaken. The results augment dietary data obtained by previous researchers (Stock 1983; Williams-Dean 1978).

Coprophagous Organisms

Macroscopic analysis recovered the remains of coprophagous animals such as flies, spider beetles, and millipedes. Flies were most abundant, and the types of flies identified from pupa cases are adapted to moist feces. The latrine fly, *Faunia scalaris* was present as were flies in the family Ephydridae. Other pupae could be identified only to the order Diptera. Spider beetles (family Ptinidae) were found in two coprolites.

These finds provide important information regarding the decomposition of the feces and hence preservation of certain components. Spider beetles infest dry substrates. They are commonly found in coprolites in the Four Corners area of the Southwest and indicate that rapid drying of feces occurred in caves in that area. Flies were much more abundant in the Hinds Cave feces. Flies infest moist feces and consequently the predominance of flies indicates that feces remained moist for many days after deposition.

Mites also infested the feces as did millipedes. The arthropod remains show that the Hinds Cave feces desiccated slowly. The evidence of slow desiccation of the Hinds Cave coprolites has an impact on the validity of the parasitological study. Many strongylate worms hatch from their eggs and migrate away from moist feces. Consequently, the chances of recovering Strongyloides, trichostrongyles, and the hookworm genera are lessened. Also, it is evident from an examination of coprolites from Chaco Canyon (Reinhard and Clary 1986) that pinworm eggs degrade in feces that stay moist for long periods of time. When evaluating the results of the parasitological analysis, these points regarding fecal ecology of Hinds Cave must be considered.

Parasitology

No nematode larvae were recovered. Only one nematode egg was found, but it was too badly preserved to allow identification. No cestode nor trematode eggs were found. The lack of definite parasite remains is consistent with Reinhard's helminth examination of 17 coprolites from Baker Cave, a nearby archaic habitation. One concludes from the combined analyses of 56 trans-Pecos archaic coprolites that either parasitism was very rare or that the coprolites did not provide suitable conditions for the preservation of helminth eggs. Although it is probable that parasitism was rare in the lower Pecos, it is my belief that until more lower Pecos coprolites are examined for helminth remains, the actual parasitic state of these people will be unknown.

Pollen

Pollen analysis was completed on 20 coprolites. A total of 47 identifiable pollen taxa were recovered. In addition, there were five types that could not be identified to any taxonomic level and were noted as Unknown 1 - Unknown 5. Of these pollen types, only seven appear to be dietary types. The remaining types are probably environmental types that were inhaled or consumed with drinking water. Fern spores were also recovered in four samples. Therefore, a total of 53 pollen and spore types were recovered in the pollen analysis.

The pollen concentration analysis, measured in terms of pollen grains per gram of dry feces, showed a large range in the amount of pollen present in the feces. The pollen concentration ranged from 2,000 grains per gram to 12,034,000 grains per gram.

A variety of environmental pollen types occurred in low percentages in most samples. The fact that they are present in most samples indicates that the feces were deposited during the pollination period of spring and summer. Dietary types were identified on the basis of several criteria.

Frequently, pollen aggregates were found which are the remains of anthers. Grass pollen aggregates were most commonly found. This indicates that the inflorescences or flowers of certain plants were consumed.

Abundance of insect pollinated types and some wind pollinated types indicates dietary origin. In this analysis high pollen frequencies were noted one or more times for six pollen types. The dietary pollen types include Agave, Echinocereus c.f., Dasylirion, high spine Asteraceae, Lycium c.f. and grass. Regarding Agave and Dasylirion, it is probable that the flowers of these plants were eaten.

In the macroscopic analysis, Echinocereus seeds were found and it is possible that the pollen was consumed with the fruits of this cactus although one can not rule out the possibility that the flowers were eaten. The pollen of high spine Asteraceae was probably ingested with seeds from plants such as sunflowers. Low frequencies of Celtis and grass in other samples indicates that these types were common in the natural pollen rain. Finally, pollen grains that are very similar to Lycium in the family Solanaceae were eaten. These might have been ingested with flowers or tea derived from the foliage of the plant.

Macroscopic Remains

Macrobotanical analysis was done with 25 coprolites. One of the largest components in terms of frequency of occurrence as well as quantity, is that of Opuntia spp. (prickly pear) seeds and pads. Prickly pear seeds were recovered in 17 samples with pads, represented by epidermis and fiber, being found in 15 samples. Collectively, prickly pear traces represent one of the major components being found in 20 (80%) of the Hinds Cave feces. Opuntia spp. spines and glochids were also recovered in six samples. Additional members of the Cactaceae family were represented by Mammillaria sp. (pincushion or nipple cactus) seeds in one sample, *Echinocereus* sp. (pitahaya or hedgehog cactus) seeds in two samples with indeterminate cactus spines being found in one sample.

Chenopodium sp. fruit was found in only two samples and in low frequencies. This is a contrast with other sites such as Dust Devil Cave where *Chenopodium* was commonly consumed (Reinhard et al. 1985).

Allium (onion) bulb fragments were found in only two (8%) of the Hinds Cave feces. This is in sharp contrast to Williams-Dean's (1978) dissertation where onion was found in 40% of the Hinds Cave coprolites. Seasonal availability or sample selection may be a factor.

Celtis (hackberry) seed fragments were found in only two samples and may also represent oportunistic foraging rather than deliberate harvesting. Seeds from the Brassicaceae (mustard) family were noted in five samples and in one case compared favorably to *Descurainea* sp. (tansy mustard), and may have been consumed as a spice. Williams-Dean (1978) reports that 13% of the Hinds Cave feces in her study contained *Prosopis* (mesquite) seeds and fruit, yet fragments of this genus were recovered in only one specimen. Seeds identified as *Diospyros texana* (Texas persimmon) were found in only two samples, and again may represent opportunistic foraging. *Helianthus* sp. (sunflower) achenes are frequently encountered in southwestern coprolites. Seeds of this genus were found in three samples. Though Williams-Dean (1978) reports the presence of *Carex* (sedge) in 8% of her specimens, Cyperaceae fruit were encountered in only one sample in this study. These fruit compare favorably to *Carex* sp.

Juglans (walnut) was represented in the Hinds Cave diet by the presence of shell fragments in two specimens. Williams-Dean (1978) reports walnut traces in 23% of the Hinds Cave samples in her study.

Evidence for the prehistoric utilization of grass at Hinds Cave is found in six samples. The samples produced an abundance of seeds comparing favorably to Sporobolus sp. (dropseed), with one sample exhibiting a number of indeterminate grass stems. Grass was clearly an important dietary component as Williams-Dean (1978) reports grass in 42% of the Hinds Cave feces.

The most abundant type of plant material recovered was that of plant fiber and epidermis. Monocot fiber was found in 14 samples with epidermis being noted in eight. Dicot fiber was recorded in 13 samples, with epidermis being seen in two. Dicot leaves were recovered in five samples. It is suspected that the majority of monocot fibers and epidermis are from Yucca and Agave leaves. In three samples fragments were large enough to be identified as Yucca sp. epidermis. Many of the dicot fibers are probably those of Opuntia though their fragmentary nature precludes further taxonomic classification.

An Acacia sp. spine was found in a sample and may represent an accidental ingestion rather than a dietary component. Additional non-diagnostic plant materials consisted of indeterminate seeds (three samples), epidermis (four samples), fruit fragments (two samples), fiber (one sample), resin (three samples), bark (one sample), spines (one sample) and unidentifiable plant material (one sample).

Evidence of the dietary usage of animal foods was abundant. Bone fragments were found in 16 samples. Because of their small size and fragmentary nature, further identification was usually not possible. One sample contained a single tooth identified to the order Rodentia. Evidence of the exploitation of lizards took the form of scales in two samples. Bones from two samples had traces of probable lizard skin. Fish were exploited as well, as demonstrated by the presence of bones in two samples with scales also being found in one sample. Including the Rodentia tooth, lizard remains and fish traces, bones were found in a total of 18 (72%) of the coprolite specimens. Williams-Dean (1978) reports the presence of bone in 97% of the Hinds Cave feces in her study. My lower frequency probably reflects the fact that we only processed five grams of each coprolite. Were larger portions examined, more bones would likely have been encountered. Additional evidence of probable meat in the Hinds Cave diet includes non-human hair in six samples and sinew in one sample. Evidence of the consumption of insects was found in 15 (60%) of the Hinds Cave feces. Indeterminate insect chitin was found in 13 samples. Two samples contained relatively large amounts of grasshopper fragments.

Fragments of stone and grit were recovered in 16 samples. Rather than representing geophagy, it is likely that this trace material was introduces through unsanitary food preparation or eating techniques. The presence of charcoal in 21 samples appears to substantiate this theory. Land snail shells comparing favorably to the genus Rabdotus were found in five samples. The small shell fragments were probably introduced into the diet as a contaminant much like the grit and charcoal.

Turkey Pen Cave

Macroscopic Remains

Several cultigens were present in the coprolites. Maize (Zea mays) was found in 23 of the specimens, and represents the dominant macrofossil component. This category consists primarily of ground maize kernels, with silk and glumes being found in one sample each. Though most kernels found were fragmentary, one sample contained several whole unbroken kernels suggesting that maize may have been consumed on the cob as well as milled or ground. The abundance of maize in the Turkey Pen Alcove feces suggests a heavy reliance (possibly a seasonal abundance) of this cultigen. Squash (Cucurbita) seed fragments were found in three samples, though in low frequencies. A single intact bean (Phaseolus vulgaris) was found in one sample and represents utilization of this important cultigen.

In terms of species diversity, wild plants represent the greatest percentage of the Turkey Pen Alcove coprolite macrofossils. Pinyon pine (Pinus edulis) seed coat fragments were found in four samples, and represented the major macrofossil component in one sample. Pinyon pine nuts, at least seasonally, represent an important food source. The seed itself, however, appears to be completely digested, thus the utilization of this species can be recognized only by the presence of the nut shell or membrane. Fruit and seeds of the common goosefoot (Chenopodium) and pigweed (Amaranthus) plants were found in 12 samples. These weedy plants, though probably not cultivated, were almost certainly encouraged since they provide a steady food source through their abundance of seed. Furthermore, the utilization of some species of Chenopodium (specifically C. ambrosioides, C. graveolens, some varieties of C. ambrina, and some varieties of C. botrys) as an anthelminthic must be considered (Reinhard et al. 1985). In some cases, due to the fragmentary nature of these similar seeds, an identification to genus was not possible, thus the seeds were labelled as Cheno Am.

Berries of juniper were recovered in five samples. These seeds, comparing favorably to Juniperus osteosperma. Beeweed (Cleome) seeds were found in three samples. Seeds of this plant were evidently consumed as a food, and it is suspected that the flowers and leaves were possibly utilized as a spice. Peppergrass seeds (Lepidium) were found in two samples and probably reflect its usage as a spice or food. Purslane (Portulaca) seeds were found in five samples. Achenes of sunflower (Helianthus c.f. anuus) were found in five samples. These seeds, though small, are an important source of oil and protein and were consumed whole. Seeds of yucca (Yucca c.f. baccata) were found in one sample and probably represent a meal of this seasonally abundant plant.

Solanaceous plants were eaten at Turkey pen cave. Seeds of ground cherry (Physalis) and an unidentified species of nightshade (Solanum) were found in two samples. A large number of Physalis seeds were found in one sample. A single Descurainea (tansy mustard) seed was found in one sample. Grass caryopses were observed in three samples, and coupled with the abundance of grass stems and fibers, probably represent a important dietary component.

The presence of monocot fiber and leaves (probably grass) in fifteen samples suggests that this food source was also of similar importance in the southwestern United States. Perhaps grass leaves were fortuitously eaten with grass florettes. Indeterminant seeds whose coats had been badly disfigured were found in two samples. Further identification of these samples was impossible due to the processes of mastication or digestion.

The ingestion of prickly pear pads (_Opuntia_ sp.) is demonstrated by the presence of cactus epidermis in three samples and was the dominant component in one of these. _Opuntia_ sp. glochids were found in four samples, though are probably accidental ingestions. A fragment of cactus spine found in an additional sample could be viewed as a probable contaminant.

Fibers, leaves and epidermis of dicotyledonous plants were found in thirteen samples and should be viewed as an important dietary component. Identification, however, has so far been unsuccessful though there is some evidence to suggest that some of the leaves may be _Atriplex_ (shadscale, saltbush) and _Portulaca_ (purslane). Future analyses coupled with a more complete leaf reference collection will clarify this component.

Though plant food was of major importance in the Turkey Pen Alcove diet, meat was also consumed. Bones of rabbit, probably _Sylvilagus_ sp. were found in three samples, with unidentified lagomorph or rodent bone chips being present in nine additional samples. Non-human hair was found in thirteen samples and a fragment of gristle or sinew was present in another. Meat, then was also an important component in the Turkey Pen

Alcove diet.

Several additional components were recovered. The presence of juniper (Juniperus osteosperma) twigs, leaves and bark and Artemisia/Chrysothamnus wood as well as Gymnospermae wood and Dicotyledoneae twigs in one coprolite each may signal the ingestion of medicinal teas. Insect chitin and feathers may also be accidental ingestions or traces of meals. Charcoal and stone were ubiquitous and should probably be viewed as accidental ingestions resulting from haphazard food preparation and consumption rather than geophagy. The presence of rounded sand grains in nine coprolites does suggest the use of milling stones.

Cordage was found in two samples. One twine fragment was included fortuitously when the diarrheal stool dessicated around the string upon which it was defecated. Another sample contained a twine fragment which was apparently eaten. It is interesting to note that a third sample, believed to be that of a dog, contained a piece of twine approximately 16 inches long.

Microscopic Remains

Pollen is consumed with flowers, or teas brewed from foliage containing flowers or buds, fruits, and even seed. Bohrer (1968) demonstrated that pollen is trapped in certain types of seeds and is eaten. It is important to remember that pollen, once introduced into the digestive tract, will be excreted for many days. Unlike macroscopic remains which may pass through the system relatively quickly, pollen grains may remain for 10 -20 days. This is especially true of small, ornamented grains (Kelso 1976; Willaims-Dean 1978).

A large number of pollen types are present in the pollen analysis. Of 32 types, 21 are insect pollinated. Some of these are in such high percentages that dietary use is certain. Mustard pollen (Brassicaceae) appears in significant percentages in three coprolites. The pollen could have been consumed with seeds or perhaps flowers. One coprolite contained large amounts of high spine composite pollen. Sunflower is a high spine type and it is possible that the pollen was introduced with the consumption of seeds. Sunflower seeds are noted in the macroscopic analysis. Alternatively, the pollen could have been introduced with the Chrysothamnus foliage that was found in the macroscopic analysis.

Cleome pollen is present in large quantities in eleven coprolites. Cleome is dietary item that was universally consumed by prehistoric Anasazi puebloans. Rohn (1971) first notes Cleome pollen at Mug House on the Mesa Verde, and Martin and Sharrock (1964) mention the presence of Cleome pollen in coprolites from Glen Canyon. Since then, Cleome pollen has been found at Antelope House (Williams-Dean 1986), Kiet Siel (Jones 1984), Hoy House (Stiger 1977), Chaco Canyon (Clary 1984), and Salmon Ruin. So common is Cleome in Anasazi coprolites, that it can be considered a "hallmark" of Anasazi diet. So much pollen is present in the Turkey Pen Cave feces, that only the consumption of flowers could introduce so much pollen into the digestive tract. It is assumed that Cleome flowers were used as a spice for they have a peppery taste (Phil Geib, personal communication).

Fabaceae pollen is present in large quantities in one coprolite. It is uncertain whether or not this is from a cultivated bean species or one of the several wild plants in the bean family such as Astragalus (milk-vetch) or Lupinus (lupine) that grow in the area.

Portulaca (purslain) pollen is present in large quantities in two coprolites. Perhaps the pollen of this species was introduced with the consumption of seeds found in the macroscopic analysis.

The fruits of the buffalo berry (Shepherdia) were of dietary importance and the presence of Shepherdia pollen in one coprolite may indicate that the Anasazi consumed this plant at Turkey Pen Cave.

Wind pollinated species were consumed at Turkey Pen Cave. Eighteen of the coprolites contain maize pollen, nine in relatively high quantities. Although maize is wind pollinated, the pollen grains are heavy and quickly fall out of air currents (Raynor et al 1972). The presence of maize in coprolites, even in small amounts, is therefore thought to be indicative of maize consumption (Martin and Sharrock 1964). Two coprolites contain large amounts of cottonwood (Populus) pollen. The presence of the pollen probably resulted from the consumption of cottonwood catkins, a native food source.

Low spine composite pollen is present in significant quantities in four coprolites. Several common genera such as Ambrosia (ragweed) and Solidago (goldenrod) produce low spine pollen so the origin of the pollen is not certain. A variety of weedy composites produce such pollen.

With grass and Cheno Am pollen, low spine composites dominate the pollen rain in much of the Colorado Plateau. Cheno Am pollen is abundant in many of the feces, but dominates two of the pollen counts. The pollen could have been consumed either with the seeds of Chenopodium or Amaranthus or with the florette of the plant.

In the macroscopic analysis, the caryopses, stems and leaves of grass were recovered. It is highly probably that the large quantities of grass pollen in two samples were introduced by the consumption of grass inflorescences.

Large pollen grains derived from cultivated squash were found in one sample. Finally, pollen of what might be a type in the rose family is abundant in one sample. This identification is tenuous and consequently speculation as to the source of the pollen is inappropriate.

Certain pollen types occur with a certain regularity in the coprolites. Maize (*Zea*) and *Cleome* pollen are most frequently encountered. This suggests a strong reliance on maize as a mainstay and underscores the importance of *Cleome* as a dietary suppliment and condiment.

Small fungal spores comparable to the urediospores of rust fungi which parasitize cereal plants were found in the coprolites.

Helminths

Pinworm eggs (*Enterobius vermicularis*) were found in eight of the 24 human coprolites. A single tapeworm egg in the family Taeniidae was found in sample 5. This suggests infection percentage of at least 33%. The taeniid egg was poorly preserved and it is likely that it represents a case of "false parasitism" (Moore et al. 1974) and not a true infection.

Antelope House

Macroscopic and pollen analysis has already been completed with Antelope House coprolites (Fry and Hall 1986; Williams-Dean 1986). Parasitological analysis, however, has not been thoroughly completed. The only goal in the examination of the Antelope House coprolites was the identification of parasite remains.

Pinworm (Enterobius vermicularis) was the most common helminth encountered. Forty-four coprolites (25%) were positive for pinworm eggs. One of these also contain the posterior of a gravid adult female. Two coprolites (1%) contained Strongyloides (threadworm) larvae. Both first stage and third stage larvae are present. Eggs of an unidentified nematode were present in five (3%) of the coprolites. The eggs are possible from a strongyle or trichostrongyle species. Finally, onchospheres of a hymenolepidid tapeworm were found in one coprolite.

When considering latrine proveniences, 22 of 47 latrines (44%) contained one or more coprolite with pinworm remains. Three latrines (6%) contained unidentifiable eggs, and two (4%) contained Strongyloides larvae.

Coprolite Evidence of Diet and Parasitism

Remains of small animals have been noted in coprolites throughout the history of coprolite research (Callen and Cameron 1960; Rhone 1971; Heizer 1967; Hall 1972; Fry 1977, 1985). Variation in the preservation of bone in coprolites hinders zooarchaeological analysis. For example, although the bone preservation from Lovelock Cave (Heizer 1967; Heizer and Napton 1969), Dust Devil Cave (Czaplewski 1985), and Hinds Cave (Williams-Dean 1978) was good enough to allow identification to genus of many bone fragments, the poor preservation of bone in coprolites from Salmon Ruin (Reinhard 1985a), Danger Cave (Fry 1977), and Hogup Cave (Fry 1977) precluded identification more specific than subphyllum.

Differences in reporting style of various coprolite analysts hinders one's ability to carry out comparative studies. For example, Czaplewski presents tabulations of Dust Devil Cave coprolite bone by individual element per coprolite (Czaplewski 1985:115-119). Consequently one can go to this analysis and determine the kind and minimum number of animals represented in the coprolite. Williams-Dean (1978) presents the taxa present in each coprolite, but doesn't break the data down into description of element. Heizer and Napton (1969) present the number of taxa present in the total number of coprolites, but fail to describe the bones from each coprolite. Stiger presents most of his data in terms of presence/absence. Fry (1977) and Fry and Hall (1986) present percentage of bone weight per coprolite. Clearly, technique of analysis and quantification are idiosyncratic among coprolite analysts and consequently, comparative analysis of all of these sites is difficult. Presented here is a comparative analysis of bone remains from coprolites.

Meat Consumption: Hunter-gatherers

The bone prevalence for coprolites recovered from hunter-gatherer sites is presented in Table 1. The identification of bone from hunter-

TABLE 1
Frequencies of bone recovered from hunter-gatherer coprolites expressed as percentages.

Site	% w/bone	n=
Lovelock Cave	61	31/51
Hogup Cave	70	36/51
Danger Cave	67	31/46
Great Basin Fremont	50	3/6
Great Basin Shoshoni	100	3/3
Dust Devil Cave	58	58/100
Hinds Cave	97	97/100
total	73	259/357

gatherer sites is thorough because of the interdisciplinary approach involving zooarchaeologists in the studies of Lovelock Cave (Heizer 1967), Hinds Cave (Williams-Dean 1978) and Dust Devil Cave (Ambler 1984; Lindsay et al. 1968; Reinhard 1985a).

At Lovelock Cave animal foods represented by valve, bone or scale include freshwater mollusks, insects, fish, and ducks. Aquatic birds arerepresented by feathers, and a variety of mammals are represented by hair. The only mammal bone found was that of Lepus spp.

Interpreting the actual number of coprolites containing bone is difficult with Lovelock Cave. The bone data from this site are tabulated by taxon (Heizer and Napton 1969). Consequently, the numbers of coprolites containing a given taxon can be determined, but because more than one taxon often occur in a single coprolite, the actual number of coprolites containing bone is inflated. To determine the number of coprolites containing bone, I referred to Roust's (1967) preliminary report. In this report he reports 23 coprolites containing fish bone, four contain bird bone, two contain both fish and mammal bone and two contain only mammal bone. Thus 31 of 51 coprolites contain bone. The taxa represented are listed by Heizer and Napton (1969). The fish species present are Catostomas tahoensis, Gila bicolor and Rhinichthys osculus. The birds include Anas spp. and Fulica americana. Lepus americanus is the only mammal represented.

In the Danger Cave and Hogup Cave analyses, hunter-gatherer Fremont and Shoshoni coprolites were recovered as well as Archaic coprolites (Fry 1977). The bones are not identified to any taxonomic level. Of the

Archaic coprolites from the caves, 67 of 97 coprolites contained bone. Three of six Fremont coprolites contained bone and three of three Shoshoni coprolites contained bone.

Dust Devil Cave is the only Archaic site from the Colorado Plateau for which there is coprolite data. Of 100 coprolites analyzed, 58 contained bone (Table 2). The taxa recovered will be examined in detail in a comparison with Hinds Cave below. For the present comparison with agricultural coprolites, it is only necessary to note that the main taxon was Sylvilagus, although rodent, lizard, bird and felinae bone was also present.

Two studies of Hinds Cave coprolites provided evidence of animal consumption. Stock (1983) studied 50 coprolites from the cave and Williams-Dean studied 100 coprolites. Since Williams-Dean's sample size is larger it will be considered here.

Hinds Cave exhibits the highest incidence of bone in coprolites of any site examined to date (Table 3). Ninety-seven of 100 coprolites contained bone (Williams-Dean 1978). A large variety of taxa are present relative to Dust Devil Cave. Sixteen small animal taxa are present of birds, reptile, fish and mammal. This is probably the most diverse spectrum of food animals found in any prehistoric hunter-gatherer site.

One point of interest is the diversity of food animals present in the hunter-gatherer coprolites. Lovelock Cave clearly documants a diet that included wetland species of fowl and fish. Dust Devil Cave documents a more restricted terrestrial animal diet, largely dependent on Sylvilagus. Hinds Cave documents a prehistoric population that had an eclectic palate

TABLE 2
Number of coprolites from Dust Devil Cave exhibiting the given taxa or combination of taxa.

Taxon or taxa	n=	%
Unidentifiable	27	27
Sylvilagus	21	21
Sylvilagus & bird	1	1
Sylvilagus & rodent	1	1
Sylvilagus and large mammal	1	1
Cricitid	1	1
Dipodomys	1	1
bird	1	1
rodent	2	2
lizard	2	2
felinae	1	1
no bone	41	41

TABLE 3
Number of coprolites from Hinds Cave exhibiting the given taxa or combination of taxa.

Taxon or taxa	n=	%
Unidentifiable	14	14
Neotoma	5	5
Neotoma & *Sylvilagus*	1	1
Neotoma & *Sigmodon*	3	3
Neotoma & *Lepus*	1	1
Neotoma & fish	1	1
Neotoma & bird	1	1
Neotoma, *Sylvilagus* & snake	1	1
Neotoma, *Sylvilagus*, lizard & fish	1	1
Neotoma, *Sigmodon* & bird	1	1
Neotoma, *Sigmodon*, lizard & fish	1	1
Neotoma, *Zenaidura* & bird	1	1
Neotoma, *Rana* & bird	1	1
Neotoma, lizard & fish	1	1
Peromyscus	1	1
Peromyscus & fish	1	1
Lepus (?)	1	1
Lepus & rodent	2	2
Lepus & bird	2	2
Lepus, *Procyon*, *Urocyon* & rodent	1	1
Sigmodon	7	7
Sigmodon, *Sylvilagus* & *Ondatra*	1	1
Sylvilagus	1	1
Sylvilagus & rodent	1	1
Sylvilagus, *Onchomys* & fish	1	1
Citellus	3	3
Colinus	1	1
Procyon	1	1
Procyon, rodent & bird	1	1
Aplodinotus & rodent	1	1
Aplodinotus & mammal	1	1
Odocoileus & fish	1	1
Ictalusrus/*Pylodictus* & mammal	1	1
Zenaidura	1	1
Sceloporus, fish & rodent	1	1
snake	1	1
fish	1	1
rodent	21	21
rodent & bird	2	2
rodent & snake	1	1
rodent & fish	1	1
mammal	6	6
no bone	3	3

for aquatic and terrestrial species. The Dust Devil Cave and Hinds Cave data are presented for comparison in Table 4.

<u>Meat Consumption: Agriculturalists</u>

Zooarchaeological studies of southwest agricultural sites sometimes emphasize the remains of large animals over small animals. This may be due to the difficulty in determining whether small animal bones are remnants of human behavior or are merely post-depositional intrusions. Also, small animal bone may not preserve as well as more robust large animal bone. Finally, field collection techniques applied on site may not be sufficient for the recovery of fragmented small bone. Exceptions, of course, are present in the literature. These include, for example, Haury's identification of small animal bone fragments in Hohokam midden samples which he feels passed through digestive systems before being incorporated in the midden (1976).

On the Colorado Plateau, small animal bone is fairly common in Anasazi and Fremont culture coprolites (Table 5). Clyde's Cavern and some Glen Canyon sites are associated with the Fremont culture (Hall 1972; Fry 1977). Unfortunately, the bone was not identified to any taxonomic level. Of the Fremont sites, bone was present in 3 of 16 coprolites from Clyde's Cavern and 5 of 10 coprolites from Glen Canyon.

Anasazi sites provide the bulk of the Colorado Plateau data. Of 30 Anasazi coprolites from Glen Canyon, 15 contain bone chips too small for identification (Fry 1977). Bone was found in 33 of 96 coprolites from Antelope House and in three of 16 coprolites from Inscription House (Fry and Hall 1986) but the bones are not identified to any taxonomic level.

TABLE 4
The number of coprolites containing bone of the given taxa from Dust Devil Cave and Hinds Cave.

Taxon	Dust Devil Cave	Hinds Cave
Unidentifiable	27	14
Mammalia	1	8
Rodentia	3	32
Cricitid	1	0
Neotoma	0	19
Dipodomys	1	0
Sigmodon	0	13
Peromyscus	0	2
Ondatra	0	1
Onchomys	0	1
Spermophilus	0	3
Sylvilagus	24	7
Lepus	0	7
Procyon	0	3
Urocyon	0	1
Felinae	1	0
Odocoileus	0	1
Aves	2	9
Colinus	0	1
Zenaidura	0	2
lizard	2	3
Sceloporus	0	1
snake	0	3
Rana	0	1
Osteichthes	0	10
Aplodinatus	0	2
Ictalusrus/ Pylodictus	0	1

TABLE 5
Frequency of bone remains from agricultural coprolites expressed as percentages.

Site	% coprolites w/ bone	n=
Clyde's Cavern	19	3/16
Glen Canyon Fremont	50	5/10
Glen Canyon Anasazi	50	15/30
Antelope House	34	33/96
Inscription House	19	3/16
Salmon Ruin	24	27/112
Hoy House	14	8/56
Step House BM II	35	7/20
Step House P III	35	6/17
Turkey Pen Cave	33	16/49
Total	29	123/422

From Salmon Ruin, 112 coprolites were examined, 27 of which contained bone (Reinhard 1985a). Salmon Ruin represents an unusual case of poor preservation of bone from coprolites, typical for open sites. Only one of the coprolites contained bone recognizable to taxonomic order: an artiodactyla vertebra. The other bones were too decomposed for identification but clearly represent small mammals (rodents or lagomorphs).

Coprolites from several sites on Mesa Verde have been examined. Of 56 coprolites from Hoy House, eight contained bone. The identifications per coprolite are as follows; one with turkey bone, one with mouse bone, one with sciurid bone, four with small rodent bone, and one with fish or reptile bone (Stiger 1977). From Basket Maker III levels of Step House, of 20 coprolites examined one contained mouse bone and six contained unidentifiable bone. Pueblo III levels from Step House produced 17 coprolites which were analyzed, two of which contained mouse bone and four had unidentifiable bone (Stiger 1977). Two separate studies of Turkey Pen Cave have been completed (Aasen 1984; Reinhard and Jones n.d.) for a total of 49 coprolites analyzed. Of these, two contain rabbit bone and 14 contain unidentifiable rodent or lagomorph bone chips.

Thus, a total of 422 coprolites from Colorado Plateau agricultural sites has been completed. Of these 123 contain animal bone, 122 of which contain small animal bone for a total of 24% containing small animal bone. The frequencies of bone vary for agricultural sites and range from a high of 50% from Glen Canyon to a low of 14% at Hoy House.

Plant Consumption: Hunter-gatherers

Dunn (1972) notes that environmental factors have a strong influence on hunter-gatherer diet and disease. Data provided by Dunn show that modern hunter gatherers living in humid, tropical conditions are host to more parasite species than hunter-gatherers in dry climates. For example, pygmies in tropical African forests and hunter-gatherers in the humid tropics of Southeast Asia are host to as many as 27 parasite species. In contrast, the Bushmen inhabiting the dry areas of southern Africa are host to only 3 species, and certain aborigine groups in xeric Australia are parasite free.

The ecological regimes in which prehistoric hunter-gatherers lived were diverse in the Southwest. Although the Southwestern United States is relatively dry, there are a variety of microhabitats inhabited by prehistoric hunter-gatherers that are quite moist. The availability of mesic adapted plants from human association with moist ecological regimes, is reflected by the hunter-gatherer diet from Lovelock Cave (Heizer and Napton 1969).

Based on Dunn's work, one would anticipate that parasitism would differ among hunter-gatherer groups subsisting in the Southwest. The largest variation in inhabited ecological zones existed in the Great Basin. Coprolites studies are available for two subsistence categories: the Desertic Adaption and the Lucustrine Adaption.

The Desertic Adaption, also the Desert or Western Archaic (Jennings 1968), was typical for the western deserts of the Great Basin in Utah.

Coprolites excavated from Danger and Hogup Caves provide empirical dietary data from this area (Fry 1977).

The environments of Hogup and Danger Caves are harsh. High soil salinity limits the number of plants available in the immediate area. Although near-by bog and mountain food sources may have been utilized, coprolite analysis indicates a strong reliance of desert plants. Opuntia spp. (prickly pear) pads and seeds of the halophyte Allenrolfea occidentalis (pickle weed) were the most common dietary components. Other dietary plants included seeds of Atriplex confertifolia, Celtis occidentalis, Chrysothamnus spp., grass seed, Lepidium montanam, Phlox spp., Pinus spp., and Scirpus. Vegetal portions of Artemisia and the narcotic bark of Cornus stolonifera were also consumed (Tables 6 and 7).

A limited pollen analysis of some coprolites from Danger and Hogup Caves was undertaken. Dietary pollen types include Cheno Am (probably related to the consumption of Allenrolfea seed), Poaceae (grass), Rosaceae (Rose family), Polygonum (knotweed), and Ephedra (Mormon tea). At Hogup Cave, sedge pollen is present.

Fry (1980) notes that discriminant analysis of the coprolite components from Hogup and Danger Caves reveals differences in subsistence at the two caves that relate to differences in the microhabitats of the caves. The presence of Cornus, Phlox and Pinus at Hogup Cave and their absence at Danger Cave as well as the increased reliance on Opuntia at Hogup Cave reflects this environmental difference.

In contrast to the Desertic Adaption, the Lucustrine Adaption is typified by the consumption of lake shore and aquatic plants and aquatic

TABLE 6
Scientific and common names for plant components found in coprolites from hunter-gatherer and agricultural sites.

Genus	Common Name
Acacia	acacia
Agave	agave
Allenrolfea	pickleweed
Allium	wild onion
Amaranthus	pigweed
Amelanchier	serviceberry
Atriplex	saltbush
Artemisia	sagebrush
Carex	sedge
Celtis	hackberry
Cenchrus	sand bur
Chaenactus	chaenactus
Chenopodium	goosefoot
Chrysothamnus	rabbitbrush
Cornus	dogwood
Cryptantha	cryptantha, cat's eye
Cucurbita	squash
Cycloloma	cycloloma
Dasylirion	sotol
Descurainia	tansy mustard
Distichlis	salt grass
Diospyros	persimon
Echinocereus	pataya cactus
Elymus	wild rye
Ephedra	mormon tea
Equisetum	horsetail
Gossypium	cotton
Helianthus	sunflower
Juglans	walnut
Juncus	rush
Juniperus	juniper
Mammillaria	hedgehog cactus
Mentzelia	stickleaf
Lepidium	pepper grass
Opuntia	prickly pear
Oryzopsis	Indian rice grass
Panicum	panic grass
Phaseolus	bean
Phlox	phlox
Phragmites	reed
Physalis	gound cherry
Pinus	pinyon pine

TABLE 6
continued

Genus	common name
Polygonum	knotweed
Portulaca	purslane
Prosopis	mesquite
Rhus	sumac
Rumex	dock, sorrel
Salsola	salsola
Scirpus	bulrush
Solanum	nightshade
Sporobolus	dropseed
Stellaria	starwort
Suaeda	seep-weed
Typha	cattail
Vitis	grape
Yucca	yucca
Zea	maize

TABLE 7

Presence/absence component occurrence of plant genera and families identified in hunter-gatherer coprolites expressed as percentages.

Taxon	L.C.	D.C.	H.C.	D.D.C.	B.C.
Allenrolfea		96	98		
Allium				2	
Amaranthus	4				
Asteraceae		4			
Atriplex	26	17	6	2	
Artemisia			6		
Celtis			6		
Chaenactus	2				
Chenopodium				34	5
Chrysothamnus		2			
Cornus		2			
Cucurbitaceae					5
Cycloloma				4	
Descurania (?)				2	15
Distichlis	22				
Eleocharis	4				
Elymus	30				
Equisetum	2				
Juglans				2	
Juncus	2				
Juniperus				2	5
Mentzelia	2			4	
Lepidium			2		
Opuntia		15	59	44	65
Panicum	2			4	
Phlox		2			
Phragmites	2				

L.C.= Lovelock Cave (n=50)
H.C.= Hogup Cave (n=51)
D.C.= Danger Cave (n=46)
D.D.C.= Dust Devil Cave (n=50)
B.C.= Bighorn Cave (n=20)

TABLE 7
continued

Taxon	L.C.	D.C.	H.C.	D.D.C.	B.C.
Pinus	8	4			
Poaceae			4	12	10
Prosopis					65
Rumex	4				
Salsola	2				
Scirpus	100	7	2		
Sporobolus	2			60	
Stellaria	6				
Sueda	16				
Typha	70				
Yucca				40	

L.C.= Lovelock Cave (n=50)
H.C.= Hogup Cave (n=51)
D.C.= Danger Cave (n=46)
D.D.C.= Dust Devil Cave (n=50)
B.C.= Bighorn Cave (n=20)

animals. In comparison to the relatively few plants utilized at Danger and Hogup Caves, there was a diversity of plants and animals eaten at Lovelock Cave. Twelve species of animals and 19 plant species were consumed.

The most important plant foods were Typha (cattail), Scirpus (bulrush) and grasses adapted to wetlands such as Elymus (wild rye) and Panicum (witch grass). The seeds and foliage of these plants were eaten. Other important plant foods include seeds of Atriplex, Distichlis stricta, and Suaeda. Plant foods of minor importance are Amaranthus spp., Chaenactus, Eleocharis, Equisetum, Juncus, Mentzelia gracilis, Phragmites communis, Pinus momophylla, Rumex, Salsola, Sporobolus asperifolius, and Stellaria (Tables 6 and 7).

From Bighorn Cave a dietary analysis was completed on 21 coprolites from the cave. The main dietary constituents are Prosopis pubescens (screwbean mesquite) and Opuntia spp. (prickly pear) pads (Table 7). Other plant foods include seeds of Descurania spp. (tansy mustard), Juniperus (juniper), Cucurbita (probably a undomesticated gourd), and Poaceae (grass).

Pollen analysis indicates that the inflorescences of Ephedra (Mormon tea), a plant in the Brassicaceae (mustard family), Poaceae (grass), Opuntia (prickly pear), Salix (willow), Yucca spp., and possibly Typha latifolia (cattail) and Chenopodium or Amaranthus were eaten.

The evidence of consumption of plant inflorescences such as Opuntia, Yucca, and Salix suggests that the cave was occupied in the spring. The presence of mature Prosopis seeds implies occupation in the fall. The wide spectrum of background pollen suggests that the cave was occupied during the warm season pollination period. I suggest that the coprolites represent a warm season occupation extending from late spring through early fall. Whether or not the cave was occupied during the cold season is unknown.

The diet at Dust Devil Cave, as determined by analysis of 50 coprolites, is more limited in diversity of foods than any other archaic site with the exception of Cowboy Cave. The people subsisted on *Opuntia* (prickly pear) pads, *Sporobolus* spp. (dropseed) seed, *Chenopodium* seed, and to a lesser degree Asteraceae achenes, probably from *Helianthis* (sunflower), and grass foliage (Table 7). The pollen spectra of 19 of 20 samples is dominated by Poaceae (grass) which occur in pollen aggregates which indicate the ingestion of either grass inflorescences or seeds (Reinhard 1985a). One sample was dominated by *Vicia* pollen.

The findings from Cowboy Cave were similar except that there was an increase prevalence of *Helianthus* achenes in the coprolites.

The preservation of material in the lower Pecos is ideal for biological study. Coprolites are very common in the caves lining the Pecos River and its tributaries. Coprolites from two caves, Baker and Hinds Caves were submitted for analysis.

Dietary analysis of Hinds Cave is based on palynological analysis of 20 coprolites and macrofloral analysis of 25 coprolites (Table 8). The analysis of these coprolites was focussed on parasitology. Consequently, only small fractions of the coprolites were examined with the result that relatively little material was recovered for macroscopic analysis. The

TABLE 8
Presence/absence data for identified plant genera and families from Baker Cave and two analyses of Hinds Cave expressed as percentages.

Taxon	G.W.	K.J.R	K.D.S.
Acacia		4	
Agave	51	60	13
Allium	40	8	29
Amaranthus	1		
Brassicaceae			8
Carex	8	4	
Celtis	4	8	3
Cenchrus	2		
Chenopodium	3	8	3
Dasylirion	7		24
Descurania		20	
Diospyros	14	8	
Echinocereus		8	
Helianthus		12	
Juglans	23	4	5
Juniperus			5
Mammillaria		4	8
Opuntia	88	80	50
Panicum	7		
Poaceae	2	24	
Prosopis	13	4	3
Quercus			3
Sporobolus	42		
Vitis	3		
Yucca	1	12	11

G.W.= Hinds Cave, Williams-Dean (1978) (n=100)
K.J.R= Hinds Cave, this study (n=25)
K.D.S.= Baker Cave, Sobolik (1988) (n=38)

dietary data presented here is therefore based both on the analysis of the twenty-five coprolites from the current analysis compared to an extensive analysis of 100 coprolites by Williams-Dean (1978).

In the macrofloral analysis, Opuntia (prickly pear) represents one of the major dietary components. A diversity of other plants was present including Mammillaria sp. (pincushion or nipple cactus) seeds, Echinocereus sp. (pitahaya or hedgehog cactus) seeds, Chenopodium sp. seeds, Allium (onion) bulb fragments, Celtis (hackberry) seeds, Descurainea sp. (tansy mustard) seeds, Prosopis (mesquite) pods, Diospyros texana (Texas persimmon) seeds, Helianthus sp. (sunflower) achenes, Carex (sedge) seeds, Juglans (walnut), and Sporobolus sp. (dropseed) seeds. The most abundant type of plant material recovered was that of plant fiber and epidermis. Most of the fiber appears to be derived from Yucca or Agave and Opuntia (prickly pear). Clearly, the inhabitants of Hinds Cave enjoyed a greater diversity of plant food than any of the archaic groups listed above adapted to desert conditions.

The dietary pollen types include Agave, Echinocereus c.f., Celtis, Dasylirion, high spine Asteraceae, Lycium c.f. and grass. Regarding Agave and Dasylirion, it is probable that the flowers of these plants were eaten.

A dietary study of Baker Cave coprolites is presented by Sobolik (1988). Opuntia is the most common food source, but Allium, Agave, Yucca, and Dasylirion are also common components. Minor components include Juniperus, Prosopis, Chenopodium, Mammillaria, seeds of Brassicaceae (mustard family), Celtis, Quercus, and Juglans.

Palynological study by Sobolik indicates that Brassicaceae flowers, Dasylirion flowers, Lamiaceae (mint family), and possibly Typha inflorescences were eaten.

Plant Consumption: Agriculturalists

The diet of southwestern agricultural peoples shows limited diversity in comparison to their hunter-gatherer predecessors. This is undoubtedly due to the fact that coprolites of agricultural peoples are predominantly represented by sites in the Four Corners area of the Colorado Plateau which results in ecological uniformity. Secondly, the utilization of maize as a dietary mainstay resulted in a certain degree of dietary uniformity between sites.

Two cultures are represented by coprolites from the Colorado Plateau. The Fremont culture, specifically the San Rafael Branch, is represented by two sites. This cultural group existed in southeastern Utah.

The Anasazi culture was widespread throughout the Four Corners states of Utah, Arizona, New Mexico and Colorado. Coprolites from many sites located in various habitats of the Colorado Plateau have been excavated. The comparison of Anasazi diet and parasitism among sites illustrates the differing manner by which a single archaeological cultural group adapted to differing habitats on the Plateau.

A total of 26 coprolites have been examined from Fremont sites. Sixteen coprolites were studied by Hall (1972) from Clyde's Cavern Utah. The cave is located between Dust Devil Cave and Cowboy cave, and environmentally is similar. The diet of the inhabitants of Clyde's Cavern is similar to that of the Archaic inhabitants of Dust Devil Cave and Cowboy

Cave. Sporobolis (dropseed) seed, chenopod seed and Asteraceae achenes are the most common, uncultivated plants. Zea mays (maize) was a commonly consumed food but was only half as common as Sporobolis. Dietary plants of minor importance were Elymus (wild rye), Lepidium (pepper grass), Pinus edulis (pinyon pine), and Scirpus (rush). Bone was present in three samples. It appears that the inhabitants of Clyde's Cavern carried on the gathering subsistence of previous archaic peoples, augmented with maize cultivation.

Ten Fremont coprolites were studied from caves excavated in the Glen Canyon area. The most common dietary components in these coprolites were Amaranthus (pigweed) seed, Chenopodium (goosefoot) seed, Cucurbita (squash) seed, and Opuntia (prickly pear). Minor dietary components include Amelanchier seed, Artemisia (sage) vegetative tissue, Asteraceae seed, gymnosperm bark, Equisetum (horsetail) stem, grass seed, Juniperus fiber, Lepidium seed, Phaseolus (bean) seed, Scirpus seed, Yucca pods and maize. Bone was present in five samples, reptile scale in one sample and insect fragments in three samples. The coprolite study indicates that in the case of these ten coprolites, the people gathered wild plant foods which were important dietary components.

The southern portion of Glen Canyon was occupied by Anasazi peoples. In comparison to other areas occupied by Anasazi peoples, Glen Canyon is a xeric, hot environment where dry farming was carried out on the plateau surrounding the canyon. Thirty coprolites excavated from caves in Glen Canyon were examined (Fry 1977, 1980; Fry and Hall 1986). In comparison to Fremont coprolites from the caves, Zea mays is a much more important food source (Table 9). Also important in the diet is chenopod seed, Cucurbita seed, and Opuntia seed. Dietary items of minor importance are Amaranthus seed, Celtis seed, Cleome seed, Asteraceae seed, Cryptantha seed, Ephedra seed, Gossypium seed, grass seed, Lepidium seed, Oryzopsis seed, Pinus seed and resin, Polygonum seed, Portulaca seed and Scirpus seed. There appears to be an increase in diversity of plants eaten by Glen Canyon Anasazi in comparison to Glen Canyon Fremont. However, the fact that three times as many Anasazi coprolites were studied probably accounts for the difference in diversity.

Pollen analysis of Glen Canyon Anasazi coprolites demonstrates consumption of Opuntia flowers, Cleome flowers, Populus catkins, foliage of plants in the Chenopodiaceae or Amaranthaceae, and Cucurbita flowers.

Moist canyon bottom habitats were also occupied by the Anasazi and are represented by the sites of Antelope House and Inscription House.

Antelope House is located in the bottom of Canyon de Chelly. Maize agriculture was probably carried out on the floor of the canyon as is the current practice among Navajo who inhabit the canyon. From Antelope House, 90 coprolites have been studied (Fry and Hall 1986). The most important plant food is Zea mays. Foods of secondary importance are Amaranthus seed, Cleome seed, cactus, Gossypium (cotton) seed, Physalis (ground cherry) seed, Pinus edulis nuts, Portulaca (purslane) seeds and Cucurbita seeds. Foods of minor importance include Phaseolus seed, grass seed, Sporobolus seed, Chenopodium seed, Vitis (grape) fruits, Equisetum stroboli, Oryzopsis (Indian rice grass) seed, Panicum (panic grass) seed, Lepidium seed,

TABLE 9
Presence/absence data from Anasazi and
Fremont coprolites expressed as percentages.

Taxa	CCF	GCF	GCA	TPC	AH	IH
Allium					2	
Amaranthus		60	33	8	10	
Amelanchier		20				
Artemisia		10				
Asteraceae	38	30	27			
Atriplex				4	1	
Cactaceae					42	50
Celtis			17			19
Chenopodium		50	53	40	4	
Cheno Am	44			12		
Cleome			17	12	16	
Cryptantha			3			
Cucurbita		90	67	20	29	
Descurainea				9		
Elymus	13				1	
Ephedra			3			
Equisetum		10			7	
Gossypium			30		18	25
Helianthus				20	4	19
Juniperus		10		20		
Lepidium	6	10	17	8	1	56
Opuntia		60	53	24	12	
Oryzopsis			17		2	31
Panicum					1	6
Phaseolus		10		4	1	25
Physalis				4	16	13
Pinus	6		3	12	29	
Poaceae		40	47	12	1	6
Polygonum			3			
Portulaca			7	20	21	6
Rhus					7	6
Scirpus	6	10	3			
Solanum				4		
Sporobolus	75				1	19
Vitus					2	
Yucca		20		4	1	
Zea	44	30	60	96	91	63

CCF= Clyde's Cavern Fremont (n=16)
GCF= Glen Canyon Fremont (n=10)
GCA= Glen Canyon Anasazi (n=30)
TPC= Turkey Pen Cave (n=25)
AH= Antelope House (n=90)
IH= Inscription House (n=16)

TABLE 9
continued

	H.H.	S.H.	C.C.	S.R.
Amaranthus	9	8	2	5
Artemisia	2	3		
Atriplex	18			
Chenopodium	11	30		13
Cleome	5	8		1
Corispermum		3		
Cucurbita	20	35	4	
Cycloloma				1
Descurainea			9	
Echinocereus				1
Eriogonum	2			
Helianthus	2	3	4	
Juniperus		3		
Opuntia	25	51		1
Oryzopsis	4	5	2	
Phaseolus	18	8		10
Physalis	27	22		1
Pinus	13	27	23	5
Poaceae	2	5		
Portulaca	18	24	15	5
Prunus	4	5		
Rhus		8		21
Shepherdia	5			
Solanum			2	
Sporobolus			4	
Zea	100	76		37

H.H.= Hoy House (n=56)
S.H.= Step House (n=37)
C.C.= Chaco Canyon (n=47)
S.S.= Salmon Ruin (n=112)

Atriplex (saltbush) foliage, Rhus trilobata (sumac or sqawbush) fruit, Helianthus (sunflower) achenes, Elymus seed, and Yucca pods (Table 9).

Palynological analysis of Antelope House adds more plants to the list of prehistoric foods (Williams-Dean 1986). Juniperus (juniper), Populus (cottonwood), Typha latifolia (cattail), Cleome (beeweed) flowers, Opuntia (prickly pear) flowers, flowers of an unknown cactus, Cucurbita flowers, Portulaca (purslane) seed or flowers were eaten.

From Inscription House in Navajo National Monument, 17 coprolites have been studied. The mesic environment of Inscription House is similar to that of Antelope House and maize agriculture was probably carried out on the floor of the canyon. Maize, cactus and Lepidium seed are the most important plant foods. Plant foods of secondary importance are Phaseolus seed, Sporobolus seed, Gossypium seed, Physalis seeds, Celtis (hackberry) fruit, Oryzopsis seed, and Helianthus achenes. Of minor importance are grass seed, Panicum seed, Portulaca seed, and Rhus fruits (Table 9). It is of interest that although the sites are ecologically similar and both are attributed to the same cultural subgroup, the Kayenta Anasazi, the diversity of plant foods that compose the major portion of the diet is greater at Inscription House. Maize dependency is more pronounced at Antelope House.

Turkey Pen Cave is located on Cedar Mesa, Utah in the Grand Gulch. This is a high elevation, cold and arid portion of the Colorado Plateau. Analysis of 20 coprolites from the site demonstrates that Zea mays (maize) was the main dietary focus. Other plants of minor dietary importance are Cucurbita seeds, Phaseolus seeds, Juniperus berries, Lepidium seeds, Yucca pods, *Physalis* seeds, *Solanum* seeds, *Descurainea* seeds, unknown grass seeds, *Cleome* seed, *Portulaca* seed, *Chenopodium* seed, *Amaranthus* seed, *Pinus edulis* nuts, *Opuntia* pads, and *Helianthus* achenes. This site dates between A.D. 200 and 400. The Turkey Pen Cave coprolites are the earliest agricultural coprolites recovered from the Southwest. Agriculture is generally thought to be less important during this early time. However, the coprolites from Turkey Pen Cave clearly show that maize dependence was established.

Palynological analysis of Turkey Pen Cave coprolites shows that *Cleome* flowers, *Populus* (cottonwood) catkins, Brassicaceae (mustard family) foliage or flowers, Fabaceae (bean family) flowers, and *Opuntia* flowers were eaten.

Several sites have produced coprolites from Mesa Verde National Monument, Colorado. Those most thoroughly studied were excavated from Hoy House and analyzed by Stiger (1977). Presence/absence data were recorded for 37 coprolites from Step House (Stiger 1977). The analysis of 56 coprolites from Hoy House shows that *Zea mays* was the major dietary component. Plant components of secondary importance are *Phaseolus*, *Cucurbita*, *Chenopodium*, *Physalis*, *Pinus edulis*, *Opuntia*, *Portulaca*, and *Atriplex*. Of minor importance were *Amaranthus*, *Cleome*, *Shepherdia* (buffalo berry), *Prunus* (chokecherry), unknown grass, *Oryzopsis*, *Artemisia*, *Helianthus*, and *Eriogonum*. The analysis of Step House coprolites resulted in the addition of *Juniperus* and *Rhus* (Table 9).

Palynological analysis of Hoy House coprolites has been completed (Scott 1979). This analysis indicates the consumption of *Cucurbita* flowers, Cleome flowers, and Portulaca foliage or flowers.

Salmon Ruin was built on the moist flood plain of the San Juan River. Although located adjacent to broad, moist bottomland, maize irrigation was apparently carried out through dry-farming the terraces overlooking the site and river. From Salmon Ruin 112 coprolites were studied. Unfortunately, the preservation of the coprolites was very poor and few contained recognizable dietary components. However, the analysis indicate that maize was a dietary mainstay. Other items of dietary importance include Amaranthus seed, Chenopodium seed, Cleome seed, Cycloloma seed, Echinocereus fruit, Opuntia fruit, Phaseolus seed, Physalis seed, Pinus edulis nuts, Portulaca seed, and Rhus trilobata fruits (Table 9). The fact that Rhus trilobata is so common at Salmon Ruin suggests that the inhabitants of the village foraged in xeric areas as opposed to the moist flood plain. Pollen analysis demonstrates consumption of Opuntia flowers and Cleome flowers.

Chaco Canyon, New Mexico has also been the focus of coprolite study. The environment of Chaco Canyon has been described as similar to those of Antelope House and Inscription House (El-Najjar et al. 1976). In my experience, however, Chaco Canyon is a shallower, drier canyon with less permanent water sources. Forty-seven coprolites were studied from Pueblo Bonito and Pueblo Alto in Chaco Canyon (Toll 1981). Like the coprolites from Salmon Ruin, the Chaco Canyon coprolites were recovered from open sites and were in a poor state of preservation. Clary (1984) reports that a relatively narrow range of plant food were recovered from the coprolites. I suspect that the range of food items would have been larger had the coprolites been preserved in a dry cave environment. Major components by frequency are Pinus edulis (pinyon pine) nuts and Portulaca (purslane) seeds. Other plant materials recovered in smaller frequencies were Oryzopsis (Indian rice grass) seeds, Sporobolus (dropseed) seeds, Amaranthus (pigweed) seeds, Helianthus (sunflower achenes), Descurainea (tansy mustard) seeds, Solanum (nightshade) seeds, and Cucurbita (squash) seeds. Palynological study of the coprolites (Clary 1984) indicates the consumption of Cleome, Sphaeralcea (mallow), and Portulaca.

Parasitology: Hunter-gatherers

Archaeoparasitological investigations of Great Basin coprolites shows a pronounced difference in helminthiasis between the Desertic Adaptation and the Lacustrine Archaic Adaptation (Table 10). Fry (1977, 1980) found that six of 46 Danger Cave coprolites and two of 50 Hogup Cave coprolites contained eggs of what is probably Moniliformis clarki, a thorny-headed worm (Fry and Hall 1969; Moore et al. 1969). In addition, one Danger Cave coprolite and four Hogup Cave coprolites contained eggs of E. vermicularis (Fry and Moore 1969). Taeniid eggs were present one Danger Cave coprolite and five Hogup Cave coprolites (Fry 1977).

The finding of taeniid eggs also presents interpretive problems. The only taeniid species that are known to produce patent human infections are Taenia solium and T. saginata. These are associated with domestic pigs and cattle respectively. Since these were not present in the prehistoric New World, it is doubtful that the eggs represent human infections. In my

TABLE 10
Parasite finds from hunter-gatherer sites.

Site Name with number of coprolites studied	# coprolites positive for specified taxa
Lovelock Cave (n=50) (Dunn and Watkins 1970)	1 Fascioloid trematode 1 Charco-Leyden crystals
Hogup cave (n=51) (Fry 1977)	4 *Enterobius vermicularis* 2 *Moniliformis clarki* 5 taeniid cestode
Danger Cave (n=46) (Fry 1977)	1 *E. vermicularis* 6 *M. clarki* 1 taeniid cestode
Hinds Cave (n=13) (Williams-Dean 1978)	negative
Hinds Cave (n=7) (Stock 1984)	negative
Hinds Cave (n=39) (Reinhard)	negative
Dust Devil Cave (n=100) (Reinhard 1985a)	negative
Baker Cave (n=17) (Reinhard)	negative
Bighorn Cave (n=35) (Reinhard)	negative

opinion, the eggs were possibly introduced into the human digestive tract with contaminated food or by close association of prehistoric man with dogs. They should not be considered prehistoric human parasites simply on the basis of their presence human coprolites.

The find of parasite eggs of species that normally occur in animals is cause for skepticism. For this reason, the presence of _Moniliformis clarki_ in human coprolites warrants attention. Although _M. dubius_ can cause patent infections in humans (Noble and Noble 1982) and _M. moniliformis_ can infect man under experimental conditions (Schmidt and Roberts 1981:552), _M. clarki_ has not been reported as a human parasite. This throws some doubt on the finds from Danger and Hogup Caves as cases of human parasitism. As Fry (1980:336) states, the presence of the eggs in the human coprolites "could represent false parasitism by ingestion of adult worms with eggs in the bodies of rodents, or true parasitism by ingestion of the larval stages in the bodies of insects." The habit of ingesting whole rodents and insects allows for either possibility (35 of the Danger Cave coprolites and 36 of the Hogup Cave coprolites contain bone from the consumption of small animals).

In attempting to determine whether the eggs represent a true infection, examination of dietary components is helpful. If false parasitism occurred, one would expect to consistently find rodent bone or hair in the coprolites that contain the parasite eggs. However, if true parasitism occurred, one would expect eggs to occur in coprolites that contain bone as well as coprolites that do not. In reviewing Fry's analysis of several Utah caves including Hogup and Danger Caves, nine coprolites contain eggs of *M. clarki*. Of these, five contain bone and four do not. The absence of bone in four of the coprolites is circumstantial evidence that true infections occurred.

In their 1969 description of *M. clarki* finds in coprolites, Fry and Hall emphasize that "many" eggs were present in the coprolites, although absolute quantification is not provided. The presence of many eggs in coprolites is more typical, in my experience, of a true parasitic infection as opposed to a false infection.

Whether or not taeniid tapeworms and acanthocephalans parasitized prehistoric hunter-gatherers in Utah is debatable. I have reservations about accepting *Taenia* as a prehistoric human parasite because of the specificity of taeniid worms with regard to definitive host. However, this is not the case with acanthocephalans which have a wide definitive host range. Consequently, I do not think it unreasonable to accept *Moniliformis* as a potential prehistoric parasite considering the prehistoric dietary utilization of insects, the fact that the two other species in the genus infect humans, and the fact that this species has a wide definitive host range which includes three known orders; Insectivora, Rodentia and Chiroptera. Known definitive host genera of *M. clarki* include *Sciurus*, *Glaucomys*, *Scalopus*, *Geomys*, *Spermophilus* (*Citellus*), *Apodemus*, *Meriones*, *Tamias*, *Entamias*, *Mephitis*, and *Pitymus*.

In contrast, a fasciolid fluke egg was recovered from one of 50 Lovelock Cave coprolites (Dunn and Watkins 1970). Some species of these flukes are infective to humans and utilize snails as intermediate hosts.

Another coprolite contained Rhabditis larvae (Heizer 1967). This genus is non-parasitic and inhabits fecal material. A third coprolite contained Charcot-Leyden crystals which often accompany, but are not specific to, amoebic dysentery (Napton and Heizer 1969).

It is apparent that helminthiasis was much more common among the Utah desert hunter-gatherers than those subsisting along the lake shores in Nevada. Both the flukes and amoebic dysentery are commonly transmitted in moist environments. The thorny-headed worm infections in the desert areas were probably related to the consumption of insects. Pinworm infection is associated with cramped living conditions and poor personal hygiene. Thus, parasitism in the two areas can be related directly to prehistoric dietary habits in different environments of the Great Basin.

Thirty-five coprolites from Bighorn Cave were submitted for archaeoparasitological study. The coprolites were well preserved and there is no indication of decomposition before final desiccation. No evidence of either intestinal helminths or arthropod ectoparasites was found.

From Dust Devil Cave, 100 coprolites were examined for evidence of parasitism. None contained remains of either helminth nor arthropod parasites. Unfortunately, no coprolites from Cowboy Cave were examined parasitologically.

Parasitological analysis was carried out on 39 coprolites from Hinds Cave and 17 coprolites from Baker Cave. In addition, Williams-Dean (1978) analyzed 13 coprolites and Stock (1983) analyzed seven coprolites from Hinds Cave. Neither Williams-Dean nor Stock found any evidence of parasitism. In this analysis, no nematode larvae were recovered. Only one nematode egg was found, but it was too badly preserved to allow identification. No cestode nor trematode eggs were found. One concludes from the combined analyses of 76 lower Pecos Archaic coprolites that helminth parasitism was rare.

The analyses of archaic hunter-gatherer sites in the southwest indicates that parasitism was rare with notable exceptions in the Great Basin. In the desert Great Basin, parasitism with pinworm, acanthocephalans and perhaps tapeworms occurred. In Great Basin lucustrine environments, parasitism with flukes and amoebids possibly occurred. Elsewhere, dilute bands of hunter-gatherers seem to be free of helminth parasites.

Surprisingly, the highest rate of parasitism was detected in the Desertic Adaption of the Great Basin as opposed to the moist environment of Lovelock Cave. Parasitism was rare in other desert groups including Dust Devil Cave, Hinds Cave, and Bighorn Cave. This indicates that among hunter-gatherer groups, environment is not the only factor involved in aquiring parasitism.

Behavior probably affected the prevalence of parasitism. Reinhard et al. (1985) report that the consumption of Chenopodium, probably C. graveolens, at Dust Devil Cave was one factor that reduced parasitism. The consumption of insects at Danger and Hogup Caves exposed their inhabitants to infection with Moniliformis clarki.

It is of interest that no definite evidence of parasitism was found in the examination of coprolites from Baker and Hinds Caves. It is probable that the Lower Pecos supported a large hunter-gatherer population in comparison to the other areas under study. This suggestion is based on the number of caves occupied, the amount of cultural debris present in those caves, and the cultural complexity of hunter-gatherer culture in the Lower Pecos (Shafer 1986). One would expect that higher population densities would result in higher parasite prevalence.

Parasitology: Agriculturalists

Parasitological analyses of Fremont coprolites are presented by Fry (1977, 1980) and Hall (1972). Hall reports on Clyde's Cavern in east-central Utah. Of 25 coprolites, four contained eggs of *E. vermicularis*, two contained eggs of an unknown acanthocephalan species, one contained eggs of what is probably *Strongyloides* (hairworm), one contained the embryonated eggs of an unknown nematode and one contained a fragment of an adult nematode. Dr. A. W. Grundman identified the helminth remains for Hall.

The acanthocephalan eggs were not identified beyond the level of order. The photographs and micrometer measurements accompanying Hall's thesis indicate that two species are present. Human infection is suggested as a possibility, although also Hall feels that false parasitism may be the source of the eggs.

The identification of *Strongyloides* was based in part on the morphology of "rhabditoid" larvae, specifically the morphology of the esophagus. The identification is supported by the statement that "Grundman doubts that *Rhabditis* could have been present in the cave" (Hall 1972: 37). Hall emphasizes that the identification of this worm is only probable. Ten Fremont coprolites from five sites near Glen Canyon were analyzed for parasite remains. Only one of these was positive and it contained taeniid eggs.

Important parasitological finds were retrieved from Elden Pueblo (Hevly et al. 1979; Reinhard et al. 1987). Unlike all other sites under study, individual coprolites were not recovered from Elden Pueblo. Instead, soil samples from amorphous latrine levels were studied. Dietary reconstruction is not possible beyond the fact that maize was consumed at this village.

The helminthological finds from Anasazi sites are presented in Table 11 and are discussed in Chapter 5. As can be seen, there is variable parasite prevalence and diversity. It is significant that hymenolepidid eggs appear at one Anasazi site and at the one Sinagua site, Elden Pueblo. This indicates that grain was stored at these sites. Although infective to humans, these tapeworms typically use rodents as definitive hosts. It is probable that grain stores attracted grain beetles and rodents which resulted in the cycling of hymenolepidids infective to humans (Reinhard et al. 1987). From this perspective, hymenolepidid infection of Anasazi is considered zoonotic.

It is also of interest that Ascaris lumbricoides (giant intestinal roundworm) and Trichuris trichiura (whipworm) make their first appearance in Anasazi agricultural sites. The direct anal-oral life cycle of these parasites suggests that fecal contamination of agricultural villages occurred. Accepting that Strongyloides is correctly identified, its appearance with strongylate worms and T. trichiura indicates that agricultural peoples were in more frequent contact with moist environments, perhaps through irrigation and lived in conditions of declining hygiene.

TABLE 11
Parasite finds from Agricultural sites. The three notations for Antelope House represent three separate coprolite samples.

Site Name with number of coprolites studied	# coprolites positive for specified taxa
	Human Coprolites
Antelope House (n=180) (Reinhard, current research)	45 *Enterobius vermicularis* 2 *Strongyloides* sp. 4 strongylate eggs 1 hymenolepidid cestode
Antelope House (n=49) (Reinhard et al. 1987)	9 *E. vermicularis* 1 *Strongyloides* sp. 1 strongylate eggs 1 hymenolepidid cestode
Antelope House (n=90) (Fry and Hall 1986)	14 *E. vermicularis* 8 rhabditid (?) larvae
Bighorn Sheep Ruin (n=20) (Gardner and Clary, n.d.)	2 *E. vermicularis*
Chaco Canyon (n=19) (Reinhard and Clary 1986)	4 *E. vermicularis*
Glen Canyon (n=30) (Fry 1977) (Moore et al. 1974)	1 *Moniliformis clarki* 3 taeniid cestode 1 unidentified trematode
Hoy House, Mesa Verde (n=56) (Stiger 1977)	4 *E. vermicularis*
Inscription House (n=16) (Fry unpublished data)	3 *E. vermicularis* 1 unidentified nematode egg 1 rhabditid (?) larvae
Salmon Ruin (n=112) (Reinhard 1985a)	9 *E. vermicularis*
Step House, Mesa Verde (n=20) (Samuels 1965)	1 *E. vermicularis*
Turkey Pen Cave (n=24) (Reinhard)	7 *E. vermicularis*
Elden Pueblo (*) (Hevly et al. 1979)	*Trichuris trichiura* present *Ascaris lumbricoides* present *E. vermicularis* present taeniid cestodes present hymenolepidid cestodes
	Canid Coprolites
Antelope House (n=13) (Reinhard 1985a)	2 *Strongyloides stercoralis*
Bighorn Sheep Ruin (n=1) (Gardner and Clary)	1 *Toxascaris leonina*
Turkey Pen Cave (n=1) (Reinhard)	negative

* soil samples, not coprolites were recovered from Elden Pueblo.

Acanthocephalan eggs are present in Anasazi sites in Glen Canyon. One coprolite from Glen Canyon contained a fluke egg (Moore et al. 1974). It is probable that this is a case of false parasitism.

CHAPTER V

ANALYSIS

The previous chapter presents coprolite data relative to parasitism and diet for both hunter-gatherers and agricultural peoples. Presented below are analyses of these data relative to three questions to be evaluated by these data. These are: 1) did hunter-gatherers suffer less parasitic stress than agricultural peoples; 2) can variance in parasitic stress be identified and explained between different agricultural sites; and 3) did parasitism, as opposed to or in addition to dietary stress, have an impact on prehistoric health, specifically with respect to anemia?

Comparative Prevalence of Helminth Parasites Among Desert Hunter-gatherers and Agriculturalists

The notion that hunter-gatherers are less exposed to parasitism is supported by several authors, as noted in the Introduction and by Reinhard (1985a). Parasitism is limited by aspects of hunter-gatherer behavior and society. Prolonged exposure to infective helminth stages is limited by seasonal movements (Thomas 1959) and daily movements (Dunn 1972; Lee 1972). Parasite eggs are consequently defecated in a variety of ecological settings, most of which in arid regions are not conducive to the survival of the parasites. This aspect of defecation and parasite dispersal is analogous to that observed in Amboseli baboon troops (Hausfater and Sutherland 1984).

Zoonoses and incidental parasitism are common in hunter-gatherer bands (Nelson 1972). This results from seasonal wanderings into varied microhabitats, each with its own complement of animal parasites (Cockburn 1971; Fenner 1970), and from consumption of incompletely cooked meats (Nelson 1972) and insects.

Small band size (Dunn 1972; Fenner 1970) helps to limit the number of infections in the band. Studies of non-human primates also show that small band size and limited contact between bands lowers parasite diversity within each band (Freeland 1976; 1979). Only parasites with long periods of infectiveness can survive in small populations (May 1983).
Hunter-gatherer diet includes a variety of undomesticated plant foods (Lee 1972), some of which may contain anthelmintic compounds (Moerman 1986; Reinhard et al. 1985).

Aridity is not conducive to helminth survival. As noted in the study of Amboseli baboon defecatory patterns (Hausfater and Sutherland 1984), most helminths are deposited in areas too dry for survival. This aspect of parasite ecology was probably involved in hunter-gatherer behavior in the aridity of the Southwestern United States.

As reviewed by Reinhard (1985a), several researchers note several aspects of agricultural lifestyle that increase human susceptibility to infectious disease. Sedentism results in the build up of fecal mounds which promote helminth survival, especially of species having a direct anal-oral life cycle. This situation is worsened by utilization of human feces as fertilizer (Cockburn 1971). These practices help to maintain human populations in chronic contact with infective helminths.

Further, wild plants, some of which contain anthelmintic, prophylactic, or purgative compounds, are replaced by cultivated foods lacking such compounds. Consequently, parasitism is not impacted by anthelminthic compounds.

Helminths with short periods of infectiveness can survive in a large population due to increased chances that infective eggs or larvae will reach a host (May 1983). Thus, population growth concurrent with agriculture leads to increased parasitism.

Disturbance of local environment through agriculture attracts a greater variety of wild animals carrying zoonoses and incidental parasites (McKeown 1976; McNiell 1979). For example, Emslie (1981) demonstrated the disturbance resulting from agriculture and consequent increase in animal species surrounding agricultural villages by examining avifauna from archaeological sites.

Storage of grain attracts arthropods and rodents which promote the life cycles of hymenolepidid tapeworm genera (of the family Hymenolepidae), some of which are infective to humans. Hymenolepis, Vampirolepis, and Raillietina are three genera of hymenolepidid parasites that parasitize humans (Schmidt and Roberts 1981).

Dependence on mesic areas exposes a population to a greater variety of parasites (Cockburn 1971). Many of the more familiar human parasites are adapted to mesic conditions. Agricultural practices result in chronic exposure of individuals to moist soils and result in an increase in parasitism. Inadequate sanitation and hygiene combined with population increase causes accelerated infection with human specific helminths. Poor personal hygiene and random excreta disposal accentuate the problem. Under these conditions, infective eggs are more easily passed by hand contact (Dunn 1979).

The factors listed above should lead to increased prevalence of infection among agriculturalists and increased number of species in agricultural parasite fauna (species richness). It is postulated that agriculturalists inhabit more uniform habitats than hunter-gatherers.

The statistical examination of the coprolite data will address species richness, prevalence and diversity. It is hypothesized that an increase in prevalence of helminth remains will be present in coprolites from agricultural sites. It is hypothesized that species richness increases in the agricultural sample in comparison to the hunter-gatherer sample. Furthermore, it is hypothesized that the diversity of helminth fauna will increase in agricultural coprolites in comparison to those from hunter-gatherer sites.

To evaluate these hypotheses, the following null hypotheses will be tested. There will be no difference noted in prevalence of parasites between agricultural and hunter-gatherer coprolite samples. There will be no difference in helminth diversity between hunter-gatherer and agricultural coprolite samples. There will be no difference in species diversity between the two samples.

The coprolite data derived from all analyses of hunter-gatherer and agricultural sites discussed in this research are used in statistical analysis with some exceptions. Because taeniid eggs are dubious evidence of true human parasitism, taeniid remains are not included in the evaluations below. Also excluded from the evaluations are the acanthocephalan eggs from Clyde's Cavern since it is unclear that these are human parasites, the remains of an adult nematode from Clyde's Cavern since its taxonomic place is obscure, and rhabditid larvae from Inscription House. These larvae are not described in sufficient detail to determine whether or not they are actually parasites as opposed to free living nematodes. Several studies are now available from Antelope House (Fry and Hall 1986; Reinhard 1985a, 1985b, 1985c; Reinhard et al. 1987). Because the analysis presented in the Results section is most exhaustive, it is included in the evaluation presented below.

Species Richness

Species richness simply refers to the number of species present in the samples. An increase in species richness indicates that a given parasite fauna includes more species than another.

In the hunter-gatherer sample, three species are represented, *Moniliformis clarki*, *Enterobius vermicularis* and a fascioloid trematode. In the agricultural coprolites six species are present; *E. vermicularis*, *M. clarki*, *Strongyloides* spp., hymenolepidid cestodes, strongylate nematodes and an unknown trematode. When the soil samples from Elden Pueblo are considered, two additional species can be added, *Trichuris trichiura* and *Ascaris lumbricoides* to the list of prehistoric helminths of Southwestern agricultural peoples.

It appears then that a greater species richness is exhibited by the sample of coprolites from agricultural sites. The data refute the null hypothesis and indicate that species richness was greater among agricultural peoples than hunter-gatherers.

Prevalence

In cursory examination of nominal data from the sites, it appears that parasitism was a more common aspect of agricultural life than hunter-gatherer life. Three of six hunter-gatherer site coprolite collections contained helminth remains. Ten of 11 agricultural sites provided evidence of helminth parasitism. A chi-square value of 6.24 indicates significance beyond the 95% confidence limit ($X^2_{0.025,1}=3.841$).

The prevalence of helminth remains in the total samples differs between the hunter-gatherer sample and the agricultural sample. Of 357 coprolites in the hunter-gatherer sample, 14 (4%) contain helminth remains. Of 513 agricultural coprolites, 89 (17%) contain helminth remains. Again the difference between prevalence between the sites is significant beyond the 95% confidence interval. A chi-square value of 35.09 is obtained ($X^2_{0.001,1}=10.83$).

Because the Antelope House collection is so large (180 coprolites) and has one of the largest prevalence values of any site (29%), it was thought that this site skewed the over-all prevalence of agricultural coprolites upward. A second analysis was done with the exclusion of the Antelope House data. The value obtained was 11.98, still significant beyond the 95% confidence interval ($X^2_{0.001,1}=10.83$).

The results of this analysis refute the null hypothesis. The data show that helminth prevalence is significantly greater in the agricultural coprolite sample versus the hunter-gatherer coprolite sample.

It is noteworthy, however, that prevalence between sites in both samples is highly variable. This indicates a degree of overlap in prevalence between the two subsistence groups. Danger Cave and Hogup Cave exhibit strikingly high prevalence. The prevalence of helminths at these sites (15% for Danger Cave and 12% for Hogup Cave) approach the over all prevalence for the agricultural sample (17% with the inclusion of Antelope House and 11% with the exclusion of Antelope House). The nature of parasitism at these sites is different than that of agricultural sites in that most of the Hogup and Danger Cave infections were zoonotic, the infective organism being Moniliformis clarki.

Some of the agricultural sites exhibit very low prevalence of helminth remains in coprolites. For example, none of the ten coprolites from Glen Canyon that are attributed to the Fremont culture contained helminth remains. In this case, the lack of helminths can be attributed to a small sample size. However, other sites with larger samples exhibit relatively low prevalence. For example, Step House exhibits a 5% prevalence, Hoy House and the Glen Canyon Anasazi exhibit a 7% prevalence, and Salmon Ruin exhibits a 8% prevalence.

Clearly, with respect to prevalence, factors other than agricultural dependence are at play. Therefore, it would be inappropriate to state that coprolites from any agricultural site will exhibit a higher prevalence than coprolites excavated from any hunter-gatherer site. However, given the data at hand, there is a probability that a sample of agricultural coprolites will exhibit more evidence of helminth parasitism than a sample of hunter-gatherer coprolites.

Diversity

The diversity of parasite fauna was evaluated using Shannon's index which is adapted to nominal data (Zar 1981). Parasite taxa were used as categories in the analysis. The evaluation was based on the number of sites exhibiting evidence of each category. Thus, for the agricultural sample, two sites each exhibited evidence of parasitism with hymenolepidids, *Strongyloides*, and strongylate worms. One site each exhibited evidence of *M. clarki*, trematode, *A. lumbricoides* and *T. trichiura*. Nine agricultural sites provided evidence of *E. vermicularis* parasitism.

For the hunter-gatherer sites, two exhibited parasitism with *M. clarki*, and *E. vermicularis*. One exhibited evidence of trematode infection.

The diversity indices (J) are values that reflect the evenness of distribution of observations per category. In a situation in which every category contains the same number of observations, the index is 1.0. When observations are clumped in only a few categories, the index approaches 0.0. Thus, increased diversity results in J values closer to 1.0 while less diverse samples produce J values less than 1.0.

The J values calculated for the hunter-gatherer and agricultural samples were 0.9602 and 0.8102 respectively. This is contrary to the prediction that the agricultural sample would be more diverse than the hunter-gatherer sample. In reviewing the data it was observed that while many parasite taxa made marginal showing in the agricultural sample, the amount of parasitism with E. vermicularis greatly increased and perhaps the large showing of sites in this category lowered the diversity index.

To test this, diversity indices were calculated with the exclusion of E. vermicularis data. The resulting J values were 0.9183 for hunter-gatherers and 0.9696 for agriculturalists. The similarity of these values leads to the conclusion that helminth diversity did not change very much with the advent of agriculture although species richness does show a substantial increase.

It is probable that agricultural lifestyle allowed for more species to establish in human populations. However, most established themselves at low prevalence levels.

The greatest change in prevalence occurred with E. vermicularis which was present in some archaic hunter-gatherer populations at low levels. Agricultural life apparently allowed for the proliferation of this species. In the hunter-gatherer sample, E. vermicularis was present in 1.4% of the coprolites. Among agricultural coprolites, E. vermicularis is present in 15.0% of the coprolites. Thus the species that really proliferated in the sedentary, crowded, and unhygienic conditions of Southwest agricultural pueblos was pinworm.

The comparison of diversity between the two samples is hampered by the low numbers of sites studied for helminth remains. As more analyses are carried out and truly meaningful numbers of infections are identified, diversity comparisons may be more useful.

Parasite Ecology of Two Anasazi Villages

As noted above and in the Results section, helminth prevalence varied between sites. Certain sites have been studied with sufficient detail to allow for more precise determination of the conditions that led to variable parasitism. The sites best adapted for such study are Salmon Ruin and Antelope House. Antelope House shows a high prevalence of helminth remains in coprolites (29%) and Salmon Ruin shows a low prevalence (8%).

Antelope House is located in cave in the bottom of Canyon de Chelly. The mesic environment of the canyon bottom makes it an ideal place for agriculture, and consequently it was inhabited by the Anasazi between AD 500 and 1250. No archaic hunter-gatherer remains have been found in the canyon with the exception of a recent find of a cave containing possible archaic artifacts (Don Morris, personal communication). Antelope House was excavated by Don P. Morris of the National Park Service between 1970 and 1974. A major goal of the excavation was the recovery of biological remains for study. Preliminary analyses were presented at the 39th annual meetings of the Society for American Archaeology in 1974 and published in 1975 in The Kiva 41(1). Final reports of the excavation and analyses were recently published (Morris 1986).

The excavation of Salmon Ruin, New Mexico was initiated in 1970 by Cynthia Irwin-Williams. Major goals of the excavation were the recovery of biological remains and establishment of pragmatic methods for field recovery of botanical remains (Bohrer and Adams 1977). The excavations ended in 1978 although attempts to stabilize the ruin carry on to date.

Tree ring evidence indicates that the village construction was initiated at A.D. 1088. The location of the village along the San Juan River provided ready access to arable land. The community was occupied until the latter part of the thirteenth century when it was burned. Many individuals were trapped inside the village by the fire. During the excavation of the site, single skeletons were often encountered in the burned rooms and one structure, the tower kiva, contained the remains of about 40 sub-adults.

Salmon Ruin was built on the edge of a shallow terrace over looking the flood plain of the San Juan River. The flood plain is very moist with dense vegetation cover. The sandy soil underlying both Salmon Ruin and Antelope House is wet. Portions of both sites were subject to flooding. In the case of Salmon Ruin, the main trash deposits outside of the Ruin were washed away. In the case of Antelope House, most of the trash deposit and an unknown number of rooms were lost to flooding.

Aspects of Parasite Ecology

Of 112 coprolites studies from Salmon Ruin, only nine (8%) contained helminth remains. Only one species is represented, that being the pinworm, *E. vermicularis*. Of 180 coprolites studied from Antelope House, 52 (29%) contained helminth remains. Four species are represented, *E. vermicularis*, *Strongyloides*, hymenolepidid cestodes and a strongylate species. Two of these species, *Strongyloides* and the strongylate species, require moist, warm conditions for infection. Aspects of behavior and environment of the sites are examined below in an attempt to explain why the differences in parasitism occurred.

Population Size

As mentioned in above, host population size is one factor that effects the nature of parasitism. Using ethnographic analogies regarding the number of people that utilize rooms in modern pueblos, the population of Antelope House was calculated on the basis of architectural reconstruction (Morris 1986:55-57). He concludes that about 150 people lived in Antelope House during the peak period of Pueblo III occupation at which time at least 36 rooms were used for various purposes.

The population of Salmon Ruin can be estimated on the basis of skeletons found in the rubble of the burned ruin. Most important with respect to population estimates are the remains of 38 juveniles found in the central tower of the Pueblo. Citing ethnographic analogy, Irwin-Williams believes that the children were sent to the highest, safest, point of the village when fire broke out (personal communication). Presuming that these skeletons represent most of the juveniles of the village and that an equal number of infants and adolescents inhabited the village, then I estimate that at least 76 subadults inhabited the village. Assuming that the number of adults equalled the number of subadults, then I suggest that 152 people lived in the village.

This estimate of population may be conservative. The ruin was only partially excavated and many more skeletons may exist in unexcavated portions of the site. The fact that 177 rooms were present in the main village (Adams 1980a:1) would suggest that the population of Salmon Ruin was much larger than that of Antelope House, assuming that all rooms were occupied at one point in time.

While acknowledging that these population figures are probably at best approximations, I suggest that the populations of Antelope House and Salmon Ruin were roughly equivalent.

Seasonality

Based on coprolite analyses (Williams-Dean 1986) Morris concludes that Antelope House was occupied year round (1986:55). Williams-Dean (1986) approached seasonality as part of her palynological study. She included macrofossil analysis as well as palynological analysis in her assessment. She identified two types of coprolites, "Spring-Summer" and "Four Seasons". The first category includes coprolites that contain components that could only be gathered in the warm months. The second category includes items that were available year-round. She notes that year-round occupation of Antelope House is probable but concludes with the caveat that "occupation . . . during cold months cannot be empirically stated, but can be suggested from the storable nature of the food remains . . . and from ethnographic records of out-of-season use of these plants."

The Salmon Ruin fire carbonized substantial amounts of stored cultivated and wild plant foods (Bohrer 1980). This suggests that the site was occupied during the winter months during which time the stores would have been needed. Adams (1980a) feels that the presence of _Chenopodium_ and _Portulaca_ seeds in the ruin indicate spring and fall activity at the ruin. It is likely then that both villages saw year round occupation, although the habitation was probably more intense during the late fall, winter, and early spring when people would need to take refuge from the cold.

Resource Exploitation

It has been pointed out above that environmental parameters are important in the formation of conditions suitable for parasitism. Most, warm conditions are optimal for the transfer of many parasite species. The analysis of the way in which peoples at Antelope House and Salmon Ruin exploited the local resources provides information relative to the ecological conditions to which they were habitually exposed.

The analysis of dietary plants, non-dietary plant remains, and avian remains indicates that Antelope House inhabitants utilized water resources to e greater degree than did those of Salmon Ruin and other Anasazi sites in general.

Water birds make up to 50% of the wild bird remains recovered from Antelope House (McKusick 1986). The species represented are *Anas platyrhynchos* (mallard), *A. strepera* (gadwall), *A. carolinensis* (green-winged teal), *Mareca americana* (American widgeon) *Spatula clypeata* (shoveler), *Bucephala albeola* (bufflehead), *Grus canadensis* (lesser sandhill crane), and *Euphagus cyanocephalus* (Brewer's blackbird). Of these, *A. platyrhynchos* has been found at four other Anasazi sites and *M. americana* has been found at one other Anasazi site. All of the ducks except *B. albeola* prefer standing, shallow pools.

Horsetail (*Equisetum*) is present in 7% of the Antelope House coprolites but is absent from any other Anasazi site. Cattail (*Typha*) pollen is present in 32 (35%) of the coprolites from the lower Pecos of Texas studied by Williams-Dean (1986) but is absent from coprolites from other Anasazi sites (Clary 1984). In my analysis of 180 coprolites for parasitological remains, I examined one coprolite that was composed solely of Typha pollen held in a fibrous matrix. Obviously the strobili of Equisetum and the inflorescences of Typha were common food sources for Antelope House Anasazi. Both are found in mesic environments associated with standing water. Equisetum is also found in wet soils of streambeds.

Pollen examination of pottery vessels and grinding stones indicates that riparian plants were processed at the village (Bryant and Morris 1986). In addition to Zea mays, Cleome, and Cheno Am (pollen of the families Chenopodiaceae and Amaranthaceae), Populus and Typha were processed and stored at the site.

A large variety of plants were evidenced in soils excavated from the site. Of plant remains found in non-fecal contexts, 37% of 78 species found in the Antelope House excavations come from what is termed "wet places" (Harlan and Dennis 1986). It is concluded from these remains that "the canyon bottom, in general, provides more plant species suitable for food than do any of the other (ecological) areas" (Harlan and Dennis 1986:139).

Riparian plants were widely used at Antelope House for construction and weaving. Roof beams are made of Populus (cottonwood). Salix (willow) and Phragmites (arrow wood) were also used as structural support and Salix in basketry. Arrow shafts were manufactured from Phragmites. The standard plant used in the manufacture of matting was *Scirpus* (bulrush). Morris (1986:548-549) concludes with respect to Antelope House, "Riparian plants perhaps were the most heavily used plants of the area."

A less complete picture is available for Salmon Ruin. However, the analysis of coprolites and the ethnobotanical reports that are available portray a contrasting picture with the riparian usage of plants and animals than those at Antelope House.

The most common plant remains recovered from the site were *Zea*, *Phaseolus vulgaris* (cultivated beans), *Pinus edulis* (pinyon pine), *Cucurbita* (squash), *Chenopodium*, *Amaranthus* (pigweed), *Allium* (wild onion), *Yucca*, *Juniperus* (juniper) and *Portulaca* (purslane). These most common plants reflect foraging in xeric areas. Thirteen other plants are listed as common, but only three of these, *Carex*, *Eleocharis* and *Scirpus*, are mesic adapted plants (Bohrer 1980; Adams 1980a, 1980b).

Seven burned store rooms were excavated. The collapsing of the burning roof and walls of the rooms smothered the fire and resulted in the preservation of carbonized plant remains. Reviewing the contents of these store rooms provides a unique view of what types of plants were harvested and stored at Salmon Ruin. All seven of the rooms contained stores of *Z. mays* (maize). Six of the rooms contained *P. vulgaris* (cultivated beans). *Cucurbita* (squash) seeds and rinds were found three rooms. Three rooms contained each of *Chenopodium* (goosefoot) seeds and *Cylindropuntia* (cholla cactus) stems, buds, and seeds. Two rooms each contained *Cycloloma* seeds and *Opuntia* (prickly pear) seeds and pads. *Cleome* (beeweed) seed, *Oryzopsis* (Indian rice grass) florets, *Portulaca* (purslane) seeds and *P.*

edulis (pinyon pine) nuts were found in one room each. Today *P. edulis* does not grow, and did not grow in prehistory, in the area of Salmon Ruin so it was probably collected at some distance from the village. These plant foods probably represent major dietary components. None of them are specific to mesic areas.

The consumption of *Prunus* (chokecherry) fruit in comparison to other foods bears on the relative importance of mesic adapted plants at Salmon Ruin. Bohrer (1980) discusses the evidence of *P. edulis* nut, *Juniperus* berry, *Allium* bulb, *Yucca* pod, and *Prunus* fruit consumption at the site based on botanical data from 53 trash strata. *P. edulis* nuts and *Juniperus* berries occurred in roughly equal numbers of strata, 48 and 43 respectively. *Allium* remains were recovered from 34 trash strata and *Yucca* remains were recovered from 26 trash strata. In contrast, *Prunus* was found in only eight strata. She notes that *Prunus* should be expected to produce a reliable crop. In comparison, *P. edulis* and *Yucca* produce undependable crops. With respect to *Prunus* Bohrer (1980:247) states that "the heavy use of pinyon nuts runs counter to its erratic seed production and distance from Salmon Ruin. The low frequency of chokecherry pits may indicate a lack of popularity, for they seem to be available and reliable." The contrast in utilization of *Prunus* with other, xeric plants suggests that Salmon peoples preferred to forage in xeric areas even though productive species were available in the local mesic environment near the village.

This tendency to consume xeric adapted plants is confirmed by coprolite analysis. *Rhus trilobata* is the most common component (23 of 112 coprolites). This plant grows in the juniper woodlands overlooking the San

Juan River plain. Its presence signals foraging in xeric environments. Other major components are _Z_. _mays_, _P_. _vulgaris_, _Chenopodium_ and _Amaranthus_. No evidence of mesic plants such as _Equisetum_, _Celtis_, or _Prunus_ was found.

Comparative pollen analysis of coprolites from Salmon Ruin and Antelope House (Table 12) documents an absence of _Typha_ and _Equisetum_ at Salmon Ruin. The pollen evidence from Salmon Ruin indicates that the flowers of _Opuntia_ (prickly pear), _Cleome_, and _Cucurbita_ were eaten. In addition, the pollen evidence indicates that consumption of _Z_. _mays_, a high spine composite, and perhaps a plant in the family Apiaceae. The evidence suggests a more maize dependent diet for Salmon Ruin with less diversity in wild plant foods than at Antelope House. Mesic associated plants are absent in the Salmon Ruin coprolites.

These data speak to the environments in which Salmon Ruin and Antelope House inhabitants lived and foraged. They demonstrate that the inhabitants of Antelope House were closely tied to the mesic canyon bottom in which they lived. Conversely, the inhabitants of Salmon Ruin utilized drier areas for habitation and food collection.

Hygiene

The patterns of excreta disposal at the two sites reflect drastic differences in general hygiene. At Antelope House approximately 150 separate fecal deposits were found in the excavation. All of these can be considered to be individual latrines. They are located throughout the site, both in plaza areas and in habitation rooms. Thus the pattern of

TABLE 12
Economic pollen type frequencies from Antelope House and Salmon Ruin coprolites. Number of coprolites containing pollen of specified taxa are presented.

Taxon	Antelope House n=27	Salmon Ruin n=30
Apiaceae	2	6
Asteraceae (H.S.)	13	12
Brassicaceae	3	8
Cactaceae	3	5
Celtis	1	0
Cheno Am *	9	9
Cleome	24	28
Cucurbita	3	3
Equisetum/*Populus*	12	2
Fabaceae	5	4
Liliaceae	1	4
Opuntia	0	2
Poaceae *	2	3
Portulaca	1	0
Rhus	6	3
Typha latifolia	17	0
Zea	18	25

* only percentages exceeding 5% of a 200 grain count are included in these categories.

excreta disposal at Antelope House resulted in the formation of many small latrines in and around habitations.

In contrast, coprolites were recovered from specific, sequestered areas in Salmon Ruin. Usually, specific rooms were set aside for the purpose of trash and feces disposal. An example of such a room is 62W in which a trench was excavated into deep trash deposits next to a narrow, masonry bench. Feces were deposited into the trench from the bench. Several other rooms were used as latrines, and coprolites were recovered from trash strata as well. The pattern of feces disposal at Salmon Ruin was one that resulted in the isolation of large amounts of fecal material in specific areas. The fact that the rooms were two stories deep and had walls up to 1.5 meters thick resulted in separation of latrines from living areas.

It is impossible to reconstruct personal hygiene. The only information relative to this aspect of life comes from Bohrer (1980). She speculates that the inhabitants of Salmon Ruin made soap from Yucca roots. This notion is based on the abundance of Yucca leaves, pods, seeds, and hearts at the site but without a single piece of root. She suggests that the roots were pulverized to make soap and consequently were destroyed.

One important aspect of Antelope House was that it was largely enclosed in a cave. This would limit air movement and prevent the removal of suspended particles from the air. Since Enterobius vermicularis (pinworm) is commonly transferred by aerial contamination, the lack of air movement at Antelope House could result in aggravation of pinworm infection.

Summary of Parasite Ecology

Several factors relevant to parasitism have been approached. These factors include general environment of the sites themselves, probable population sizes, seasonality, resource exploitation and hygiene.

With respect to certain factors, no difference between the sites is apparent. The sites are essentially similar with respect to general environment. Both are built on moist soils and are adjacent to riparian or mesic environments. The population reconstructions suggest that the populations of the two sites were roughly equivalent. Both sites were probably year round habitations.

The major differences are seen in resource exploitation and hygiene. The inhabitants of Antelope House lived in a moist environment relative to Salmon Ruin. Those of Salmon Ruin seemed to have relied more on xeric food sources. The excreta disposal pattern at Antelope House was erratic in comparison to the defined, isolated latrines established at Salmon Ruin. These latter two factors probably had a pronounced influence on parasitism.

The utilization of mesic areas kept inhabitants of Antelope House in contact with moist soils where the facultative parasite _Strongyloides_ and the strongylate species could survive their extracorporal stages. The fact that dogs at Antelope House served as reservoir hosts for _Strongyloides_ (Reinhard 1985c) could have helped in the maintenance of _Strongyloides_ in the soil. The defecation of feces near and in habitations could have led to human _Strongyloides_ infection.

The wide distribution of latrines throughout the site combined with poor air circulation may have contributed to higher levels of pinworm infection. The considerable difference in pinworm prevalence between the two sites suggests that the inhabitants of Antelope House were more crowded than those of Salmon Ruin. This might be the predictable result of an increasing population residing in the confines of a cave.

Diet, Parasitism and Anemia

The coprolite data are especially relevant to the debate regarding anemia in the Southwestern agricultural peoples, variously attributed to iron deficient diet (El-Najjar et al. 1976) and parasitism (Reinhard et al. 1987). They are best suited to the evaluation of the maize dependency hypothesis of prehistoric anemia. To do this I shall address the role of diet as opposed to parasite infection as etiologic agents in prehistoric anemia.

First I shall review the coprolite data base as it stands to date and the skeletal analyses available for sites from which coprolites have been studied. Secondly, I shall review the nature of prehistoric southwestern diets as evidenced in the coprolite data. Thirdly, I shall review origin of the maize dependency hypothesis and derive from this dietary expectations to be tested by the coprolite data base. Finally, I shall compare the expectations of the maize dependency hypothesis with the coprolite data.

The Data Base

Traditionally, macroscopic analysis (both floral and faunal) and, secondarily, pollen analysis are applied in coprolite study (Bryant 1974a, 1974b, 1986; Bryant and Williams-Dean 1975; Fry 1985). Although helminth analysis has a long history with certain researchers (Fry 1974, 1977; Fry and Hall 1969, 1975; Moore et al. 1969, 1974; Dunn and Watkins 1970), helminth analysis has only recently become consistently applied in coprolite analysis. Consequently, there are more data derived from macroscopic analysis then pollen study. In general then, dietary comparison between sites is more consistently based on macroscopic remains (Fry 1980; Fry and Hall 1986). The fact that so many Southwestern coprolites have been analyzed for helminth remains (n=1,027) is largely due to the intensive efforts of a small number of parasitologists in the 1980's (Gardner and Clary unpublished; Reinhard 1985a, 1985b, 1985c; Reinhard and Clary 1986; Reinhard et al. 1987; Reinhard et al. 1988) building on previous work of anthropologists in the 1960's and 1970's (Dunn and Watkins 1970; Fry 1977, 1980; Fry and Hall 1969, 1975; Fry and Moore 1969; Hall 1972; Moore et al. 1969, 1974). Coprolites from both hunter-gatherer as well as agricultural contexts have been analyzed.

Hunter-gatherer coprolites have been recovered from the Great Basin (Lovelock Cave, Danger Cave, Hogup Cave), the Colorado Plateau (Dust Devil Cave), the western portion of the Mojave Desert (Bighorn Cave), and from the lower Pecos of western Texas (Hinds Cave and Baker Cave). Macroscopic component analysis has been completed with a total of 483 coprolites (Table 13), pollen data are available from 339 coprolites (Table 14), and helminthological data are available from 361 coprolites (Table 15).

All of these sites are dry caves. The preservation of pollen and macroscopic components is excellent for all sites. The hunter-gatherer

TABLE 13
Sites used in this study for which macroscopic analyses have been completed from hunter-gatherer contexts.

Site	Reference	# coprolites studied
Lovelock Cave	(Heizer and Napton 1969)	50
Danger Cave	(Fry 1977)	46
Hogup Cave, Archaic	(Fry 1977)	51
Hogup Cave, Shoshoni		3
Dust Devil Cave	(Reinhard 1985a)	20
Bighorn Cave	(this study)	20
Hinds Cave	(this study)	25
	(Williams-Dean 1978)	100
	(Stock 1983)	50
Baker Cave	(Sobolik 1988)	38

TABLE 14
Sites used in this study for which pollen analyses have been completed from hunter-gatherer contexts.

Site	Reference	# coprolites studied
Lovelock Cave	(Napton and Kelso 1969)	50
Danger Cave	(Kelso 1970)	8
Hogup Cave, Archaic	(Kelso 1970)	33
Dust Devil Cave	(Reinhard 1985a)	20
Bighorn Cave	(this study)	20
Hinds Cave	(this study)	20
	(Williams-Dean 1978)	100
	(Stock 1983)	50
Baker Cave	(Sobolik 1988)	38

TABLE 15

Sites used in this study for which helminthological analyses have been completed from hunter-gatherer contexts.

Site	References	# coprolites studied
Lovelock Cave	(Dunn and Watkins 1970)	50
Danger Cave	(Fry 1977)	46
Hogup Cave, Archaic	(Fry 1977)	51
Hogup Cave, Shoshoni		3
Dust Devil Cave	(Reinhard et al. 1985)	100
Bighorn Cave	(this study)	35
Hinds Cave	(this study)	39
	(Williams-Dean 1978)	13
	(Stock 1983)	7
Baker Cave	(this study)	17

coprolites are ideal for the preservation of helminth remains with the possible exception of Hinds Cave. In the case of Hinds Cave in the lower Pecos, the present of fly puparia, beetle exoskeletons and millipede remains indicates that the feces desiccated more slowly than is typical for dry cave sites. This may have had a negative effect the preservation of helminth remains.

Coprolites from agricultural sites on the Colorado Plateau have been studied. Two cultural groups are represented, the Anasazi and the San Rafael Fremont. For the Anasazi, both Basketmaker and Pueblo Periods are represented in the coprolite series. To date, 538 coprolites from agricultural sites have been examined for macroscopic remains (Table 16). Pollen data have been collected from 323 coprolites (Table 17). Helminthological analysis has been completed on 666 coprolites (Table 18).

Quantification of macroscopic remains is available in terms of presence/absence per coprolite for all sites. Weight quantification is also available from Bighorn Cave, Danger Cave, and Hogup Cave. Pollen data are based on 200 grain minimum counts for all sites. Parasitological data is presented in terms of the number of coprolites containing helminth eggs of given species.

Both cave sites and open sites are represented in the agricultural coprolite collection. Coprolites from the cave sites are ideal for the preservation of all types of data. The open sites in Chaco Canyon and that of Salmon Ruin show poor preservation of macroscopic floral components, and for that reason macroscopic floral data from these sites will not be used

TABLE 16
Sites for which macroscopic analyses are available from agricultural contexts. Asterisks indicate Fremont culture sites, all others Anasazi sites.

Site	Reference	# coprolites studied
Hogup Cave *	(Fry 1977)	6
Clyde's Cavern *	(Hall 1972)	16
Glen Canyon *	(Fry 1977)	10
Glen Canyon	(Fry 1977)	30
Antelope House	(Fry and Hall 1986)	90
Antelope House	(Reinhard 1985a)	62
Inscription House	(Fry and Hall 1986)	16
Turkey Pen Cave	(this study)	24
Turkey Pen Cave	(Aasen 1984)	28
Step House BM III	(Stiger 1977)	20
Step House Pueblo	(Stiger 1977)	17
Hoy House	(Stiger 1977)	56
Lion House	(Stiger 1977)	4
Salmon Ruin	(Reinhard 1985a)	112
Chaco Canyon	(Clary 1984)	47

TABLE 17
Sites for which pollen analyses are available from Anasazi agricultural contexts.

Site	Reference	# coprolites studied
Glen Canyon	(Martin and Sharrock 1964)	31
Antelope House	(Williams-Dean 1986)	92
Antelope House	(Table 4)	27
Turkey Pen Cave	(Reinhard and Jones n.d.)	24
Turkey Pen Cave	(Aasen 1984)	28
Hoy House	(Scott 1981)	59
Salmon Ruin	(Table 4)	30
Chaco Canyon	(Clary 1984)	28

TABLE 18
Sites for which helminthological analyses are available from agricultural contexts. Asterisk indicate Fremont culture sites, all others Anasazi sites.

Site	Reference	# coprolites studied
Hogup Cave *	(Fry 1977)	6
Clyde's Cavern *	(Hall 1972)	16
Glen Canyon *	(Fry 1977)	10
Glen Canyon	(Fry 1977)	30
Antelope House	(Fry and Hall 1986)	90
Antelope House	(Reinhard et al. 1987)	62
Antelope House	(this study)	180
Inscription House	(Fry and Hall n.d.)	16
Turkey Pen Cave	(this study)	24
Step House Pueblo	(Samuels 1965)	20
Hoy House	(Stiger 1977)	56
Lion House	(Stiger 1977)	4
Salmon Ruin	(Reinhard 1985a)	112
Chaco Canyon	(Reinhard and Clary 1984)	20
Bighorn Sheep Ruin	(Gardner and Clary n.d.)	20
Elden Pueblo	(Hevly et al. 1979)	**

** Soil samples, not coprolites, were studied from Elden Pueblo.

in statistical analyses presented below. Macroscopic faunal data was well preserved in coprolites from these sites.

Like the hunter-gatherer coprolite data, macrofloral presence/absence data are available for all coprolites from all sites. Weight quantification is available from Glen Canyon Fremont sites, Glen Canyon Anasazi sites, Antelope House, and Turkey Pen Cave. The poor preservation of Salmon Ruin and Chaco Canyon coprolites render meaningful weight quantification impossible. Pollen and parasite data are quantified in the same manner as hunter-gatherer coprolites.

In the analyses available for the Southwest, various sample sizes are represented. Certainly, some samples are too small for consideration such as from Lion House (four coprolites), Hogup Cave Fremont (six coprolites), Hogup Cave Shoshoni (three coprolites) and Glen Canyon Fremont (10 coprolites). Three other analyses are marginal with respect to sample size; Inscription House (16 coprolites), Clyde's Cavern (16 coprolites) and the Pueblo Period occupation of Step House (17 coprolites). The remainder of the studies are based on 20 or more coprolites, a number which is suitable for statistical analysis.

The Sinagua site of Elden Pueblo deserves special note. Privy deposits were found in this open site. However, no distinct coprolites were found. The fecal deposits were represented by dark, organic strata in several rooms. Macroscopic data are not available nor are palynological data relevant to diet. However, helminth data were well preserved in the deposits and are presented in Table 11 and noted in Table 18. Because helminth prevalence could not be quantified from this site in the same way as sites from which coprolites were excavated, helminthological data from Elden Pueblo will not be presented in any statistical evaluations.

I surveyed the paleopathology literature for skeletal studies of porotic hyperostosis and cribra orbitalia that would be relevant to the sites for which coprolite data are available. Skeletal pathology studies are available for five agricultural sites (Table 19). Two of these, Inscription House and Antelope House, are presented by El-Najjar et al. (1976). For Antelope House, skeletal pathology for the general region of Canyon de Chelly is presented. Two analyses are available for Chaco Canyon: El-Najjar et al. (1976) and Akins (1986). Although Akins' study is more desirable than El-Najjar's with respect to sample size, Akins notes that her criteria for diagnosing porotic hyperostosis were more conservative than those used by El-Najjar. In the interest of maintaining continuity for statistical evaluation, I chose to use El-Najjar's data in this study.

Skeletal pathology data for Mesa Verde is presented by Miles (1975). He differs from most paleopathologists by classifying the lesions of porotic hyperostosis as erythroblastosis fetalis. However, it is clear from his description of the lesions that his erythroblastosis fetalis is equivalent to porotic hyperostosis. Walker (1985) excludes Miles' work from his analysis because Miles does not indicate the number of crania studied. My review of Miles' data confirmed Walker's observation and consequently I am excluding Miles' data from analyses below.

Finally, Shipman (n.d.) presents a study of pathology at Salmon Ruin. Shipman presents a minimal estimate of porotic hyperostosis in the Salmon

TABLE 19

Incidence of porotic hyperostosis among subadult skeletons from sites for which coprolite data are available.

Site	Reference	Porotic hyperostosis/ total subadults
Chaco Canyon	(El-Najjar et al. 1976)	10/12
Chaco Canyon	(Akins 1986)	22/36
Inscription House	(El-Najjar et al. 1976)	7/11
Canyon de Chelly, Pueblo Period	(El-Najjar et al. 1976)	15/17
Canyon de Chelly, Basketmaker Period	(El-Najjar et al. 1976)	36/50
Salmon Ruin	(Shipman n.d.)	5/50

Ruin skeletal collection. This leads to a certain amount of ambiguity in the analysis. However, I believe that inclusion of the data in statistical analyses is instructive.

The Nature of Prehistoric Diet

The diets among prehistoric southwestern peoples tend to be specialized. The trend of specialization is evident among Archaic hunter-gatherer groups and extends into agricultural times.

Macroscopic floral data for hunter-gatherer sites is presented in Tables 20-21. As can be seen, most diets include a large variety of components, but relatively few components are found in large frequencies. Thus, most diets seem to be specialized around a nucleus of a few plant foods with a diversity of plants occasionally eaten. One can characterize these diets by the dominant components exhibited in the coprolite series. For example, the diet of Lovelock Cave is based on *Scirpus* and *Typha*, that of Danger Cave is based on *Allenrolfea*, that of Hogup Cave is based on *Allenrolfea* and *Opuntia*, that of Bighorn Cave is based on *Prosopis* and *Opuntia*, etc. Only in the case of Dust Devil Cave, does this tendency break down. There are few components in the Dust Devil Cave diet, and specialization is not clearly evident among these. However, the diet represented by Dust Devil Cave coprolites is a winter diet (Reinhard 1985a) and the lack of diversity probably reflects a time when few plants were available for consumption. The diet reflected by the Danger Cave and Hogup Cave diets are also most likely winter diets. The other hunter-gatherer diets are most likely warm season diets. The diversity indices presented in Tables 20-21 provide an idea of relative specialization at the sites.

TABLE 20
Direct counts of identifiable plant components recovered from hunter-gatherer coprolites used in this study.

Taxon	L.C.	D.C.	H.C.	D.D.C.	B.C.
Allenrolfea		44	50		
Allium				1	
Amaranthus	2				
Asteraceae		2			
Atriplex	13	8	3	1	
Artemisia			3		
Celtis			3		
Chaenactus	1				
Chenopodium				17	1
Chrysothamnus		1			
Cornus		1			
Cucurbitaceae					1
Cycloloma				2	
Descurania (?)				1	3
Distichlis	11				
Eleocharis	2				
Elymus	15				
Equisetum	1				
Juglans				1	
Juncus	1				
Juniperus				1	1
Mentzelia	1			2	
Lepidium			1		
Opuntia		7	30	22	13
Panicum	1			2	
Phlox		1			
Phragmites	1				
Pinus	4	2			
Poaceae			2	6	2

L.C.= Lovelock Cave (n=50)
D.C.= Danger Cave (n=46)
H.C.= Hogup Cave (n=51)
D.D.C.= Dust Devil Cave (n=20)
B.C.= Bighorn Cave (n=20)
* Shannon's Diversity Index, J values presented

TABLE 20
continued

Taxon	L.C.	D.C.	H.C.	D.D.C.	B.C.
Prosopis					13
Rumex	2				
Salsola	1				
Scirpus	50	3	1		
Sporobolus	1			30	
Stellaria	3				
Sueda	8				
Typha	35				
Yucca				20	
Diversity*	0.71	0.58	0.58	0.94	0.73

L.C.= Lovelock Cave (n=50)
D.C.= Danger Cave (n=46)
H.C.= Hogup Cave (n=51)
D.D.C.= Dust Devil Cave (n=20)
B.C.= Bighorn Cave (n=20)
* Shannon's Diversity Index, J values presented

TABLE 21
Direct counts of identifiable plant components recovered from hunter-gatherer coprolites from the lower Pecos area.

Taxon	G.W.	K.J.R	K.D.S.
Acacia		1	
Agave	51	15	5
Allium	40	2	11
Amaranthus	1		
Brassicaceae			3
Carex	8	1	
Celtis	4	2	1
Cenchrus	2		
Chenopodium	3	2	1
Dasylirion	7		9
Descurania		5	
Diospyros	14	2	
Echinocereus		2	
Helianthus		3	
Juglans	23	1	2
Juniperus			2
Mammillaria		1	3
Opuntia	88	20	19
Panicum	7		
Poaceae	2	6	
Prosopis	13	1	1
Quercus			1
Sporobolus	42		
Vitus	3		
Yucca	1	3	4
Diversity*	0.76	0.80	0.82

G.W.= Hinds Cave, Williams-Dean (1978) (n=100)
K.J.R= Hinds Cave, this study (n=25)
K.D.S.= Baker Cave, Sobolik (1988) (n=38)
* Shannon's Diversity Index, J values presented

Values approaching 1.0 reflect little specialization. As values decrease, an increase in dietary specialization is indicated. Thus Dust Devil Cave coprolite data exhibit little dietary specialization while maximum specialization is seen in the values for Hogup and Danger Caves.

Macroscopic floral data for agricultural sites are presented in Table 22. The agricultural sites probably represent year round occupations, and therefore the coprolites probably reflect the sorts of food eaten throughout the year. Williams-Dean (1986) was able to distinguish warm season dietary components among the coprolites from Antelope House. Other coprolites from that site represent what she identifies as "year round" dietary components that could be stored and consumed in winter.

Although maize agriculture was widely practiced in the Southwest, maize did not necessarily play an all important role in Southwestern agriculturalist diets. This is especially true of the Fremont culture. Fremont coprolites from Clyde's Cavern, Utah show little evidence of consumption of maize nor any other cultigen. Fremont coprolites from Glen Canyon show that squash was commonly consumed, but maize was a minor dietary component. Opuntia pads, seeds of Amaranthus and Chenopodium, and wild grass seed were also commonly consumed.

Maize plays a more important role in Anasazi diet, but reliance on maize is variable. Certainly at Antelope House, Turkey Pen Cave, Hoy House, and Step House, maize was a dietary mainstay. It should be noted that other plant foods supplemented maize in the diet. It is important to remember that maize is readily identifiable in coprolites due to the presence of durable and distinctive cupule fragments. In contrast, squash

TABLE 22
Direct counts of identifiable plant components from agricultural sites.

Taxa	CCF	GCF	GCA	TPC	AH
Allium					2
Amaranthus		6	10	2	9
Amelanchier		2			
Artemisia		1			
Asteraceae	6	3	8		
Atriplex				1	1
Cactaceae					38
Celtis			5		
Chenopodium		5	16	10	4
Cheno Am	7			4	
Cleome			5	4	14
Cryptantha			1		
Cucurbita		9	20	6	26
Descuranea				3	
Elymus	2				1
Ephedra			1		
Equisetum		1			6
Franseria				3	
Gossypium			9		16
Helianthus				5	4
Juniperus		1		5	
Lepidium	1	1	5	2	1
Opuntia		6	16	7	11
Oryzopsis			5	9	2
Panicum					1
Phaseolus		1		1	1
Physalis				1	14
Pinus	1		1	19	26
Poaceae		4	14	3	1
Polygonum			1		
Portulaca			2	6	19
Rhus					6
Scirpus	1	1	1		
Solanum				1	
Sporobolus	12				1
Vitus					2
Yucca		2		1	1
Zea	7	3	18	50	82
Diversity*	0.83	0.890	0.87	0.77	0.69

CCF= Clyde's Cavern Fremont (n=16)
GCF= Glen Canyon Fremont (n=10)
GCA= Glen Canyon Anasazi (n=30)
TPC= Turkey Pen Cave (n=25)
AH= Antelope House (n=90)
* Shannon's Diversity Index, J values

TABLE 22
continued

	IH	HH	SH	CC*	SR*
Amaranthus		5	3	1	6
Artemisia		1	1		
Atriplex		10			
Cactaceae	8				
Celtis	3				
Chenopodium		6	11		14
Cleome		3	3		2
Corispermum			2		
Cucurbita		11	13	2	
Cycloloma					1
Descuranea				4	
Echinocereus					1
Erigonum		1			
Gossypium	4				
Helianthus	3	1	1	2	
Juniperus			1		
Lepidium	9				
Opuntia		14	19		1
Oryzopsis	5	2	2	1	
Panicum	1				
Phaseolus	4	10	3		11
Physalis	2	15	8		1
Pinus		7	10	11	6
Poaceae	1	1	2		
Portulaca	1	10	9	7	6
Prunus		2	2		
Rhus	1		3		23
Shepherdia		3			
Solanum				1	
Sporobolus	3			2	
Zea	10	56	28		43
Diversity**	0.89	0.78	0.86	--	--

IH= Inscription House (n=16)
HH= Hoy House (n=56)
SH= Step House (n=37)
CC= Chaco Canyon (n=47)
SS= Salmon Ruin (n=112)
*= Results effected by poor preservation.
** Shannon's Diversity Index, J values presented

is more completely digested and is represented only by seeds and occasionally pollen or phytoliths. Beans are almost completely digested (Stiger 1977) and are difficult to identify in coprolites. Thus maize may be over represented in coprolite studies.

Although many gathered plant species were consumed at these sites, certain species stand out as being more dominant. Opuntia and Pinus edulis were important at Antelope House, Chenopodium and Pinus edulis were important at Turkey Pen Cave, Utah, Chenopodium, Physalis, and Opuntia were commonly consumed at Step House, and Physalis, Chenopodium, Portulaca and Pinus edulis were important foods at Hoy House.

Frequency data may provide an inaccurate idea of the relative importance of plant foods. Often wild plant foods occur in many coprolites but only in trace amounts in each coprolite. These trace amounts probably represent spices and condiments. For example, Cleome, and Portulaca were consumed in historic times as spices (Whiting 1939). Presumably, the small amounts of these plants in coprolites represents a similar use in prehistory. The nutritional value of these plants when used in small amounts as spices is probably minimal.

Maize consumption at some Anasazi sites was relatively low. Of Glen Canyon Anasazi coprolites, 60% contain maize remains and of Inscription House coprolites, 63% contain maize remains. This is in contrast to 91% for Antelope House, 96% for Turkey Pen Cave, 100% for Hoy House, and 88% for the Pueblo occupation of Step House. The main dietary components for the Glen Canyon Anasazi are similar to the Fremont components from the same area. Squash, Chenopodium, and Opuntia were major dietary components along with maize. The 17 coprolites from Inscription House reflect a diverse diet dominated by plant foods such as _Opuntia_ pads, _Lepidium_ seed and maize.

Weight quantification provides a better base for evaluating the importance of maize in diet in relation to other plants. Of identifiable plant components, on the average 61% of coprolites from Antelope House consist of maize and 65% of the coprolites at Turkey Pen Cave consist of maize. In contrast, only 25% of Glen Canyon Anasazi coprolites consist of maize and a scant 12% of Glen Canyon Fremont coprolites consist of maize. The weights bear strong testimony to the variability of maize consumption at Anasazi sites. The weight and frequency data also throw into doubt El-Najjar and Robertson's (1976:143) speculation that in Canyon de Chelly and similar areas such as Chaco Canyon and Inscription House "maize constituted over 75% of the diet".

The diversity indices for agricultural sites (Table 22) are fairly consistent in comparison to the hunter-gatherer sites. This may be due to season specific diets reflected by the hunter-gatherer coprolites which resulted in more extreme values. Alternatively, the more consistent values among agriculturalists may reflect the fact that all sites are located on the Colorado Plateau and there is consequently little deviation due to differences in plant species availability. The value for Antelope House seems to be lower than the majority of agricultural sites and reflects a stronger trend in dietary specialization.

Despite the relative conformity in diversity indices, there is a substantial amount of variation in components in Anasazi diets from site to site. The variation is seen in both wild and cultivated foods. This contrasts with previous research in which Anasazi diet has been characterized as relatively uniform (Clary 1984; Reinhard and Jones n.d.). In comparing Anasazi dietary components in Table 22, one can readily see that utilization of wild plant foods varies both in kind and amount from site to site. Fry (1980:332) characterized the Anasazi as "foraging specialists who practiced horticulture of maize, beans, and squash but not depend exclusively on these cultivars." I believe that this characterization best fits Anasazi diet in general. Although maize was clearly a dietary mainstay, specialized foraging was also a critical part of Anasazi nutrition.

The Maize Dependency Hypothesis

The maize dependency hypothesis is born from the tacit assumption that prehistoric diets are specialized, an assumption supported explicitly by the coprolite data presented above. It originated in a comparative analysis of pathology from the sites of Antelope House, Arizona and Gran Quivira, New Mexico (Christy G. Turner, personal communication).

A striking difference in frequency of porotic hyperostosis in the skeletal series from the two sites was noted. It was hypothesized that difference in diet (specifically maize consumption) accounted for the higher incidence of porotic hyperostosis at Antelope House (55%) in comparison to Gran Quivira (17%).

This hypothesis seems plausible with respect ecology of the sites and the chemistry of maize. Antelope House is located in a moist canyon bottom which was, and is, suitable for maize agriculture. Gran Quivira is located in a xeric area of juniper and cholla. The hydrology of the area makes it unsuitable for maize agriculture (Vivian 1964). Maize contains high amounts of phytic acid which bonds with iron and prevents its intestinal absorption. Phytase, which counteracts the effect of phytic acid, is lacking in maize. Consequently, maize dependency results physiologically in iron deficiency which ultimately results in anemia.

In their classic paper on the ecology and diet of Anasazi peoples, El-Najjar et al. (1976) expand the maize dependency hypothesis. They establish a ecological dichotomy which is applied to Anasazi subsistence. The two ecological zones are defined as "canyon bottom" habitats and "sage plain" habitats. The canyon bottom ecological zone typifies Canyon de Chelly in which Antelope House is located, Navajo National Monument in which Inscription House is located, and Chaco Canyon. The sage plain encompasses the areas of Navajo Reservoir, New Mexico and Gran Quivira.

The ecology of the two areas is thought to have profound effects on diet. The lower plant and animal diversity in canyon bottoms would result in increased dietary emphasis on maize agriculture and decreased meat consumption. Conversely, in sage plain habitats, more of the diet would be derived from wild plant foods with relative decrease in maize consumption and increased meat consumption.

Beyond the ecological aspects of the hypothesis, there are cultural implications. Specifically, the diet of early Anasazi peoples of the Basketmaker Period would be less maize reliant than the subsequent Pueblo Period. Higher meat consumption and lower relative maize consumption among Basketmaker peoples resulted in reduced levels of anemia as represented in the archaeological record by porotic hyperostosis. The hypothesis with respect to maize is succinctly summarized by El-Najjar's (1976:329) statement that "Heavy dependence on a single food item, such as maize, may have been responsible for the high incidence of porotic hyperostosis in the New World. . . . The nutritional properties of maize together with maize processing techniques are the two main factors responsible for porotic hyperostosis in groups whose diets consisted primarily of maize".

The work of El-Najjar and his colleagues provided testable expectations relevant to prehistoric anemia. It was also the first attempt to bring aspects of culture and ecology into focus as etiological factors in disease. El-Najjar and Robertson (1976) call for continued interdisciplinary research into the problem.

Unfortunately, the need for continued research was rapidly replaced by acceptance of the maize dependency hypothesis as factual, not theoretical. El-Najjar et al. (1982) cite previous work in the Southwest (El-Najjar et al. 1976) and state that the Anasazi analyses "show definite correlation between maize (Indian maize) as a major dietary component and porotic hyperostosis." In actuality, the correlation between maize consumption and porotic hyperostosis was never tested.

Coprolite data are now available from all three canyon bottom areas (Antelope House, Inscription House and Chaco Canyon). These data allow for the evaluation of the maize dependency hypothesis. Maize is readily identifiable in coprolites. Animal residue (bone, scale and chitin) provides indirect evidence of meat consumption. It is important to remember, however, that coprolite animal residue represents consumption of small animals. This leads potentially to an inaccurate picture of animal protein consumption. Meat from large animals is not usually identifiable on the basis of coprolite analysis.

Dietary remains have been quantified in different ways in different studies. For the purposes of this paper, quantification is presented in terms of the percentage frequency of coprolites that contain specified dietary components (maize kernels, maize pollen, animal residue) as seen in Table 9.

Both macroscopic and palynological analyses of coprolites are used to reconstruct prehistoric diet. Maize is easily identifiable in both types of analysis. The seed coat of maize is remarkably durable so maize kernels are easily recognized macroscopically. Even when ground, the seed coat fragments can be recognized, providing the coprolite has not undergone extensive decomposition.

Maize pollen is rare in natural pollen rain even where maize is grown. The large, heavy maize pollen grains are not carried more than a few meters from their origin by air currents (Raynor et al. 1972). Consequently, it is assumed that maize pollen is of dietary origin when found in coprolites (Martin and Sharrock 1964). The pollen is consumed with maize kernels or with the tassels from maize plants. The pollen grain morphology of maize is distinctive. The grains exceed 90 micrometers in diameter, have annulated pores which exceed 12 micrometers in width, and the pollen grain wall has an arrangement of internal structures that give the grain a finely stippled appearance when examined under interference phase contrast at high power.

It is usually impossible to identify meat in coprolites. The consumption of animal protein is inferred by the presence of animal residue (bone, insect exoskeleton, fish and lizard scales). Bone is introduced into the coprolite by consumption of complete small animals (rabbits, rodents, lizards, fish). I do not include hair as evidence of meat consumption because of the possibility that hair could be accidentally ingested from non-dietary sources. Because larger animals were butchered and the bones were not usually consumed, it is impossible to detect meals which included large animals. Consequently, the frequencies of bone consumption should be regarded as minimal estimates of the actual numbers of meals which included meat. It may be possible to use zooarchaeological data derived from midden analysis to fill out the picture of animal consumption. However, such analyses are not available from all sites as mentioned earlier in the section entitled Study Sites. Thus, for the direct comparison of animal consumption presented here, only coprolite data are used.

Hypothesis Expectations

The maize dependency hypothesis provides several testable expectations. These expectations can be applied to the coprolite data base. They are as follows:

1) The "canyon bottom" sites (Antelope House, Inscription House, and Chaco Canyon) are similar in diet. Consequently, they will show no significant differences in maize consumption. This will be tested by comparison of coprolite pollen and macroscopic maize data from the three canyon bottom sites.

2) The canyon bottom sites are similar with respect to meat consumption. Consequently, coprolites from canyon bottoms will show no difference in animal residue content. This will be tested by comparison of animal residue (bone and scale) in coprolites from the canyon bottom sites.

3) Anasazi of the early Basketmaker Period consumed less maize than those of the later Pueblo Period. Therefore, Basketmaker coprolites contain less maize than Pueblo coprolites. This will be evaluated by testing the null hypothesis that there is no difference between the two groups.

4) For those sites for which both coprolite data and skeletal data are available (Salmon Ruin, Antelope House, Inscription House), the prevalence of porotic hyperostosis in the skeletal series will covary with the prevalence of maize in the coprolites. This will be evaluated by testing the null hypothesis that no significant covariance will be present. Maize pollen frequency data will be used in the analysis.

5) For those sites for which both coprolite data and skeletal data are available (Salmon Ruin, Antelope House, Inscription House), the prevalence of porotic hyperostosis in the skeletal series will covary with the prevalence of animal residue in the coprolites. This will be evaluated by testing the null hypothesis that no significant covariance will be present.

Test Results

The first and second test expectations relating to maize and meat consumption are essential in evaluating the dietary validity of grouping Canyon de Chelly, Inscription House, and Chaco Canyon together for statistical analysis as was done by EL-Najjar et al. (1976). If statistical differences in maize consumption and meat consumption are evident, then the grouping of these sites as similar with respect to diet and ecology is incorrect.

With respect to maize consumption, analysis of the pollen and macroscopic data show significant differences. Reliable macroscopic data are available from Antelope House and Inscription House. From Antelope House, 82 of 90 coprolites (91%) contain macroscopic remains of maize. From Inscription House, 10 of 16 coprolites (63%) contain maize. Chi square evaluation results in a value of 7.36 which is significant beyond the 95% confidence interval ($X^2_{0.01,1}$=6.635). Palynological data are available from Antelope House coprolites and Chaco Canyon Coprolites. From Antelope House, maize pollen was present in 70 of 92 coprolites (76%) and from Chaco Canyon, 28 of 28 coprolites (100%) contained maize pollen. The chi square value for these data is 6.68 which is significant beyond the 95% confidence interval ($X^2_{0.01,1}$=6.635).

Analysis of animal residue in the coprolites documents some significant differences. Four of 16 Inscription House coprolites (25%) contain animal residue, 35 of 55 Antelope House coprolites (64%) contain animal residue, and 25 of 35 Chaco Canyon coprolites (71%) contain animal residue. The chi square value for the Inscription House-Antelope House data is 0.609 is insignificant ($X^2_{0.5,1}=3.841$). However the value for Inscription House-Chaco Canyon comparison is 7.850 which is highly significant ($X^2_{0.01,1}=6.635$) as is the 9.426 value for the Antelope House-Chaco Canyon comparison ($X^2_{0.005,1}=7.879$).

The coprolite evidence indicates that the grouping of the canyon bottom sites has little dietary validity. This is true especially with respect to maize and animal consumption. With respect to Antelope House and Inscription House for which there are reliable macrofloral data, we find differences beyond maize consumption. The diversity indices (Tables 22-23) for the sites show pronounced plant food specialization at Antelope House in comparison to a more diversified diet at Inscription House. The extremes in range for Anasazi diversity indices are represented by Antelope House (0.6983) and Inscription House (0.8995). This indicates that far from being similar in diet, these two sites are more dissimilar than any other combination of Anasazi sites.

The dissimilarity in diet between Antelope House and Inscription House is also emphasized by the utilization of plant foods at one site that are absent or nearly absent at the other. One could argue that the presence of certain plant foods at Antelope House that are absent at Inscription House could be due to the larger sample of coprolites analyzed from Antelope House. However, there are several plant foods that are prominent in the Inscription House diet that are absent or near absent in the Antelope House diet. These include Phaseolus, Sporobolus, Celtis, Oryzopsis, and Lepidium. This documents a difference in foraging specialization between the sites as well as a difference in cultivar emphasis.

The third test expectation states that maize dependency increases in the Pueblo Period over the preceding Basketmaker Period. From Pueblo occupations, 209 coprolites have been examined from five sites of which 181 (88%) contain maize. From Basketmaker occupations, 72 coprolites have been examined from 2 sites of which 63 (88%) contain maize. An insignificant chi square value of 0.000 was obtained ($X^2_{0.5,1}$=3.841). The coprolite data do not reflect any difference in maize consumption between Basketmaker and Pueblo times but rather demonstrate that maize agriculture was well established by Basketmaker times.

The fourth test expectation is that the maize consumption data and skeletal data will co-vary. The percentage of coprolites containing maize pollen and the percentage of skeletons exhibiting porotic hyperostosis from Salmon Ruin, Antelope House and Chaco Canyon were used in the calculation of the correlation coefficient. The calculated r value of 0.6363 and r^2 value are insignificant ($r_{0.05(2),1}$=0.997: t=1.0692, $t_{0.05(2),1}$=12.706) and suggests that maize consumption varies independently of porotic hyperostosis frequency.

The fifth test expectation is that meat consumption data will co-vary with the skeletal data. The percentage of coprolites containing animal residue and the percentage of skeletons exhibiting porotic hyperostosis from Salmon Ruin, Antelope House, Inscription House and Chaco Canyon are used in the calculations. When all data for all sites are used in the calculations, the r value is 0.7114 and the r^2 vale is 0.5062. This value is insignificant at the 95% confidence interval ($t=2.8825$, $t_{0.05(2),2}=4.303$). When the data are run from only the canyon bottom sites using the percentage of subadults exhibiting porotic hyperostosis the r value is 0.5738 and the r^2 value is .3292. This is also insignificant ($t=0.8554$, $t_{0.05(2),1}=12.706$). Therefore, it appears that meat consumption varies independently of porotic hyperostosis frequency.

With regard to the first two test expectation, it appears that the diets of the three canyon bottom sites as defined by El-Najjar et al. (1976) are very different. The differences extend beyond maize and meat consumption to differences in the amount of dietary specialization and ultimately to the wild plant taxa consumed at the sites. Antelope House exhibits a maize based diet in contrast to Inscription House in which undomesticated plant taxa and domestic beans play a larger role relative to maize.

The other test expectations are not met by the analysis. Maize agriculture was common in Basketmaker times and an decreased emphasis on maize by Basketmaker peoples is not supported by the data analysis. There is no significant covariance of dietary data, either maize or animal residue, with skeletal evidence of anemia.

Since these test expectations derived from the maize dependency hypothesis are not supported by the data, I suggest that there is little direct impact of diet on prehistoric anemia.

Anasazi Parasitism

As discussed earlier in this chapter, parasitism among southwestern agriculturalists increased in comparison to that of previous hunter-gatherers. This increase especially effected the prevalence of <u>Enterobius vermicularis</u>. This parasite species is transferred in conditions of poor hygiene and crowding. The effects of hygiene on parasite incidence have been alluded to.

At most Anasazi sites, pinworm is the only helminth parasite that has been found. Occasionally, other helminth infections have been found, but their numbers are small relative to <u>E</u>. <u>vermicularis</u>. One concludes from the data that conditions of poor sanitation and crowding were common at Anasazi sites.

An important question is whether parasitism had an impact on prehistoric anemia. This question can be addressed statistically by comparison of sites for which parasite data from coprolites and porotic hyperostosis data from skeletal series are available. These sites include Chaco Canyon, Antelope House, Inscription House, and Salmon Ruin.

Correlation coefficients (r) and correlation indices (r^2) were calculated on the basis of the percentage prevalence of coprolites positive for parasites and the percentage incidence of porotic hyperostosis in skeletons of subadults. The r^2 values indicate how much of the variability in one data set can be accounted for by correlation with the second data set. The calculations are run in four ways. The first pair of calculations include all helminth data for Salmon Ruin, Chaco Canyon, Antelope House and Inscription House and correlate with the over-all incidence of porotic hyperostosis. The r value obtained was 0.7963 and r^2 was 0.6340. These are significant at the 95% confidence limit ($t=4.3519$, $t_{0.05(2),2}=4.303$). The second pair of calculations included pinworm prevalence from all four sites and resulted in a r value of 0.8795 and a r^2 of 0.7735. The r value is significant beyond the 95% confidence interval ($t=7.766$, $t_{0.02(2),2}=31.599$). The third pair was based only on pinworm data from the canyon bottom sites of Antelope House, Inscription House and Chaco Canyon. In the case of these data, $r=0.9707$ and $r^2=0.9423$. These values are significant at the 95% confident limit ($t=16.8232$, $t_{0.05(2),2}=12.706$). The last calculation included all helminth data from the canyon bottom sites. For this data set, $r=0.5563$ and $r^2=0.3094$. These values are insignificant ($t=0.8055$, $t_{0.05(2),2}=12.706$).

The correlation indices are strikingly high. Based on the data at hand, 77% of the variability in porotic hyperostosis for all four sites is accounted for by pinworm prevalence in coprolites. In the same way, 63% of the variability of porotic hyperostosis for all four sites is accounted for by helminth prevalence in coprolites. When only canyon bottom sites are examined, 94% of the porotic hyperostosis is accounted for by pinworm prevalence. No significant correlation of general helminth prevalence in the canyon bottom sites and porotic hyperostosis is evident.

These data do not necessarily reflect a causal relationship between helminth parasitism and anemia. Indeed, since pinworm is largely apathogenic and is not implicated in modern studies as a cause of anemia, there is no reason to believe that helminth parasitism caused anemia in the Anasazi sites discussed here. However, the strong correlations suggest that the factors that affect pinworm parasitism and anemia are linked.

Undoubtedly, high pinworm prevalence is due to poor sanitation. In such conditions, enteric bacterial and protozoal disease organisms are transmitted. Contamination of foodstuffs probably occurred in the fouled environment of prehistoric habitations. Fly pupae cases and puparia have been noted in coprolites which indicates the presence of flies in feces. It is possible that water borne disease organisms were also prevalent.

The correlation of pinworm prevalence in coprolites and porotic hyperostosis prevalence in skeletal series can be explained as a relationship with microparasitism. With respect to porotic hyperostosis, microparasitism had a causal effect. With respect to pinworm prevalence, the conditions conducive to microparasitism were also conducive to higher pinworm transmission.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The major points of this analysis can be summarized as such:

1) Prehistoric hunter-gatherers suffered less parasitism than subsequent agricultural peoples.

2) The nature of hunter-gatherer parasitism was largely zoonotic. Parasite infection occurred as a result of insect consumption in the case of Moniliformis clarki and possible poorly cooked meat in the case of taeniid tapeworms.

3) Hunter-gatherer parasitism was highest at the Great Basin desert sites of Hogup and Danger Caves. One would expect higher parasitism among the larger populations in the lower Pecos of Texas or in populations residing on the Nevada lake shore caves such as Lovelock Cave. The increased parasitism among dilute desert hunter-gatherer bands indicates that factors other than population density and local ecology molded hunter-gatherer parasitism. One of these factors is the consumption of insects and uncooked meat noted above.

4) Agricultural peoples suffered parasitism with a greater diversity of parasites including human specific species. Storage of grain resulted in hymenolepidid tapeworm parasitism. Poor hygiene resulted in parasitism with Ascaris lumbricoides and

Trichuris trichiura. Association with mesic environments resulted in parasitism with Strongyloides and a strongylate worm.

5) The greatest increase in prevalence of any species among agricultural peoples is seen in the rise of pinworm (Enterobius vermicularis). This reflects population increase, sedentism and poor personal hygiene.

6) Comparison of the parasite ecology of two Anasazi villages documents the mitigating influence of behavior on prehistoric parasitism. Inhabitants of Antelope House in Canyon de Chelly, Arizona forage extensively in riverine habitats and consequently were infected with mesic adapted parasites. Random excreta disposal kept the inhabitants of the village in constant contact with infective parasites. In contrast, the foraging habits of the inhabitants of Salmon Ruin, New Mexico were aimed at desert areas where parasite infection could not take place. Furthermore, there was a more organized plan for excreta disposal at Salmon Ruin which isolated the villagers from their feces.

7) The impact of parasites on prehistoric anemia was assessed. It is unlikely that helminthiasis had a pronounced impact on prehistoric health directly. Variations in behavior and ecology in the region probably mitigated parasitism among villages.

8) A strong correlation is demonstrated between parasite prevalence and porotic hyperostosis. This suggests a link, although not causal, between prehistoric anemia and parasitism.

9) The maize dependency hypothesis as a cause for prehistoric anemia was evaluated on the basis of coprolite dietary data. A trend in specialization through Archaic hunter-gatherer populations is documented which gives rise to specialization on cultivated foods at some agricultural sites. This supports the basic premise of the maize dependency hypothesis. However, direct correlation of corn or meat consumption with anemia prevalence could not be demonstrated.

10) With respect to prehistoric anemia, maize dependency may have been an underlying cause, but the positive correlation of anemia prevalence and parasite prevalence indicates that infectious disease was also a cause of anemia.

It has been a central goal in bioarchaeology to estimate biological stress with which prehistoric peoples coped. As pointed out in the Introduction, evaluation of stress is typically documented by the presence of osseous and dental disorders. The results of this study indicate that parasitological data derived from coprolites are another means of documenting biological stress.

The study demonstrates the utility of archaeoparasitological data in assessing prehistoric stress of hunter-gatherers versus agricultural peoples. The data indicate that parasitism did indeed increase during agricultural times, but that stress was mitigated by aspects of behavior and ecology. As a contributing factor to pathology, the data do not strongly demonstrate that helminthiasis had a pronounced effect on health of agricultural peoples. However, the helminthological data show a strong positive covariance with osteological evidence of anemia and indicate that the helminth remains are a general indicator of infectious disease that probably contributed to anemia.

One important aspect of this research has been the demonstration of a correlation of archaeoparasitological prevalence and skeletal pathology. This indicates that parasitological analyses complement data derived from skeletal analysis. Thus, it appears that parasitological data can be considered a useful bioarchaeological approach in conjunction with skeletal analysis.

Coprolite analysis supports the axiom that hunter-gatherers faced less exposure to infectious disease than agricultural populations. The data also serve to elaborate on the kinds of infectious disease that occurred among agricultural peoples. Most obvious is the increase exposure to human-specific anal-oral parasites that are transmitted by hand contact such as Enterobius vermicularis. Other types of parasites not present in hunter-gatherer populations appear among agriculturalists. Human specific anal-oral parasites associated with fecal contamination such as Trichuris trichiura and Ascaris lumbricoides appear in agricultural populations. Importantly, mesic adapted parasites such as Strongyloides infect agricultural peoples. Thus it seems that those parasites associated with poor hygiene and crowding as well as mesic-adapted parasites show the greatest increase with the advent of agriculture.

Beyond the specific goals of the study, further insight into Archaic and Anasazi diet has been gained. It has been demonstrated that a tendency to specialize on a relatively narrow range of plant foods in

Archaic hunter-gatherer populations gave way to an agricultural diet with concentration on maize. However, even among Southwestern Anasazi populations, foraging supplanted an agricultural subsistence. This may have blunted the negative nutritional impact of maize dependency.

The new knowledge obtained in the study relating to both diet and parasitism should add impetus to the growing interest in coprolite studies in general, and archaeoparasitology in specific. Future research should focus on integrating skeletal pathology data and parasitological data. Continued effort should be made in refining the accuracy of archaeoparasitological taxonomic identification. As such research continues, a more coherent use of dietary, parasitological, and osteological data in the framework of bioarchaeology will emerge.

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APPENDIX

Provenience Data for Coprolites Under Study

Site	Lab #	Provenience Data
Hinds Cave	1	B-1 Fill above L-3, copr.(4)/1
Hinds Cave	2	B-1 F-2
Hinds Cave	3	B-1 B6-XI(K) copr.(5)/9
Hinds Cave	4	B-1 B6-XI(K)
Hinds Cave	5	B-1 B6-XI(K) copr.(5)/19
Hinds Cave	6	Lens 7 Cop. H
Hinds Cave	7	Lens 7 Cop. A
Hinds Cave	8	Lens 7 Cop. C
Hinds Cave	9	Lens 7 Cop. G
Hinds Cave	10	Lens 5 Cop. H copr.(3)/1
Hinds Cave	11	Lens 5 Cop. G
Hinds Cave	12	Lens 5 B6-XI(K) copr.(2)/13
Hinds Cave	13	Lens 5 B6-XI(K) copr.(5)/22
Hinds Cave	14	Lens 5 B6-XI(K) copr.(5)/5
Hinds Cave	15	Lens 5 B6-XI(K) copr.(5)/5
Hinds Cave	16	Lens 5 B6-XI(K) copr.(5)/3
Hinds Cave	17	Lens 5 B6-XI(K) copr.(5)/3
Hinds Cave	18	Lens 5 B6-XI(K) copr.(5)/10
Hinds Cave	19	Lens 5 BI-V A-H copr.(5)/2
Hinds Cave	20	Lens 5 B6-XI copr.(10)/2
Hinds Cave	21	Lens 5 B6-XI copr.(5)/7
Hinds Cave	22	Lens 5 B6-XI copr.(6)/12
Hinds Cave	23	Lens 5 B6-XI copr.(5)/4
Hinds Cave	24	Lens 5 B6-XI copr.(5)/6
Hinds Cave	25	Lens 5 B6-XI copr.(5)/21
Turkey Pen	1	FS 236 Strat B, S. prof., pit 49
Turkey Pen	2	FS 236 Strat B, S. prof., pit 49
Turkey Pen	3	FS 244 Strat B, S. prof., pit 50
Turkey Pen	4	FS 244 Strat B, S. prof., pit 50
Turkey Pen	5	FS 238 Strat D, S. prof., pit 49
Turkey Pen	6	FS 263 Strat E, S. prof., pit 54
Turkey Pen	7	FS 263 Strat G, S. prof., pit 50
Turkey Pen	8	FS 166 Strat E, W. prof., pit 59
Turkey Pen	9	FS 166 Strat E, W. prof., pit 59
Turkey Pen	10	FS 164 Strat D, W. prof., pit 50
Turkey Pen	11	FS 264 Strat F, W. prof., pit 54
Turkey Pen	12	FS 264 Strat F, W. prof., pit 54
Turkey Pen	13	FS 264 Strat F, W. prof., pit 54
Turkey Pen	14	FS 264 Strat F, W. prof., pit 54
Turkey Pen	15	FS 264 Strat F, W. prof., pit 54
Turkey Pen	16	FS 242 Strat B, W. prof., pit 49
Turkey Pen	17	FS 242 Strat B, W. prof., pit 49
Turkey Pen	18	FS 172 Strat F, S. prof., pit 54

APPENDIX
continued

Site	Lab #	Provenience Data
Turkey Pen	19	FS 172 Strat F, S. prof., pit 54
Turkey Pen	20	FS 240 Strat E, S. prof., pit 59
Bighorn	1	Stratum II
Bighorn	2	S1 E7
Bighorn	3	S1 E7
Bighorn	4	S1 E7
Bighorn	5	S1 E7
Bighorn	6	S1 E7
Bighorn	7	S1 E7
Bighorn	8	S2 E8, Stratum III
Bighorn	9	S1 E6
Bighorn	10	N4 W4
Bighorn	11	N4 W4
Bighorn	12	N4 W4
Bighorn	13	N4 W4
Bighorn	14	N2 W4, Stratum III
Bighorn	15	S1 E6, Stratum III
Bighorn	16	S1 E6, Stratum III
Bighorn	17	S2 E6
Bighorn	18	S2 E6
Bighorn	19	Stratum 2
Bighorn	20	Stratum 2

VITA

Karl J. Reinhard was born in Hamilton, Montana and was raised in Alaska, Maryland, and Arizona. He entered the University of Arizona in 1972 and completed a Bachelor of Arts degree in 1977, majoring in Anthropology and minoring in Biology and Chemistry. During undergraduate training, he spent four field seasons excavating at Anasazi and Hohokam sites in the Southwest. He specialized in ceramic analysis and osteology. While completing his undergraduate degree, he worked with Southwestern, Mayan, and Near Eastern ceramics and also initiated cremation analysis of sites in Nogales, Arizona.

From 1977 to 1979 he participated as assistant director in excavations of a Hohokam site in the Tucson Basin and Patayan caves in northern Arizona. Additional fieldwork was carried out in the Petrified Forest, Arizona and at various Hohokam sites.

In 1980 he initiated study at Northern Arizona University and completed his Master of Science Degree in Biology in 1984. At that time he initiated doctoral studies at Texas A&M University. Graduate studies emphasized palynology, ethnobotany, parasitology, and paleopathology. During these years he completed three field seasons of archaeological work in the Arctic.

Reinhard's major publications deal with Pueblo trade, Hohokam archaeology, Anasazi diet and parasitism, Archaic diet and parasitism, and cremation analysis. He has articles published in *American Antiquity*, *American Journal of Physical Anthropology*, *Homo*, and the *Journal of Parasitology*, and he co-authored a short treatment of Hohokam archaeology published by the University of Arizona Press. Currently he resides at 4911 Hidden Valley Road, Tucson, Arizona 85715.