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Coprolite Analysis:

The analysis of ancient human feces for dietary data

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Although archaeological fieldwork is hot and dirty, the most "earthy" side of the discipline is the laboratory analysis of coprolites. Each coprolite contains the remains of one to several actual meals eaten in prehistory, and analysis of many coprolites provides a picture of ancient diet that is unique in accuracy.

What Is a Coprolite?

The term *coprolite* originally referred to fossilized feces in paleontological context. In archaeology, the term broadened to refer to any formed fecal mass, including mineralized, desiccated, or frozen feces and even the intestinal contents of mummies. Coprolites contain the remains of animals (parasites) that lived in the humans, the foods that humans ate, and the remains of animals that lived in the feces after defecation. The majority of recognizable remains consist of undigested or partly digested food residue. With the naked eye, one can identify plant cuticle, bark, seeds, fruit coats, fibers, animal bone, feathers, lizard and fish scales, mollusc shell, crustacean fragments, fish otoliths, insects, and other food items. Microscopic remains include parasites, pollen grains, phytoliths, other small plant structures, animal hair, fungal spores, diatoms, mites, and starch granules. In short, anything indigestible that people swallowed can be found. Beyond visual identification, chemical components of coprolites include proteins, lipids, steroids, carbon and nitrogen isotopes, and many major and trace elements.

Coprolites are most common in arid areas in the Americas. In North America, coprolites are most commonly found in the Mojave Desert, the Colorado Plateau, the Great Basin, and the Chihuahuan Desert of the western and southern portion of the continent. Central Mexican sites also contain coprolites. These have been studied from the Rio Zape Valley in Durango, Mexico, and from the Tehuacan Valley of Mexico. In South America, coprolites are most commonly found in the Atacama Desert of Chile and Peru, but finds have been made in Brazil. Coprolites have also been found at York, England, and Israel. Thus, coprolites are preserved in arid areas and, on occasion, in moist regions.

How Are Coprolites Studied?

Vaughn M. Bryant, Jr., Kristin Sobolik, and Karl Reinhard are the only full-time coprolite analysts at this time. They have built their work on that of the late Eric Callen, who was the first coprolite analyst and whose contributions are summarized by Bryant. It is these four individuals who have developed the techniques of analysis. Coprolites are first photographed, described, and then rehydrated. To answer a question that most people ask, coprolites do not usually smell. After rehydration, the coprolites are disaggregated and rinsed through a fine mesh to separate macroscopic from microscopic residues. The macroscopic remains are dried and separated into component parts visually or with a dissecting microscope. Different types of microscopic remains are separated by heavy-density flotation. Light materials, such as pollen and parasite eggs, float, and heavier components, such as phytoliths and larger plant fragments, sink. After examination for parasite eggs and other items of interest, the pollen is isolated from the light remains through chemical digestion in acetolysis solution. The heavier remains are collected and examined. Phytoliths are isolated through chemical digestion in hydrogen peroxide and potassium dichromate. The end results from processing any given coprolite are many vials containing different types of remains.

Informational Potential of Constituents

Macroscopic remains tell much about the species of plants eaten. Plant cuticle is essentially the epidermal layer of plant leaves and stems (Figure 1). The cell patterns of cuticles are sometimes distinctive to specific plants. It is possible to identify the major succulent plants in the Southwestern United States based on the cuticle. In other cases, plant cuticle is less informative and can be used to identify only plant families.

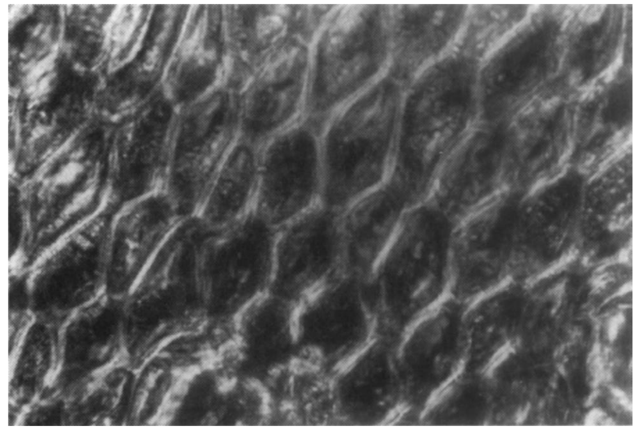

Figure 1. Plant cuticle from Agave showing distinctive cell outlines. Photograph by Karl Reinhard.

Bark is outer plant tissue from woody species. It is especially difficult to identify because so few traits of bark are distinctive.

Seed coats pass through the digestive tract and are recognizable (Figure 2). The seeds are identifiable because the outer layer, called the *testa,* is very resilient, and almost every coprolite analysis reveals the consumption of seeds. Seeds, then, become an important source of comparative data. Seeds reveal different patterns of diet. In some cases, the seeds signal the consumption of fruits. For example, when whole prickly-pear seeds are found, it is usually from eating prickly-pear fruit. In other cases, the seeds represent selective harvesting of cultivated or wild species when the seeds are collected, winnowed, and make up the major portion of a meal. Seeds are often cooked, ground, or otherwise modified before consumption. Careful study of the seeds by Kate A. Rylander using scanning electron microscopy revealed the kinds of tools used to grind the seeds. Chemical analysis of the seeds also reveals how the seeds were boiled, parched, or cooked in some other way. Sometimes, the seeds are derived from fruits that are collected, dried, and mashed into a pulp (Figure 2). Again, scanning electron microscopy discloses these aspects of preparation. Seeds were such an important prehistoric food source that some cultures carried out "second harvests." This refers to the practice of sifting seeds out of old feces for consumption in times of famine. Fleshy fruits are also evident by the fruit coat called *pericarp,* or outer layer. Sometimes, the pericarp is distinctive enough for identification. Chili pericarp, for example, is identifiable in coprolites.

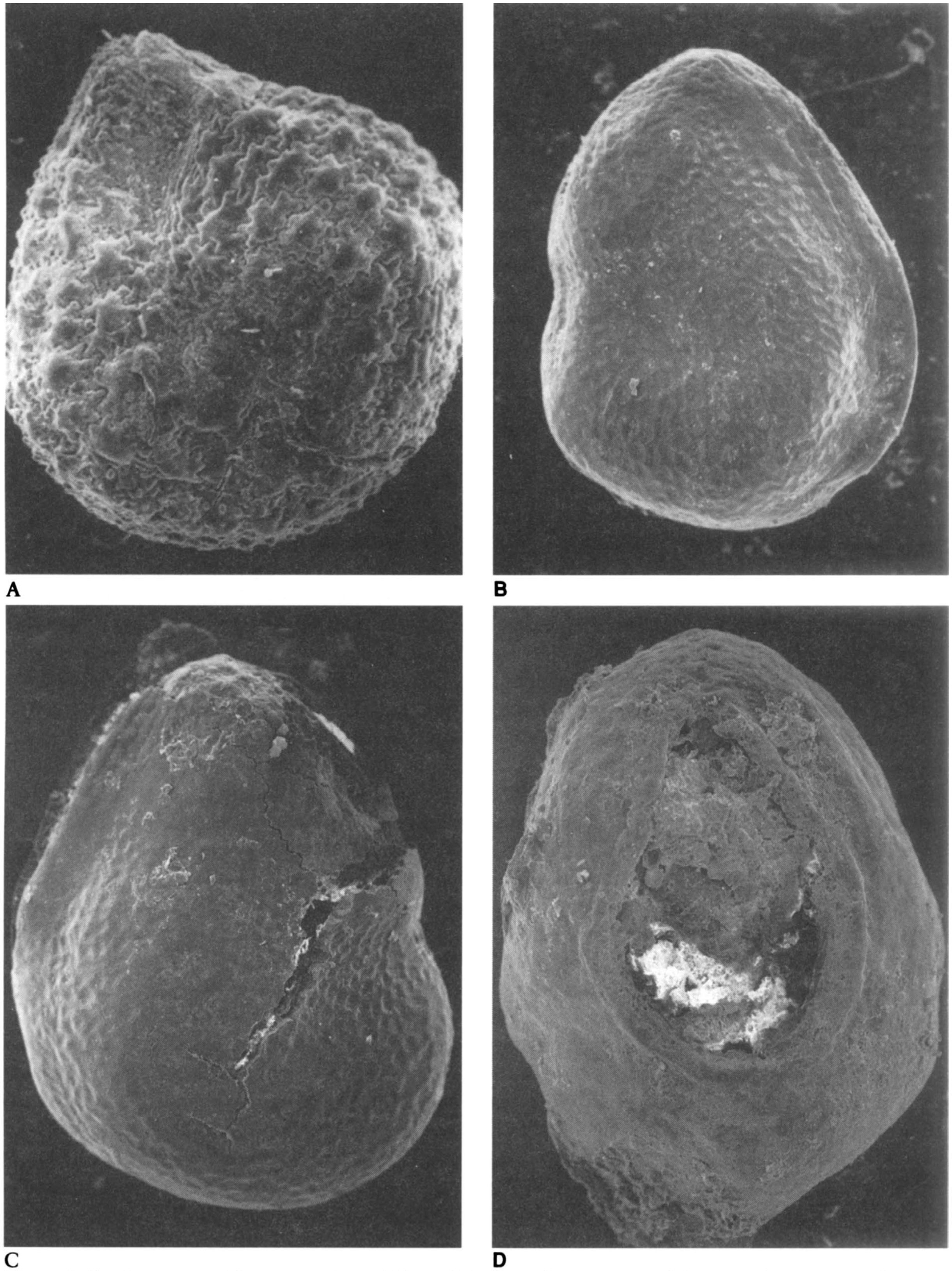

Figure 2. Seeds recovered from coprolites. (*A*) *purslain* (portulaca *spp.*) *seed from an Anasazi coprolite showing excellent preservation potential of unmodified seeds;* (*B*) *well-preserved saguaro cactus* (Carnegia gigantea) *seed from a Hohokam coprolite;* (*C*) *partly fragmented saguaro seed damaged by crushing;* (*D*) *hilum of saguaro seed damaged by crushing. Such severe damage to seeds was done by processing seeds separated from the fruit into a saguaro flour or by mashing preserved fruits into a prehistoric fruit peel. Photograph by Karl Reinhard.*

However, the pericarp of other fruits is not distinctive. In these cases, examination of seeds in the same coprolite that contains pericarp may provide significant clues to the source of the fruit.

Fibers are difficult to identify, yet are common in coprolites. Fiber refers specifically to the stringlike strands of plant vascular tissue (Figure 3). Some fibers are distinctive—the fibers of mesquite (*Prospis glandulosa* and *P. pubescens*) are easily identifiable—but most are not. There are clues to the source of fiber from other plant components. Often, the plant cuticle or phytoliths found in a coprolite can be used to infer the origin of the fiber.

It is of interest that small fragments of charcoal can be found in coprolites. Even if the fragments are too tiny to allow identification of the source species, charcoal provides evidence of cooking practices. In Archaic times, for example, food was often cooked on parching trays in which food was swirled around with burning coals. This action results in the consumption of charcoal particles.

Small animals were commonly eaten by prehistoric peoples. Consequently, every coprolite study reveals animal remains such as bone, feather, shell, and exoskeleton. Bone has received the most attention, as summarized by Reinhard in 1992. The analysis of bone provides significant cultural information. In general, hunter-gatherers ate small animals more frequently than did horticulturalists. Different hunting strategies can also be analyzed by examining bone from coprolites. The diversity of animal remains, indicates the degree of specialization in hunting practices (Figure 4). The bone can also show which parts of the animals were most commonly eaten (Figure 5). Bone sometimes reflects processing of small animals; for example, fish bone in coprolites from southern Peru is typically ground but not burned. This indicates that ancient Peruvians ate fish paste that was made of raw fish, perhaps spiced or augmented with plant foods. These sorts of observations provide information on prehistoric food preferences and cuisine. Some bone is digested and absorbed and, therefore, may have been an important source of calcium for prehistoric peoples. Beyond bone, animal dermal derivatives (feathers and scales) are found in coprolites. The quills of feathers are obvious in macroscopic analysis. Microscopically, the fine details of feather fragments can be analyzed to determine the taxon of bird eaten. Scales from fish or reptiles can sometimes be identified to genus or species (Figure 6).

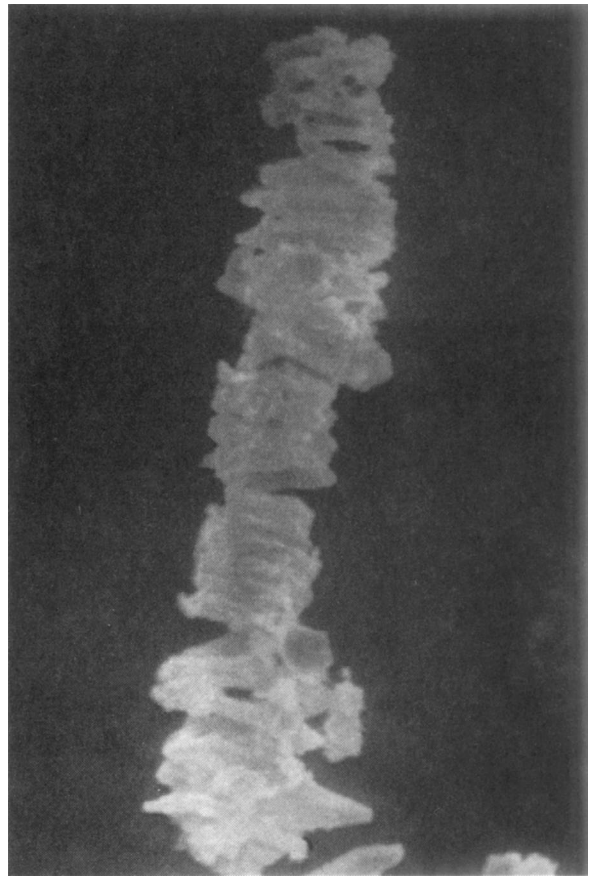

Figure 3. Helical fiber from plant vascular tissue recovered from a Hohokam coprolite. Photograph by Karl Reinhard.

Coprolites also contain invertebrate remains, the most common of which are insects. Insects from coprolites fall into two categories: insects that were eaten as food and insects that were eating the feces. Grasshoppers were the most common prehistoric dietary insect. Spider beetles and flies commonly infested feces and are evident in analysis. Other arthropods that occur less frequently are freshwater and saltwater crustacea such as crayfish and shrimp. Millipede remains have been found in coprolites from the lower Pecos area of Texas. Ethnocentrically, this is an unappealing food item, but millipedes may have looked good to ancient hunter-gatherers. Along coastal environments, mollusc-shell fragments are found in coprolites. Both snails and clam fragments were ingested. In the ancient Chilean Chinchorro culture, the consumption of small snails is evident in a substantial portion of coprolites from mummies (4000 B.C.). These fragments were probably accidentally ingested as the

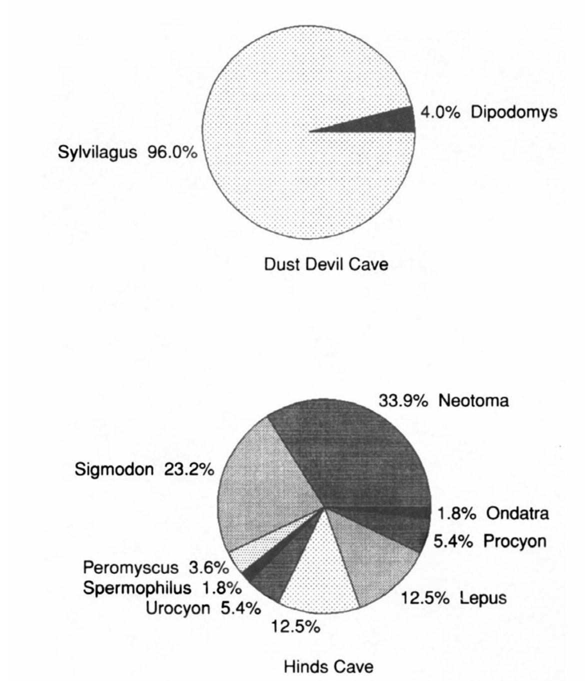

Figure 4. Comparison of animal-bone diversity from Archaic coprolites excavated from Dust Devil Cave, Utah, and Hinds Cave, Texas. The bones show that the Dust Devil Cave inhabitants specialized in rabbit hunting. In contrast, the Hinds Cave inhabitants had a broad-spectrum hunting strategy. By Karl Reinhard.

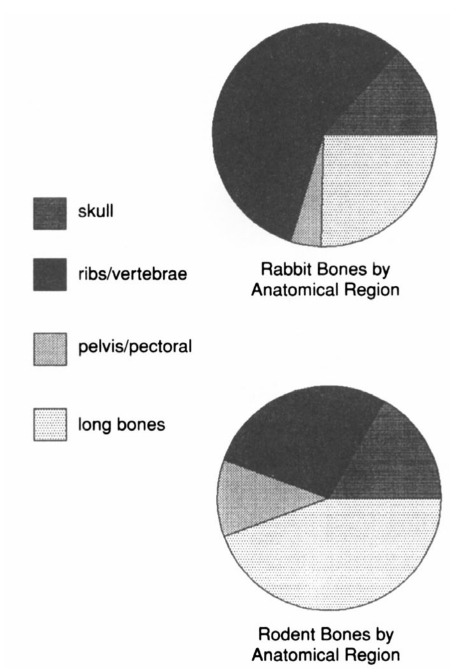

Figure 5. Comparison of rabbit and rodent bone from Dust Devil Cave coprolites by skeletal element. The inhabitants of Dust Devil Cave sectioned and ate entire rabbits but preferred to eat primarily the legs of rodents. By Karl Reinhard.

Figure 6. A scale from the giant fence lizard from an Anasazi coprolite. These are commonly recovered from human coprolites. Photograph by Karl Reinhard.

snail was sucked or pried from its shell. Later mummies from Peru (A.D. 1000) contain finely ground shell that was intentionally consumed.

A wide variety of microscopic remains can be found in coprolites. Parasite remains are some of the most significant microscopic components. Other animal remains that are visible microscopically are mites that infested the feces after deposition.

Pollen grains can be extremely abundant in coprolites. Pollen is introduced into the intestinal tract through drinking, mucosal contamination through inhalation, and eating materials that are contaminated with airborne pollen. When the ambient airborne pollen is consumed accidentally in these ways, the amount of pollen in the digestive system is small. People intentionally ate a wide variety of foods that contained pollen. In some cases, pollen from certain plants, such as cattail and horsetail, was collected and eaten as complete meals (Figure 7). In North America, flowers of certain plants, such as squash, were eaten, and flowering parts of plants were apparently made into teas. For some fruits, such as that of the saguaro, the residual flower is attached to the fruits, and eating the fruits introduced pollen into the digestive tract. In contrast, the floral elements fall off of prickly-pear fruit. Therefore, eating saguaro fruit introduces pollen into the digestive tract but eating prickly-pear fruit does not. The seeds of certain species have pollen adhering to their surfaces. For example, eating the seeds of amaranth (*Amaranthus* spp.) also results in the consumption of pollen. By understanding which seeds or fruits carry pollen and which do not, the coprolite analyst can determine what plant foods were originally eaten.

Phytoliths are tiny crystals of calcium or silica compounds that form in plant cells (Figure 8). These are most common in the vegetative portions of plants (leaves and stems). Since humans consumed large quantities of vegetative tissue rich in phytoliths, the phytolith content of coprolites can be remarkably high. Although these microscopic remains had been identified in coprolites in the 1970s (see review by Reinhard and Bryant 1992), it was not until 1990–1993 that the full information potential of phytoliths in coprolites was explored by Dennis Danielson and Timothy Meade. This evaluation produced several important discoveries. Phytoliths can make up to 10 percent of the volume of Archaic coprolites. Because phytoliths are harder than tooth enamel, chewing them caused tooth wear and tooth loss. Phytoliths are most abundantly derived from the vegetative portions of plants and also legume pods. Therefore, phytoliths provide dietary information unavailable through other analyses. For example, beans are often completely digested except for their phytoliths. The major task ahead for phytolith analysis is the development of regional identification keys for phytoliths. Once this is accomplished, phytolith analysis will become a highly significant aspect of coprolite study.

Starch granules may prove to be important in future coprolite research. With many root crops, none of the techniques summarized above is useful in identifying the plant species that were consumed. This is a special problem in the South American Andean region, where root crops such as potatoes and manioc were commonly eaten. As of the late 1990s, researchers were exploring the potential of using starch crystals to identify plant species.

A variety of microscopic remains result from processing plants. Seed-coat fragments, for example, result from grinding seeds into flour. The microscopic fragments of ground seed testae add to food-preparation information. Other small plant fragments also occur in coprolites. These include fragments of vascular bundles, cuticle, and silicified structures. The information potential of these other remains has not been fully investigated.

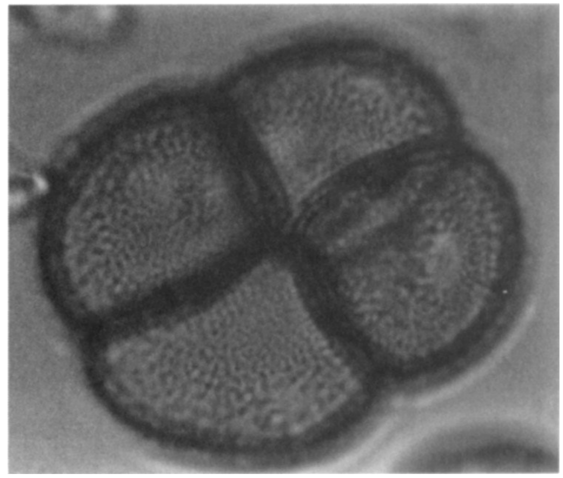

Figure 7. Pollen grain from cattail recovered from a coprolite. In this case, the coprolite was composed almost entirely of cattail pollen grains. Photograph by Karl Reinhard.

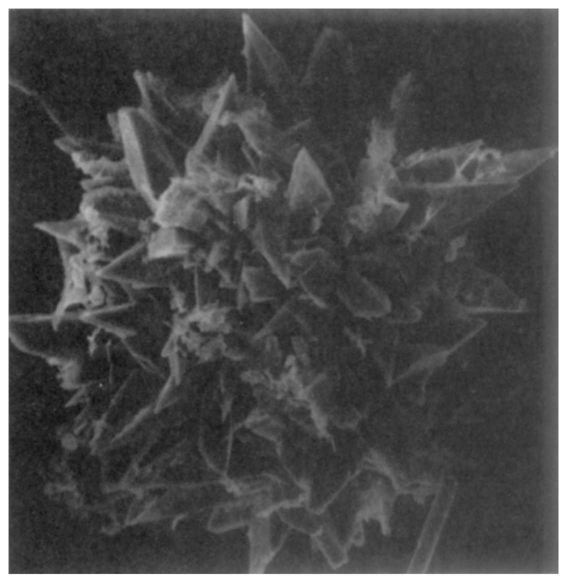

Figure 8. Calcium-oxalate phytolith from pricklypear epidermis extracted from an Archaic Utah coprolite from Dust Devil Cave. The consumption of prickly-pear pads introduced large numbers of these crystals into the coprolite. Photograph by Karl Reinhard.

Algal and fungal remains are sometimes present in coprolites. Fungal spores provide some dietary information. Corn smut (genus *Ustilago*) was used among

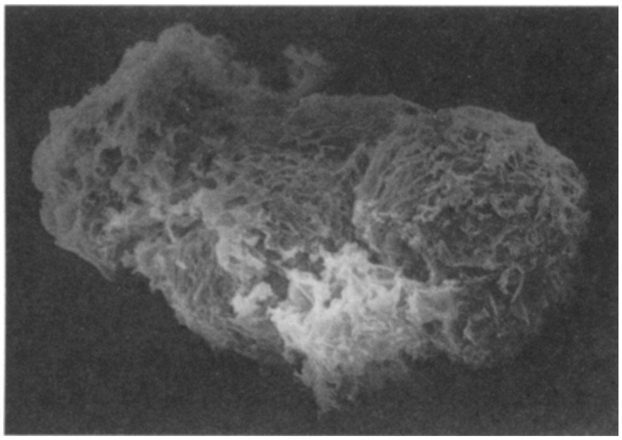

Figure 9. Spores of the fungus Endogane *ssp. from coprolites. Photograph by Karl Reinhard.*

historic Native American tribes as a spice. Among Anasazi coprolites, the spores of corn smut are especially common and indicate that it was used prehistorically. Species of another fungus genus, *Endogane,* have been found in Archaic coprolites from Dust Devil Cave (Figure 9). The fungus grows on the roots of grasses. To disseminate its spores, the fungus produces a button-size structure, called a *sporocarp,* which is eaten by rabbits. The spores are then liberated in the rabbits' feces. The fact that the spores were in human coprolites indicates that the viscera of rabbits were eaten. On rare occasion, silica diatoms (algae) are found in microscopic examination. The distinctive morphologies of diatom species makes them readily identifiable, and, because different diatoms are found in different habitats, the diatoms indicate with which ecological zones humans have had contact.

Chemical analyses can expand even further the information potential of coprolites. Visual analysis of coprolites can reveal much about the consumption of small animals by prehistoric peoples but little about the consumption of large animals. That is because large-animal bone was not often swallowed. The development of a technique for analyzing residual animal protein (Newman et al. 1993), since applied to coprolites by Mark Q. Sutton, has solved that problem: The technique identifies the protein residue of large and small animals. Therefore, one can now assess the relative consumption of all sizes of animals through coprolite study

Another question that is important in coprolite analysis is whether men and women are equally represented in coprolites. One might expect that coprolites were associated more with women than men, since women are more often present at a home base camp. Steroid analysis was successfully tried with nonhuman coprolites by Arden B. Bercovitz in 1989. It focuses on identifying estrogen and testosterone in coprolites and reveals whether coprolites came from females or males. This technique may be applied in the future to human coprolites.

Another class of molecules that preserve in feces are lipids. Although it has been known since the 1970s that lipids preserve in coprolites and can be extracted, the interpretive potential of lipid analysis has not been explored.

Elemental chemistry and stable carbon and nitrogen isotopic chemistry of coprolites are being evaluated. The isotopic analysis of coprolites provides insight into which plants produce what isotopic signals. Also, the defecated coprolite signals, when compared to the signals from bone, provide a good idea of the original nature of diet and of how much food material from different isotopic categories is absorbed in the body and how much is defecated. Many major and trace elements are present in coprolites. These have been used in the past to assess health of prehistoric peoples relative to excreted-element values for modern, normal human populations (Fry 1977).

These are some of the types of information and interpretive potentials in coprolite analysis. One major point that is clear from this overview is that coprolite analysts must be generalists. They must be familiar, at least on a basic level, with many fields in anthropology and biology and should have university degrees in both areas.

How Are Coprolite Data Interpreted?

Coprolite analysis presents very specific data regarding prehistoric use of particular plant, animal, and fungal species. Coprolites also provide an idea of the relative amounts of these species that were consumed (precise quantification must await further experimental research). However, they provide a picture of diet only during the few hours before defecation. Therefore, their value in long-term dietary reconstruction can be limited. Because of this, coprolite interpretation must be made with respect to the season of site occupation. If it can be demonstrated that a site was occupied year-round, then coprolites from that site provide a picture of year-long diet. However, if the site was used for a brief period of time, then the year-long dietary picture is incomplete. For example, analysis of Hogup and Danger caves in Utah shows that the caves were occupied briefly in the fall (Fry 1977). Analysis of other hunter-gatherer sites indicates that they were usually occupied temporarily, during either the warm or cold seasons. Some horticultural sites were occupied year-round, and coprolites from these sites provide data regarding the complete use of plants and animals at those sites.

Coprolite data must also be interpreted with perspective to the ancient climates. For some arid areas, the climate has stayed relatively stable, but pronounced change is true for other areas. The Archaic occupation of Dust Devil Cave in Utah predates a major climatic change event called the Altithermal. Before that time, the climate was more temperate than it is today. This affected the ecological life zones on Navajo Mountain, where the cave is located, such that the zones were lower and more accessible. Therefore, interpretation of the coprolite data in context of the ancient environment provides a more accurate idea of distances between the cave and food resources.

Recent Contributions and the Future of Coprolite Studies

The Colorado Plateau has been the research area for refinement of coprolite studies. Several recent studies and syntheses of coprolite data have led to significant conclusions about ancient diet on health. Paul E. Minnis analyzed coprolite data from Anasazi sites on the Colorado Plateau and showed that different regions of the Plateau exhibited distinct dietary patterns and that this regional differentiation was stable throughout Anasazi prehistory. Therefore, beyond distinctions in pottery styles or architectural styles, the different subgroups of the Anasazi can be distinguished by dietary traditions.

Reinhard compared hunter-gatherer diet and parasitism to that of horticultural peoples. His study showed that diet had little effect on the pathological state of Southwestern peoples in comparison to parasitism, which is a reversal of previous notions (El-Najjar and Robertson 1976). One counterintuitive revelation of the study was that hunter-gatherers had a less diverse wild-plant-food base than horticulturalists. Five alternative hypotheses were presented to account for this difference: (1) horticulturalists supplemented a diet of maize with a diversity of collected plants to augment the nutritional value of their maize; (2) horticultural diets reflect year-round use of plants, which results in apparent greater plant diversity; (3) horticulture broadened the range of available food plants through encouragement of weedy plants; (4) horticultural peoples exploited more plants to spice a relatively bland maize diet; and (5) population growth associated with horticulture stressed the subsistence base, with resultant utilization of a broad range of gathered plants.

Sutton and Reinhard (1995) applied cluster analysis to Colorado Plateau coprolite data to evaluate these hypotheses. Sutton originally adapted cluster analysis to coprolite data from California and discovered associations of plants and animals that were seasonally specific. The clustering of these associations at different sites revealed seasonal use of the sites. With the Colorado Plateau coprolites, Sutton discovered three different categories of food-component associations that provided insight into Anasazi cuisine: a fresh-maize category, a ground-maize category, and a maize-absent category. The first category included a series of plants and animals that were associated with fresh maize. The plant foods in this cluster, other than maize, are harvestable in the spring and indicate the range of spring diets. Some of the foods, such as beans and rabbit, were associated only with maize and indicate what dietary supplements and spices were eaten with maize. Fewer plants were associated with ground maize, and these were storable. Therefore, the ground-maize category reflects winter diet. The plants that were not associated with maize reflect either bingeing on seasonably abundant foods (pinyon nuts and prickly-pear fruits) or starvation foods (yucca leaves).

This detailed analysis addressed the hypotheses for horticultural wild-plant use presented by Reinhard. The first hypothesis is viable since it appears that wild foods were used to supplement and spice a maize diet. The second hypothesis is less valid because dietary diversity peaks in the summer and fall months, and, therefore, prolonged occupation would not enhance diversity. The third hypothesis is viable since some of the common wild-plant foods are disturbance annuals. The fourth hypothesis is viable, and it appears that the Anasazi used a variety of wild plants to spice several maize-based recipes. The fifth hypothesis is not viable since very few coprolites contained strictly nonmaize foods. Therefore, the application of cluster analysis to Antelope House coprolite data (Sutton and Reinhard 1995) indicates that several factors resulted in increased use of wild plants among horticulturalists.

This series of studies defines the future of coprolite research. The analytical techniques developed by Callen, Bryant, and Reinhard, combined with the statistical techniques of Minnis and Sutton, have proven to be particularly powerful for reconstruction of ancient cuisine, diet, and health. The future of coprolite research will see more such statistical evaluation of coprolite information.

See also Archaeoparasitology; Paleonutrition; Paleopharmacology; Palynology; Phytolith Analysis

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