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Understanding the Pathoecological Relationship between Ancient Diet and Modern Diabetes through Coprolite Analysis: A Case Example from Antelope Cave, Mojave County, Arizona

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CA+ Online-Only Material: Supplements A–C

The elevated prevalence of non-insulin-dependent diabetes mellitus (NIDDM) in Native Americans of the Southwest has been explained by several authors in terms of a dietary change from preindustrial traditional foods to modern foods. Physiology adapted to traditional foods became deleterious during the process of modernization. Although several versions of this hypothesis exist, they all relate to the rise in modern NIDDM with change from prehistoric subsistence practices to modern dietary practices. This is especially true for the Southwestern desert tribes of Arizona and New Mexico. Coprolite analysts have been recovering the sort of data needed by diabetes researchers to explore the prehistoric dietary foundations for NIDDM. Diabetes researchers have missed these studies that are essential in understanding ancient diet. We are taking this opportunity to show how coprolite analysis of diet provides data relevant to understanding debates. Our case example comes from Antelope Cave, Mojave County, Arizona. There was a high reliance on fiber-rich plant foods with low glycemic indexes. However, these were not just famine foods as suggested by the original "thrifty gene" hypothesis. These were the foods eaten on a day-by-day basis during all seasons, in both feast and famine.

Southwestern Native American tribes, including the Akimel O'odham (Pima), Tohono O'odham (Papago), Quechan (Yuma), Ak-Chin (Maricopa), Haulapai, Mojave, and the Arizona and New Mexico Pueblo tribes, suffer high rates of diabetes. Specifically, the members of these tribes are susceptible to type 2, or non-insulin-dependent, diabetes mellitus (NIDDM). The elevated prevalence of NIDDM has been explained by several authors in terms of a "thrifty genotype" that was adaptive in ancient times but became deleterious during the process of modernization. Although several versions of the thrifty-gene hypothesis exist, they all relate to the rise in modern NIDDM with change from prehistoric subsistence practices to modern dietary practices. Neel (1962) first presented a thrifty-genotype hypothesis to explain why NIDDM occurs at such high rates in some modernizing tribal populations. It is hypothesized that this genotype evolved during thousands of years of feast or famine conditions. With food seasonally unavailable to hunter-gatherers, excessive caloric intake resulting in quickly elevated insulin secretion was adaptive. However, for populations that rapidly modernized, this genotype was maladaptive in the context of constant dependable sources of food.

The loss of high fiber in traditional diets has been linked to the emergence of NIDDM (Wolever et al. 1997). This has been demonstrated in experimental study. Williams et al. (2001) characterized "Indian," "Anglo," and "mixed" diets among the Akimel O'odahm and related these diets to diabetes prevalence. They found that complex carbohydrates, dietary fiber, insoluble fiber, vegetable proteins, and the proportion of total calories from complex carbohydrate and vegetable proteins were significantly higher in the Indian than in the Anglo diet. The risk of developing diabetes in the Anglo-diet group was 2.5 times higher than in the Indian-diet group.

Other researchers have sorted out the individual effects of the components of traditional diets. Hung et al. (2003) determined that the fiber content of carbohydrate food confers benefits in terms of diabetic control. Their work supports a dietary-fiber hypothesis proposed by Trowell (1975:764) that "dietary fiber depleted starchy foods are conducive to the development of diabetes mellitus in susceptible human genotypes." Also, these traditional diets were rich in food with low glycemic indexes (GIs). The GI is an indicator of carbohydrate's ability to raise blood glucose levels. Hung et al. (2003) found that for carbohydrates, the GI appears to be a better predictor of the metabolic effects of a diet than sugar content. Willett, Manson, and Liu (2002) summarized the value of the GI based on experimental studies of animals and humans. They stated that a high intake of carbohydrate foods with high GIs produces greater insulin resistance than intake of low-GI foods. Hu, van Dam, and Liu (2001) found that a low-GI diet with a high amount of fiber lowers the risk of NIDDM.

The traditional diets of the Tohono and Akimel O'odham have been studied with regard to NIDDM. However, the information concerning prehistoric traditional diet for Southwestern tribes in general is sketchy. This is similar to the knowledge of Aboriginal diet in Australia. As Gracey (2000: 1361) notes, "Most information about Aboriginal diets is anecdotal or semiquantitative. More effort needs to be invested in studies that more clearly and precisely define dietary pat-

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terns in Aboriginal people, especially children, and how these patterns influence their growth, nutritional status, and health, prospectively." Gracey's comment is relevant to the study of Southwestern traditional diet.

The debates summarized above show that diabetes researchers have been actively searching for an effective method for reconstructing ancient diet. This is especially true for the Southwestern desert tribes of Arizona and New Mexico. Coprolite analysts have been recovering exactly the data desired by diabetes researchers for nearly 4 decades (Bryant 1974*a*, 1974*b*; Bryant and Dean 2006; Bryant and Williams-Dean 1975; Poinar et al. 2001; Rasmussen et al. 2009; Reinhard 1992; Reinhard and Bryant 1992, 2008). Diabetes researchers have missed these studies that are essential in understanding ancient diet. We are taking this opportunity to show how coprolite analysis of diet provides data relevant to the diabetes debates. Our case example comes from Antelope Cave, Mojave County, Arizona.

Martinson et al. (2003), followed by Reinhard (2007) and Reinhard and Bryant (2008), developed the concept of "pathoecology," which is the evaluation of environmental determinants of disease. The term was first used by Karl R. Reinhard (Karl J. Reinhard's father), an epidemiologist who worked on the history of disease development in the Arctic (Reinhard 1974*a*, 1974*b*). K. R. Reinhard applied this concept to emerging diabetes (Reinhard and Greenwalt 1975). K. J. Reinhard (1988) began pathoecological study of subsistence variation on parasitic disease. The connection between episodic malnutrition and parasitic disease with anemia as represented in skeletal remains was demonstrated later (Reinhard 1992, 2007). Also, coprolite data were linked to patterns of dental disease (Danielson and Reinhard 1998; Reinhard and Danielson 2005). Today, there is direct relevance of coprolite data to understanding the nutritional health, metabolic health, dental health, and level of parasite infection among prehistoric people. It was from this pathoecological perspective that Antelope Cave coprolites were analyzed.

Archaeological Background of Antelope Cave

Antelope Cave is located on the Arizona Strip in the northwest corner of Arizona, about 25 miles southeast of St. George, Utah. It is a large limestone grotto sunk into the semiarid rolling plains of the Uinkaret Plateau about 4,660 feet asl. The cave interior (fig. 1) measures 350 feet north-south by 150 feet east-west. Prehistoric Native Americans first lived in this subterranean cavern 4,000 years ago, and various Native groups occupied or visited the cave until AD 1150. The most abundant cultural materials recovered from the site were left behind by Ancestral Puebloan (Virgin Anasazi) peoples who lived there successfully, perhaps seasonally, for at least 450 years (AD 700–1150). It appears that the cave may have been a seasonal camp repeatedly visited to store artifacts such as sandals and nets, to gather local plants, and to hunt rabbits to eat and then to prepare their hides for the manufacture of soft fur/skin robes.

Figure 1 is a plan drawing of Antelope Cave. The main entrance to the cave (now gated by the Bureau of Land Management) is on its southeast edge above large slabs of jumbled limestone. Once inside, a massive layer of broken limestone roof fall, beginning 10 feet below the entrance, extends over the eastern half of the cave. The dry and gray powdery midden deposit covers most of the western half. The surface of the midden slopes down rapidly from south to north, ending at a large secondary sinkhole, the bottom of which is 75 feet below the entrance to the cave.

Altschul and Fairley (1989) and Lyneis (1995) review the archaeology of the Arizona Strip, including the prehistoric Virgin Anasazi, some of whom were the primary occupants of Antelope Cave more than 1,000 years ago. We offer here a synopsis of their work and add information from Antelope Cave.

The Archaic Period (7000–300 BC) on the Arizona Strip is typified by distinctive styles of projectile points that represent early dispersed hunter-gatherer groups. Some Archaic-style points—Rocker side-notched, San Rafael side-notched, and Elko corner-notched—are reported from Antelope Cave. In support, charcoal samples from the cave yielded three calibrated ^{14}C dates of 2028–1893 BC, 1891–1744 BC, and 1699–1444 BC (Janetski and Wilde 1989), further confirming the initial occupation of Antelope Cave by Archaic groups.

Basketmaker II (300 BC–AD 400) is the first Anasazi period to be recognized in the Southwest. Basketmaker II sites are typically pit structures or rock shelters and caves with slab-lined storage pits. Five are known on the Arizona Strip, including Antelope Cave, which has yielded a wooden atlatl (spear thrower) carbon dated at AD 100. Also, a small excavated area (fig. 1; University of California, Los Angeles [UCLA] excavation unit AC59-3, 4) near the west wall of the cave lacked ceramics but contained finely woven square-toed sandals and obsidian projectile points. This area is tentatively attributed to the Basketmaker II period (Johnson and Pendergast 1960:3).

Basketmaker III (AD 400–800) is represented by small pithouse villages, plain gray pottery, and cultivated beans to go with the growing of maize and squash. Probable Basketmaker III traits at Antelope Cave include cultivated beans, plain gray ceramics, and the wooden nock ends of arrows. In addition, three new radiocarbon dates from Antelope Cave indicate that the Ancestral Pueblo more than any other group made the greatest use of the site during late Basketmaker III through early Pueblo I times. The new dates are cal AD 680–890, cal AD 710–960, and cal AD 680–890. These new radiocarbon assays equate nicely with those from the Brigham Young University excavations in 1983 (Janetski and Hall 1983:40, 43).

The Pueblo I and Pueblo II periods (AD 800–1150) are characterized by the continuation and elaboration of Basketmaker III cultural traits. Pithouse villages are usually small and increase in number, and the houses may have benches

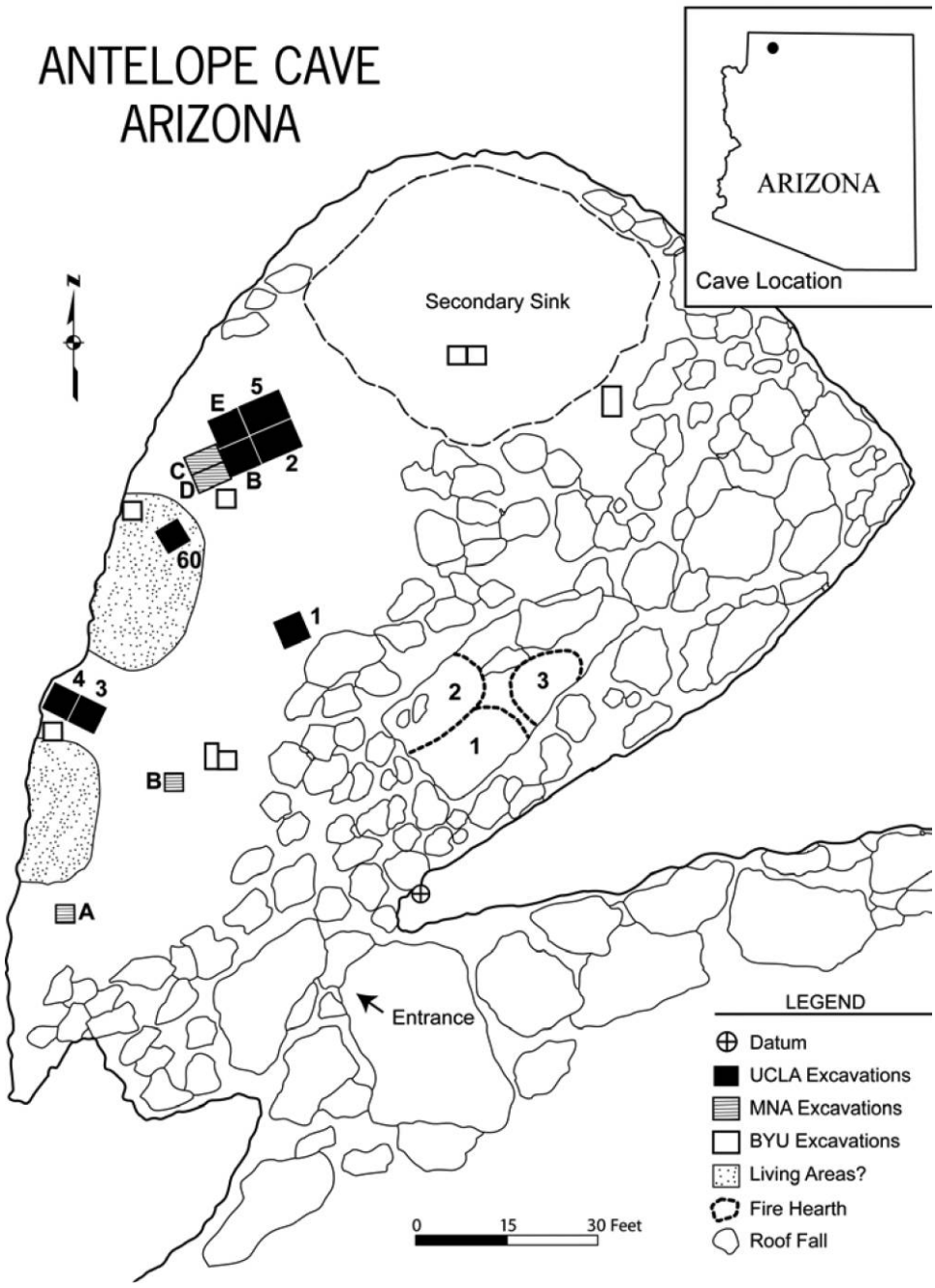

Figure 1. Antelope Cave, surface features and excavation units (University of California, Los Angeles [UCLA]; Museum of Northern Arizona [MNA]; Brigham Young University [BYU]).

and ventilators. Aboveground masonry structures first occur during this time period. Black-on-gray and black-on-white decorated pottery make their appearance early on. Corrugated pottery is a new style that debuts in the Pueblo II period (AD 1000–1150). Round- or pointed-toed sandals begin to replace square-toed sandals by Pueblo I times. At Antelope Cave, five Virgin Anasazi types of decorated ceramics as well as round-toed yucca sandals mark these two culture stages. However, the seasonal use of Antelope Cave by Ancestral Puebloans was in decline by AD 1000. Of the 3,100 pottery sherds recovered during the UCLA excavations, only three were corrugated. This suggests little use of the cave during much of Pueblo II.

Several Anasazi sites have been dated to Early Pueblo III (AD 1150–1225) on the Arizona Strip. At this time, Antelope Cave had been pretty much abandoned by the Virgin Anasazi. Where they went or what happened to them is uncertain.

Prehistoric Southern Paiute groups began to move into Virgin Anasazi territory around AD 1000, and these newcomers eventually either absorbed or replaced the Ancestral Pueblo peoples on the strip. A large twined and pitch-covered Paiute water basket was recovered from the surface of Antelope Cave by Vilate Hardy of La Verkin, Utah, in the early 1950s. The location of this specimen in the cave provides a bit of evidence that either the Virgin Anasazi were in contact with the Southern Paiute or the Southern Paiute actually occupied the cave sometime after it was abandoned by the Pueblo people. More details of the archaeology of the region are presented in CA+ online supplement A.

Material and Methods

We analyzed 25 coprolites from Antelope Cave. Of these, 20 were human in origin and four were dog or some other canid in origin. One coprolite sample was actually consolidated cave sediment. Samples of 10 coprolites were submitted to two molecular biology labs, one at Fundação Oswaldo Cruz and one at the University of Oklahoma. The molecular results are not available at this time.

Initially, our goal was to select one coprolite from each Antelope Cave provenience. This involved identifying the most human-like coprolite from each provenience. However, four of the first 10 coprolites sampled in this way turned out to be of animal origin. Subsequently, the coprolite collection was examined with the goal of identifying human coprolites only. Therefore, those coprolites that had the most distinct human morphology and that did not contain obvious animal hair were included for study. The sampling followed the guidelines for distinguishing human from animal coprolites published by Chame (2003). The details of the analysis procedure are presented in CA+ online supplement B.

Results

The dietary results are presented in CA+ online supplement C. The tables in supplement C present definitions of terms, data for microresidues, and the macroresidue results. These results for the human coprolites are presented in table C1. Coprolites 6 and 22 are omitted from these results because analysis revealed that they were not human coprolites. Number 6 was an animal coprolite, and number 22 was consolidated cave sediment.

Most of the human coprolites analyzed for macroscopic and microscopic food remains appear to be from late summer and early fall depositions. At this time period, a diversity of wild-plant fruits and seeds were available for harvesting, and there would still be ambient pollen from sagebrush, grass, cheno-ams, and ragweed-type plants. Therefore, this coprolite series cannot be considered to represent a year-round diet.

There are four principal processed plant foods represented in the Antelope Cave coprolites. These are maize, wild-grass caryopses, sunflower seeds, and cheno-am seeds that have been ground to a fine flour. Much of the flour made from these plants passed through a 0.5-mm screen. Grinding was a significant part of preparing food at Antelope Cave. A caryopsis is a dry seed-like fruit produced by wild and cultivated cereal grasses. Maize and wild-grass caryopses consistent with dropseed were found in six coprolites each. They did not co-occur. Dropseed was very abundant in five coprolites, and maize was very abundant in six. Microscopically, maize starch occurred in seven coprolites. Thus, maize was slightly more important than wild-grass caryopses.

Sunflower achenes occurred in four coprolites and dominated three of these. An achene is a small, dry, indehiscent fruit with the seed distinct from the fruit wall. The composite family, among others, produces achenes. Microscopically, ground achene fragments were present in six coprolites. Therefore, it appears that sunflower achenes were significant to Antelope Cave users. Ground achenes, in our experience, are unique to Antelope Cave. Importantly, the entire achenes—shell and seed—were ground.

Flour was also made of cheno-am seeds and was found in three coprolites, but it was dominant in only one. In botanical archaeology terms, "cheno-am" is applied to fruits and pollen. These fruits look like small black seeds. They have a round starchy core surrounded by a thick seed coat. Cheno-am fruits come from plants in *Chenopodium*, *Amaranthus*, or related genera. Cheno-am pollen could be from either the family Chenopodiaceae or the genus *Amaranthus*. Cheno-am pollen is often ingested with cheno-am fruits. Cheno-am seeds are a common component of Southwestern diet in agricultural and preagricultural times. In our experience from coprolite analysis, the production of flour from cheno-am seeds is more an aspect of Archaic diet such as that represented at Dust Devil Cave, Utah (Reinhard, Ambler, and McGuffie 1985). The finely ground cheno-am flour at Antelope Cave is unusual for Ancestral Pueblo coprolites.

In addition to the four principal flour foods, a seed that could be four-winged saltbush was found in two coprolites. Unidentifiable seeds and wolfberry were observed in one coprolite each.

Following maize and wild grass, prickly pear pads were an important food source. Four coprolites included macroscopic remains of prickly pear, while 11 contain microscopic remains. Prickly pear was very abundant in two coprolites. However, in seven coprolites, prickly pear co-occurred with other foods. Therefore, prickly pear was an important stand-alone food, and it also supplemented other foods.

Discussion

There is no doubt that NIDDM has an evolutionary connection with ancient diet. Coprolite analysts provide the most insightful and empirical information about the nutritional content of traditional diets. The dietary data from the Antelope Cave coprolites can be directly applied to diabetes debates. We are using this site, combined with analysis with

other sites, to identify patterns of food use that formed an evolutionary pressure for the fixation of the thrifty gene.

Antelope Cave coprolite analysis highlights the nutritional nature of ancient foods. The analysis demonstrates the following points. First, prehistoric foods consistently had low GIs. Second, prehistoric diet was remarkably high in fiber. Third, there was a high reliance on hypoglycemic-effect foods. Fourth, inulin-rich foods were a consistent part of diet. This fourth aspect of prehistoric diet has already been established in the literature (Leach, Gibson, and Van Loo 2010; Leach and Sobilik 2010).

The GI measures the influence of carbohydrates on blood sugar levels. High-GI foods rapidly break down during digestion and rapidly release glucose into the bloodstream. Low-GI foods break down more slowly and release glucose gradually into the bloodstream. The GI is assigned to foods based on a standard of glucose that has a GI of 100. Low-GI foods have a value of less than 55. High-GI foods exceed a value of 70.

Some Antelope Cave food GIs can be approximated from modern counterparts. Prickly pear was a very important prehistoric food. It has a GI of 7, which is the lowest recorded for Southwestern plant foods and one of the lowest values for any recorded human food. Modern cultivated sunflower achenes have a GI of 10. Modern cultivated amaranth has a GI of 25. The prehistoric sunflowers and cheno-ams were uncultivated and probably had lower indexes than these. Thus, based on available GI values for modern versions of prickly pear, amaranth, and sunflowers, it appears that the wild-plant diet at Antelope Cave focused on very low-GI species. The total GI for stews made of wild-plant seeds and rabbit may have been close to the modern value of Traditional Akimel O'odham (Pima) acorn and venison stew, which is 23.

Looking for GI values of traditional Southwestern foods provides insight into the maize of Antelope Cave. Traditional Akimel O'odham maize hominy made from indigenous maize has a GI of 57. This was probably the highest GI for available foods at Antelope Cave.

As for the fiber content of the Antelope Cave diet, it was very high. Fiber appears in the form of xylem, phloem, epidermis, glumes, achene shells, seed testa, and fruit shells in Antelope Cave coprolites. In general, half of the weight of each coprolite was composed of fiber fragments larger than 0.25 mm. Microscopically, the concentrations of undigested plant fragments ranged from hundreds of thousands to millions of fragments per gram of coprolite. This fiber content is remarkable from the modern perspective but comparable to other Southwestern prehistoric coprolite series. By volume, about three-quarters of Antelope Cave coprolites are composed of insoluble fiber.

Prickly pear cactus pads were a common food in the prehistoric Southwest. Indeed, Reinhard (1992) identified prickly pear as one of the main dietary components in the region. Table 1 presents the frequency of coprolites positive for prickly pear as measured by the analysis of phytoliths from coprolites. Prickly pear pads contain distinctly shaped calcium oxalate crystals. By extracting phytoliths from coprolites, it is possible to assess the dietary reliance of ancient people on prickly pear pads. The data show that 77% of hunter-gatherer coprolites contain prickly pear phytoliths. For agricultural peoples, the frequency drops to 62%. This shows that prickly pear pads were a central part of the diet even after agriculture was established.

Table 1. Summary of phytolith finds from several Southwestern sites

		Opuntia		Agavaceae	
Site	*n*	*n*	%	*n*	%
Hunter-gatherer:					
Hinds Cave, Texas	14	13	93	14	100
Dust Devil Cave, Utah	17	10	59	16	94
Bighorn Cave, Arizona	17	14	82	16	94
Total	48	37	77	46	96
Ancestral Pueblo:					
Bighorn Sheep Ruin, Utah	20	10	50	12	60
Antelope House, Arizona	25	20	80	18	72
Salmon Ruin, New Mexico	20	9	45	10	50
Antelope Cave, Arizona	20	14	70	1	5
Total	85	53	62	41	48

Note. Hunter-gatherers consumed prickly pear (*Opuntia*), yucca, and/or agave very commonly. Both yucca and agave are in the family Agavaceae. Consumption of Agavaceae food plants declined dramatically among the Ancestral Pueblo but was still common in some areas. However, prickly pear remained a common food in the Ancestral Pueblo diet.

NIDDM researchers have long recognized the antidiabetic properties of prickly pear of the species *Opuntia streptacantha*, *Opuntia ficus-indica*, *Opuntia engelmannii* var. *lindheimeri*, and *Opuntia fuliginosa* (Frati-Munari et al. 1988, 1989*a*, 1989*b*, 1989*c*, 1989*d*; Meckes-Lozoya and Ibáñez-Camacho 1989; Meckes-Lozoya and Roman-Ramos 1986). Frati-Munari et al. (1988, 1989*b*, 1989*c*, 1991) demonstrated that broiled prickly pear pads had a hypoglycemic effect in diabetic humans. Various authors demonstrated the hypoglycemic effects of prickly pear on animals, including pancreatectomized rabbits (Ibáñez-Camacho and Roman-Ramos 1979), rats (Trejo-Gonzalez et al. 1996), pigs (Laurenz, Collier, and Kuti 2003), and other lab models (Ibáñez-Camacho, Meckes-Lozoya, and Mellado-Campos 1983). All of these lines of research demonstrated that prickly pear pads cause lower blood glucose levels in diabetic patients and animals. Meckes-Lozoya and Ibáñez-Camacho (1989) evaluated the hypoglycemic activity of prickly pear throughout the seasonal cycle of the plant and found no variation in the hypoglycemic activity of this plant.

Coprolite analysis focusing on consumption of desert succulent plants shows that prickly pear was a universal food source for prehistoric southwesterners (Reinhard and Danielson 2005). The discovery of prickly pear at Antelope Cave expands the known use of prickly pear to the Uinkaret Pla-

teau. The consistent use of this plant through thousands of years of desert subsistence could have exerted part of an evolutionary pressure for the fixation of the thrifty gene.

Prickly pear pads were not the only desert succulents that were important in the Southwestern diet. Agave and yucca are desert succulents that were very commonly eaten by hunter-gatherer and agricultural peoples (table 1). They were exceptionally common in preagricultural diets. After the agricultural revolution in the Southwest, phytolith analysis indicates that about half of the human coprolites contain agave or yucca. Agave and yucca are fibrous desert succulents that provided several sources of food to prehistoric people (Leach and Sobolik 2010). Agave is a demonstrated dietary source of inulin. Yucca is not as well studied as agave, but it is also an inulin source. Inulin has minimal effect on blood sugar. For both agave and yucca, the buds and hearts of the plants were eaten. The hearts were available year-round. To collect the hearts, the plants had to be pried from the ground. The leaves were then cut from the base of the plant, leaving just the "heart" of leaf bases. The resulting structure looks like a very large artichoke heart. The hearts were then baked for up to 2 days in large underground rock-lined ovens. The cooked leaf bases were then pulled from the heart and chewed to extract carbohydrates. This resulted in a wad of fiber in the mouth called a "quid." The quids were swallowed or spit out. Fiber from quids is very commonly found in prehistoric coprolites and testifies to the high-fiber nature of yucca and agave. Both yucca and agave are fiber rich. Montonen et al. (2003), Salmerón et al. (1997*a*, 1997*b*), Brand-Miller et al. (2003), Pick et al. (1996), Guévin et al. (1996), Tabatabai and Li (2000), and Marlett, McBurney, and Slavin (2002) emphasized that fiber-rich foods were part of the traditional diets for tribal cultures that are experiencing rises in obesity and NIDDM.

Yucca in coprolites occurred only in traces at Antelope Cave. However, more than 300 yucca quids from the midden show that people did eat yucca there. Therefore, the Antelope Cave evidence is consistent with the general picture that desert succulents were important subsistence sources for Southwestern prehistoric people.

The growing dietary database from coprolite analysis supports the thrifty-gene hypothesis in general, but with a significant modification. There was a high reliance on high-inulin fiber-rich plant foods with low GIs. However, these were not just famine foods, as suggested by the original hypothesis. These were the foods eaten on a day-by-day basis during all seasons, in both feast and famine. They continued to be eaten even after agriculture was developed. Antelope Cave coprolites show that this high-fiber diet was eaten during the warmer seasons of food abundance. Other sites, such as Antelope House in Canyon de Chelly, show that the reliance on high-fiber foods, especially yucca and prickly pear, was accentuated in winter and periods of ecological crisis (Sutton and Reinhard 1995). Therefore, we hypothesize that it was the consistent reliance on these foods that fixed the thrifty gene in Southwestern tribes. This hypothesis can be tested in future coprolite analyses and by review of existing data collected by coprolite analysts over the past decades.

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Supplement A from Reinhard et al., "Understanding the Pathoecological Relationship between Ancient Diet and Modern Diabetes through Coprolite Analysis"

(Current Anthropology, vol. 53, no. 4, p. 506)

Archaeological Background

Archaeological research on the Arizona Strip has been sporadic, and thus its prehistory is poorly known compared with other regions of the American Southwest. Altschul and Fairley (1989) offer a detailed overview of the environment and archaeology of the strip. Lyneis (1995) updates our knowledge of the prehistoric Virgin Anasazi, some of whom were the primary occupants of Antelope Cave over 1,000 years ago. The following synopsis is based on these two comprehensive publications plus additional information on Antelope Cave.

Evidence of Paleo-Indian presence on the Arizona Strip before 7000 BC is extremely minimal, being made up of one Clovis-like dart point and two Silver Lake point fragments.

The Archaic Period (7000–300 BC) also is typified by distinctive styles of projectile points that represent early dispersed hunter-gatherer groups. Some Archaic-style points—Rocker side-notched, San Rafael side-notched, and Elko corner-notched—are reported from Antelope Cave. In support, charcoal samples from the cave yielded three calibrated ^{14}C dates of 2028–1893 BC, 1891–1744 BC, and 1699–1444 BC (Janetski and Wilde 1989), further confirming the initial occupation of Antelope Cave by Archaic groups. A few other sites (not lithic scatters) on the Arizona Strip have Archaic Period components, including Rock Canyon Shelter, approximately 7 miles north of Antelope Cave.

Basketmaker II (300 BC–AD 400) is the first Anasazi period to be recognized in the Southwest. In general, it is characterized by maize and squash cultivation, lack of ceramics, square-toed fiber sandals, human-hair cordage, slab-lined storage cists, pithouses, atlatl darts, coiled baskets, and rabbit-fur blankets. The question of whether the Basketmaker Puebloans evolved from Archaic hunter-gatherer groups is unresolved. Basketmaker II sites are typically pit structures or rock shelters and caves with slab-lined storage pits. Five are known on the Arizona Strip, including Antelope Cave, which has yielded an atlatl carbon dated at AD 100. Also, a small excavated area (fig. 1; UCLA excavation unit AC59-3, 4) near the west wall of the cave lacked ceramics but contained finely woven square-toed sandals and obsidian projectile points. This area is tentatively attributed to the Basketmaker II period (Johnson and Pendergast 1960:3).

Basketmaker III (AD 400–800) is represented by small pithouse villages, plain gray pottery, and cultivated beans to go with the growing of maize and squash. Bows and arrows begin to replace atlatls and darts during this period. Habitation sites are scattered over the Arizona Strip, and many are difficult to interpret because of the general lack of reliable dating. Probable Basketmaker III traits at Antelope Cave include cultivated beans, plain gray ceramics, and the wooden nock ends of arrows. In addition, three new radiocarbon dates from Antelope Cave indicate that the Anasazi more than any other group made the greatest use of the site during late Basketmaker III through early Pueblo I times. The ^{14}C determinations are as follows.

Beta 257788	1220 ± 40 BP	680–890 cal AD (2σ)
Beta 257787	1190 ± 40 BP	710–960 cal AD (2σ)
Beta 257786	1230 ± 40 BP	680–890 cal AD (2σ)

Specimen Beta 257788 was run on a corncob (cat. 244–4835) from the 66–72-inch level of University of California, Los Angeles (UCLA) excavation unit AC59-5 (fig. 1). It represents the beginning of the Basketmaker III Anasazi occupation in this area of the cave. Beta 257787 dates a yucca quid (cat. 244-1490) from UCLA AC59-2, 24–30 inches below the surface. This sample was specifically selected to date the level containing a newly discovered tick that had been eaten by one of the cave's occupants (Johnson et al. 2008). The third date, Beta 257786, is from a yucca quid (cat. 244-658) in the top level (0–6 inches) of UCLA AC59-2. Unfortunately, the dated specimen appears to be from badly disturbed midden at the top of the excavation unit. These three new radiocarbon assays equate nicely with those from the Brigham Young University excavations in 1983 (Janetski and Hall 1983:40, 43).

The Pueblo I and Pueblo II periods (AD 800–1150) are characterized by the continuation and elaboration of Basketmaker III cultural traits. Pithouse villages are usually small and increase in number, and the houses may have

benches and ventilators. Aboveground masonry structures first occur during this time period. Black-on-gray and black-on-white decorated pottery make their appearance early on. Corrugated pottery is a new style that debuts in the Pueblo II period (AD 1000–1150). Round- or pointed-toed sandals begin to replace square-toed sandals by Pueblo I times. At Antelope Cave, five Virgin Anasazi types of decorated ceramics as well as round-toed yucca sandals mark these two culture stages. However, the seasonal use of Antelope Cave by Ancestral Puebloans was in decline by AD 1000. Of the 3,100 pottery sherds recovered during the UCLA excavations, only three were corrugated. This suggests little use of the cave during much of Pueblo II.

Several Anasazi sites have been dated to Early Pueblo III (AD 1150–1225) on the Arizona Strip. The sites are still small, but some are larger than the settlements of previous periods. As usual, the family household remains the basic economic unit. At this time, Antelope Cave had been pretty much abandoned by the Virgin Anasazi. Where they went or what happened to them is uncertain.

Prehistoric Southern Paiute groups began to move into Virgin Anasazi territory around AD 1000, and these newcomers eventually either absorbed or replaced the Ancestral Pueblo peoples on the strip. A large twined and pitch-covered Paiute water basket was recovered from the surface of Antelope Cave by Vilate Hardy of La Verkin, Utah, in the early 1950s. The location of this specimen in the cave provides a bit of evidence that the Virgin Anasazi were either in contact with the Southern Paiute or the Southern Paiute actually occupied the cave sometime after it was abandoned by the Pueblo people.

Figure 1 is a plan drawing of Antelope Cave. The main entrance to the cave (now gated by the Bureau of Land Management) is on its southeast edge above large slabs of jumbled limestone. Once inside, a massive layer of broken limestone roof fall, beginning 10 feet below the entrance, extends over the eastern half of the cave. The dry and gray powdery midden deposit covers most of the western half. The surface of the midden slopes down rapidly from south to north, ending at a large secondary sinkhole, the bottom of which is 75 feet below the entrance to the cave.

Scientific investigation of the midden deposit began in 1954 when Robert Euler of the Museum of Northern Arizona (MNA) directed the excavation of four test pits (A, B, C, D). In 1983 and 1986, Brigham Young University (BYU) archaeologists under contract with the Bureau of land Management sampled six areas in the cave, including the secondary sink (Janetski and Hall 1983; Janetski and Wilde 1989). Their work provided excellent perishable and nonperishable cultural materials as well as important radiocarbon dates. Between the MNA and BYU excavations, archaeologists from UCLA carried out extensive investigations in the cave. In 1956 and 1957, under the direction of Robert Euler, UCLA crews from summer archaeology field schools in Utah dug units E and B adjacent to MNA pits C and D. Encouraged by Vilate Hardy and supported by a grant from the Department of Anthropology and Sociology at UCLA, three UCLA archaeologists spent 19 days in June of 1959 excavating units AC59-1 through 5 (Johnson and Pendergast 1960). AC59-1 is located close to the rock fall at the center of the cave. The midden became damp and rocky and was abandoned at 48 inches below the surface. AC59-3 and 4 were placed in a debris mound at the west edge of the cave. This area yielded early Basketmaker materials (Johnson and Pendergast 1960). AC59-2 and 5 were located in the culturally richest area of the midden near the north end of the cave, where the deposit is 72 inches deep. UCLA archaeologists returned to Antelope Cave for a few days in April 1960 to complete the excavation of AC59-5 and investigate two "living areas" abutting the west edge of the cavern. These possible living areas, the largest measuring 30 × 15 feet, were relatively flat and in 1959 appeared to be generally clear of surface cultural debris such as twigs, pottery fragments, corncobs, etc. Test unit AC60 was excavated to sample the subsurface of the larger "living area." The soil in the pit was brown rather than the typical gray midden of the site. A large limestone rock was exposed 2 inches below the surface, and two superimposed burned areas or fire hearths were encountered before rocks at 12 inches below the surface prevented further excavation. Among the rock fall on the eastern half of the site is a huge flat limestone slab. Three shallow fire hearths were noted on its surface by the UCLA crew in 1959, but they were not completely recorded until 2009. Fire hearth 3, the smallest of the three in diameter, is 2 inches thick and composed of very black charcoal fragments along with burned pine needles. Radiocarbon analysis of soil from hearth 3 (Beta 264019, 180 ± 40 BP, 1650–1950 cal AD [2σ]) indicates that visitors were still using the cave hundreds of years after it was abandoned by the Virgin Anasazi.

Prehistoric human coprolites from UCLA's work at Antelope Cave provide the basic data for this report. The excavations recovered 190 feces. They were found scattered in all excavation units with the exception of pits E and AC60, the latter of which may be in a family living area. The highest concentration of coprolites, 13, occurred in the 30–36-inch level of AC59-4, which yielded Basketmaker II materials. Twenty-five coprolites were selected for dietary analysis. Their provenience in Antelope Cave is listed in table A1 in the order of their assigned laboratory numbers.

Table A1. Major and minor food components listed for each coprolite based on the analyses summarized in supplementary results and tables

Lab no.	Main association	Secondary association
1	Roasted prickly pear pads	Dropseed seeds and pollen could be from a meal of caryopses without grinding or cooking
2	Not fully cooked stew of finely processed maize flour and rabbit	
3	Possibly a stew of highly processed sunflower and small-mammal meat and bone	High grass and cheno-am pollen concentrations result from earlier meals of these plants (probably seeds)
4	Fully cooked stew of maize and wolfberry fruit with small-animal meat and bone	Other foods are represented by prickly pear, sunflower, and other grass residues
5	Cooked stew of animal meat, bone, and ground dropseed flour	Prickly pear pads
7	Cooked stew of maize flour and small-mammal meat and bones	Prickly pear pads
9	Stew of small-mammal meat and bone and finely ground unidentifiable seed prepared with sagebrush	Prickly pear pads
10	Roasted prickly pear pads	
11	Crushed four-winged saltbush seeds, roasted prickly pear pads, stems or leaves of unidentifiable plant, and small-mammal meat and bone	
12	Stew of cooked maize and small-animal meat and bone	Prickly pear pads
13	Finely ground dropseed flour	Prickly pear pads, four-winged saltbush, sunflower, and other grass
14	Stew of sunflower and small-mammal meat and bone	Wild grass and cheno-am seeds
15	Parched and cooked plant food, source unidentifiable, with small-animal meat and bone	Prickly pear pads
16	Stew of sunflower and small-mammal meat and bone	
17	Stew or soup made from ground grass and small-mammal meat and bone	Prickly pear pads
18	Parched coarsely ground maize and roasted prickly pear pads	Termites probably from a previous meal
19	Roasted prickly pear pads and small-mammal meat and bone	Maize
20	Seed cake or stew composed of finely ground cheno-am fruits associated with ground dropseed caryopses	Maize
21	Roasted prickly pear pads	Cooked maize and dropseed
23	A stew of roasted prickly pear pads, cheno-am seed, and small-mammal meat and bone	

Note. The main association column lists the major foods found in each coprolite and an interpretation of the nature of the original foods. The secondary association is based on traces of the designated foods that may reflect vestiges of a separate meal or secondary foods from the same meal as the main association. The designation "cooked" or "completely cooked" is based on the presence of heat-altered starch or loss of starch completely. The designation "not fully cooked" is based on the presence of pristine, unaltered starch. The designation "processed" refers to ground foods. "Roasted" prickly pear is evidenced by the heat-altered white appearance of epidermal fragments. "Meat" is inferred by the find of bone and hair. Most identifiable bone and hair was either cottontail or jackrabbit. It is likely that all of the meat represented by bones is from rabbits with the exception of coprolite 4. Feather calami (quill bases) in 4 suggest that birds were eaten. "Parched" designation is based on association of carbon mixed with plant tissue. This could be from parching plant foods by swirling them with hot coals. "Stew" is a suggested method of preparing an association of foods applied to reoccurring associations.

Reference Cited Only in Supplement A

Johnson, Keith L., Karl J. Reinhard, Luciana Sianto, Adauto Araújo, Scott L. Gardner, and John Janovy Jr. 2008. A tick from a prehistoric Arizona coprolite. *Journal of Parasitology* 94:296–298.

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Supplement B from Reinhard et al., "Understanding the Pathoecological Relationship between Ancient Diet and Modern Diabetes through Coprolite Analysis"

(Current Anthropology, vol. 53, no. 4, p. 506)

Material and Methods

Preliminary Steps

The specimens were assigned laboratory numbers and logged into a laboratory notebook by lab number and provenience (table B1). After photographing each specimen, we made specific observations about the shape, size, and content (as evident from the surface) of each coprolite. We also noted evidence of decomposition, such as the presence of larvae cases and beetle and arthropod holes. The coprolites were subsampled, and each subsample was weighed. Then the subsamples were rehydrated for 48 hours in 0.5% trisodium phosphate. *Lycopodium* tablets, each containing 12,500 spores, were added to the rehydrating samples. One tablet was added for each gram of coprolite with the exception of sample 15. One tablet was added to every 2 g of that sample. The rehydrated coprolites and dissolved *Lycopodium* tablets were disaggregated with a magnetic stirrer. The magnetic stirrer releases microfossils that might otherwise be trapped in the plant remains. The samples were then screened through a 150-μm mesh. The fluid passing through the screen was collected in a large glass beaker and then centrifuged in 100-mL centrifugation tubes. The concentrated solid microscopic remains were then transferred to 50-mL tubes for microfossil extraction. The macroscopic remains on top of the screens were transferred to blotter paper and dried for analysis.

Macrofossil Dietary Analysis

The dried macrofossil remains were screened through 2.0-mm, 1.0-mm, and 0.5-mm geological sieves. The remains from each screening were examined with a binocular dissecting microscope. The remains were sorted by hand using forceps, tweezers, and wooden spatulettes. The macroscopic plant constituents were identified using the seed comparative collection and by published and online seed-image databases. In certain instances, wet mounts were made of plant tissue so that the cellular and phytolith arrangements could be examined with the compound microscope.

Microfossil Analysis

The key to microfossil quantification, analysis, and interpretation is the addition of *Lycopodium* spores. To calculate the concentrations of microfossils in samples of sediment, we added known number of *Lycopodium* spores into the samples (Reinhard et al. 2006). By adding a known number of exotic spores, we can estimate the amount or concentration of all types of microfossils. Concentrations of parasites, pollen grains, and starch grains are calculated with the following formula: microfossil concentration $= [(f/m) \times e]/v$, where $f =$ microfossils counted, $m =$ marker *Lycopodium* spores counted, $e =$ *Lycopodium* spores added, and $v =$ volume of sediment.

For this analysis, *Lycopodium* spore batch 212761 was used. Previous analysis shows that approximately 12,500 spores are present in each tablet.

In order to retain *Lycopodium* spores for each type of analysis, a sequential microfossil analysis was done. First, parasitological scans were accomplished. Twelve microscope preparations were made and examined for parasite eggs and larvae at 250 × with photographs taken at 400 ×. The same slides were scanned for starch, calcium oxalate phytoliths, plant tissue, animal hair, and any other identifiable remains. This stage of analysis focuses on heavier mineral remains such as phytoliths.

The sediments were then treated with heavy-density zinc bromide solution. The solution is made with zinc bromide diluted to the desired specific gravity of 1.9 with 2% hydrochloric acid. The heavy-density solution was added to each centrifuge tube containing the microfossils. The tubes were centrifuged for 15 minutes to separate heavy from light remains. Three microscope preparations from the light fractions were analyzed for starch grains and parasite eggs. Then the analysis proceeded to palynology.

The extraction of the pollen involved chemical destruction of silica, cellulose, and starch, leaving concentrated and stained pollen. The light fraction of microfossil remains were treated with hydrofluoric acid (40%). The acid was added to centrifuge tubes with the sediments. The tubes were placed in a hot water bath (95°–98°C) for an hour. The remains were then washed three times with distilled water and subsequently rinsed twice with glacial acetic acid preparatory to acetolysis. The acetolysis mixture of one part sulfuric acid and eight parts acetic anhydride was added to each tube. All tubes were then placed in a hot water bath for 15 minutes. Finally, the samples were washed with acetic acid and then several times with water until the supernatant was clear.

Following the chemical extraction, the residue was washed with 95% alcohol and transferred to small vials in alcohol. Microscope slides were prepared by pipetting a drop of residue onto a slide, allowing most of the alcohol to evaporate, and mixing in a drop of glycerol. A cover glass was placed on top and sealed with fingernail polish. A minimum count of 200 pollen grains was made for each sample at 400 × .

One important detail relates to identification of maize pollen. Many of the maize pollen grains were broken and torn by food processing. To prevent overcounting maize pollen, only fragments that exhibited an annulus were counted. Each maize pollen grain has only one annulus. Therefore, by counting only fragments with annuli, we prevented overcounting maize pollen.

Table B1. Coprolites analyzed from Antelope Cave by laboratory and field specimen (FS) numbers

Lab no.	FS/excavation unit/depth in inch level	Weight (g)	Weight of macro residue (g)	No. *Lycopodium* tablets added
Human coprolites:				
1	2487/AC59-4/30–36	3.66	1.65	4
2	1516/AC59-2/24–30	2.67	1.23	3
3	617/AC59-1/30–36	15.77	8.76	8
4	2302/AC59-4/6–12	6.39	3.55	6
5	2103/AC59-3/12–18	30.55	14.17	15
7	644/AC59-2/0–6	5.32	2.45	3
9	3172/AC59-5/12–18	7.0	3.42	4
10	3557/AC59-5/18–24	5.77	2.96	3
11	54/surface find	2.56	1.59	3
12	153-294a/B/24–36	1.84	.93	2
13	153-294b/B/24–36	2.51	1.55	3
14	617/AC59-1/30–36	8.02	4.58	4
15	1516/AC59-2/24–30	3.07	5.35	3
16	641/AC59-2/0–6	3.95	1.28	4
17	2103/AC59-3/12–18	29.27	16.32	15
18	2487/AC59-4/30–36	2.6	1.13	3
19	3557/AC59-5/18–24	2.97	1.53	3
20	3957/AC59-5/24–30	6.78	4.07	7
21	4874/AC59-5/36–42	.2	.06	1
23	244-000/surface find	10.25	5.49	5
Sediment sample, noncoprolite:				
22	244-4547/AC59-5/36–42	14.49	...	7
Animal coprolites:				
6	153-294/B/24–36	7.54	...	4
8	2955/AC59-5/6–12	7.46	...	4
A1	153-262/B/12–24	8.18	...	4
A2	4773/AC59-5/48–54	10.85	...	5

Note. Weight and *Lycopodium* data are not available for Fundação Oswaldo Cruz 616 and 643 because dietary analysis of these samples is in progress.

Reference Cited Only in Supplement B

Reinhard, Karl J., Sherrian K. Edwards, Teyona R. Damon, and Debra K. Meier. 2006. Pollen concentration analysis of Ancestral Pueblo dietary variation. *Palaeogeography, Palaeoclimatology, and Palaeoecology* 237:92–109.

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Supplement C from Reinhard et al., "Understanding the Pathoecological Relationship between Ancient Diet and Modern Diabetes through Coprolite Analysis"

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Results

Preservation

The only decomposer insects discovered in the analysis were spider beetles, which were found in six coprolites. These never amounted to more than a trace of a gram, and never more than three were recovered from a coprolite sample. No invertebrate burrows were observed in the coprolites. No fly remains were found. Some mites were noted in microscopic analysis, but these were few and may have been ingested with plant food. No free-living nematodes were found. These observations attest to the excellent preservation of the Antelope Cave coprolites. Spider beetles prefer dry substrates. Flies and nematodes prefer moist substrates. The presence of a few beetles and the absence of flies and nematodes shows that the coprolites desiccated rapidly.

Diet

The dietary results are presented in the tables in this supplement. The definition of terms used in data tables is presented in tables C1 and C2. The data for microresidues is presented in tables C3–C8, and the macroresidue results are in tables C9–C13. The pollen counts and concentrations are presented in tables C14–C24. These results for the human coprolites are summarized below. Coprolites 6 and 22 are omitted from these results because analysis revealed that they were not human coprolites. Number 6 was an animal coprolite, and number 22 was consolidated cave sediment.

Coprolite laboratory number 1, FS 2487, is composed macroscopically of prickly pear pad fragments with traces of whole dropseed (*Sporobolus*) caryopses. The microfossils independent of pollen are exclusively from prickly pear. The pollen count is dominated by grass. This shows a meal of prickly pear pads, which were most likely roasted as evidenced by the heat-altered white appearance of epidermal fragments. The dropseed seeds and pollen could be from an earlier meal of caryopses eaten off of the plant without processing or cooking.

Coprolite laboratory number 2, FS 1516, is composed mostly of finely ground maize kernels, finely ground sunflower achenes, unknown plant epidermis and fiber, and bone. The bone is highly fragmented and eroded. The microfossils are dominated by maize starch with grass stem/epidermis fragments. There are traces of ring structures from prickly pear vascular bundles. The pollen has some cottonwood-type grains, but this type presents a problem because cottonwood can resemble many other spores and pollen from other taxa. This coprolite represents a meal of highly processed maize and probably rabbit apparently eaten together, perhaps in a stew, which would explain the erosion of the bone fragments. The maize was not extensively cooked because the maize starch is in a pristine form.

Coprolite laboratory number 3, FS 617, is composed macroscopically of a mix of finely ground sunflower achenes and bone. The bone is fragmented and eroded rabbit or rodent bone. Microscopically, sunflower fragments dominate the remains. The microfossil residue is rich in fibers, sunflower achene fragments, and seed coat fragments to the point that we could not estimate the actual numbers of them. Palynologically, the higher grass and cheno-am pollen concentrations could be influenced by earlier meals. This represents a meal of highly processed sunflower and fragmented small mammals, apparently eaten together, perhaps in a stew. The flour made of sunflowers would have been nearly inedible unless processed into a stew.

Coprolite laboratory number 4, FS 2302, is composed of feather calami (quill bases), whole wolfberry seeds from fruit, coarsely ground maize, and fragmented bone probably from rabbit. The nonpollen microremains are diverse. Round starch granules averaging 18 μm in diameter with hila dominate the microscopic spectrum. These are probably from maize. Leaf epidermis fragment, grass epidermis, and xylem tracheids represent grasses and other vegetation. Prickly pear is represented by glochidia fragments and ring structures. Traces of sunflower achene fibers are also present. Palynologically, wild grass dominates the pollen spectrum. It may be that this coprolite represents a meal of bird and perhaps small-animal meat eaten with maize and wolfberry fruit. Wolfberry must be cooked to disperse poisonous compounds. This

may have been a stew, but it was not highly cooked because none of the 297 observed starch granules exhibit heat alteration. The prickly pear, sunflower, and other grass residues are from previous meals.

Coprolite laboratory number 5, FS 2103, is composed macroscopically of very finely ground plant residue, highly fragmented animal bone, finely ground dropseed, and an unidentified grass seed. The pollen is dominated by grass. The nonpollen microfossils are dominated by cactus calcium oxalate cactus druses and cactus glochidia. The druses and glochidia are from a type of cactus that is new to us. The absence of starch in this sample suggests extensive cooking in water, which would have destroyed the starch. Therefore, it may be that this was a stew of animal meat, bone, and ground dropseed.

Coprolite laboratory number 7, FS 644, macrofossils were dominated by fragmented bone and very finely ground maize. Microscopically, unidentifiable plant residue dominated the count. This sample appears to be derived from a combination of maize flour and small mammal, possibly eaten together in the form of a stew or soup. It appears that this was highly cooked in water because only one starch granule, a cooked maize grain, was observed. The pollen analysis revealed small amounts of wind-pollinated background types.

Coprolite laboratory number 9, FS 3172, is composed of fragmented bone and finely ground unidentifiable seed. The microscopic analysis shed no light on the origin of the seed. This is an enigmatic sample except that it is a repeat of the association of fragmented small-mammal bone with finely ground seed that is common in Antelope Cave coprolites. The pollen suggests the intentional use of sagebrush, *Artemisia*. There is a high concentration of sagebrush pollen and pollen aggregates of this taxon. Sagebrush is toxic to humans, but it is also medicinal. Treatments made of sagebrush taken internally kill intestinal worms and have an antibacterial effect. It was also used to treat internal bleeding (Tilford 1997).

Coprolite laboratory number 10, FS 3557, shows only prickly pear pad parts, both macroscopically and microscopically. The masses of fiber in this sample are probably from prickly pear. The prickly pear epidermis is whitened and made brittle by heat exposure and probably represents roasted prickly pear. The pollen analysis shows low concentrations of a diversity of pollen types but does not suggest economic use of these taxa.

Coprolite laboratory number 11, FS 54, is dominated by crushed seed, possibly four-winged saltbush with traces of bone fragments. Microscopically, there is an abundance of conductive vascular tissue from plants. Pollen analysis does not help identify the origin of the seed. Only small amounts of background types are present.

Coprolite laboratory number 12, FS 153-294a, is dominated macroscopically and microscopically by maize with traces of fragmented bone. The condition of maize starch shows that these foods were cooked. Of 220 observed maize starch granules, 219 show alteration due to cooking. Therefore, it appears that this is the result of eating a stew of maize and small-animal meat and bone. Interestingly, no maize pollen was recovered from this coprolite.

Coprolite laboratory number 13, 153-294b, is dominated macroscopically and microscopically by finely ground dropseed. There is also a lesser amount of crushed unknown seed similar to four-winged saltbush, probably from a previous meal. There is a high concentration of wild-grass pollen and aggregates of wild-grass pollen. This indicates that wild grass was consumed. There are traces of prickly pear in the form of microscopic glochidia, probably from a previous meal.

Coprolite laboratory number 14, FS 617, is dominated macroscopically and microscopically by ground sunflower achenes. There are also traces of bone and traces of cheno-am seeds. It is likely that the cheno-am seeds are from a previous meal, and a stew or soup of sunflower and small mammal was the meal most represented by this coprolite. Cheno-am pollen aggregates are present in this coprolite. Poaceae aggregates may be the residue of a previous meal of wild-grass seed.

Coprolite laboratory number 15, FS 1516, is a very difficult coprolite to interpret. There is fragmented small-mammal bone. However, the majority of the macroscopic and microscopic remains are of black granular material composed of carbon mixed with plant tissue. This could be from parching plant foods with hot coals. The pollen reveals one grass-pollen aggregate of two grains, but this is not significant.

Coprolite laboratory number 16, FS 641, is dominated macroscopically and microscopically by ground sunflower achenes. There is also fragmented small-mammal bone. This is a mixture of sunflower flour and crushed animal. Like coprolite 3, I believe these foods must have been a stew, because a flour made of sunflowers would have been nearly inedible. This coprolite is unique in that pollen was nearly absent. Extensive examination of several microscopic preparations reveal only one pollen grain. The absence of ambient pollen is very interesting. It might be that this coprolite was deposited in the cave at a time of low pollination, possibly winter.

Coprolite laboratory number 17, FS 2103, is dominated by fragmented small-mammal bone, jackrabbit claws, and extremely finely ground dropseed. Microscopically, there are hundreds of starch granules that are not birefringent. This appears to be a stew or soup made from ground grass and fragmented small mammal. There is a high concentration of wild-grass pollen with aggregates. This pollen was ingested with the seeds and inflorescences.

Coprolite laboratory number 18, FS 2487, is like coprolite 15. Fragmented bone appears with ash mixed with plant residue in a black granular substrate. The advantage with his coprolite is that there was some material liberated from the

aggregates. There was some coarsely ground maize. Microscopically, cactus glochidia and conductive plant tissue was clumped with ash with a few ring structures. This suggests that prickly pear pads were roasted, which resulted in the incorporation of ash or perhaps parched maize with prickly pear. Eleven thousand maize pollen grains per gram of coprolite were recovered. The majority of these are torn and fragmented from grinding. Three termites were found and may reflect dietary use of these insects.

Coprolite laboratory number 19, FS 3557, revealed macroscopic remains of fragmented small-mammal bone, tufts of jackrabbit hair, and aggregates of prickly pear epidermis with fiber and phytoliths. Microscopically, glochidia and prickly pear druses were the most common remains. This indicates that rabbit and prickly pear were eaten together. Wandsnider (1997) reviewed the method of cooking in Plains roasting pits and notes that plants and rabbits were roasted together. It appears that the composition of this coprolite, including hair, represents the preparation of rabbit and prickly pear together. Interestingly, 50,000 pollen grains of maize per gram of coprolite were evidenced by the pollen analysis. About half of these are torn. Thus, the pollen evidence shows that maize was eaten, probably independently and previously to the prickly pear and rabbit.

Coprolite laboratory number 20, FS 3957, is composed of finely ground cheno-am fruits associated with ground dropseed caryopses. Microscopically, remains of cheno-am and Poaceae dominate, although there are traces of sunflower. The pollen spectrum was dominated by wild grass, and many wild-grass pollen aggregates were noted. This appears to have been a seed cake or stew.

Coprolite laboratory number 21, FS 4874, contains a diversity of items and shows that analysis of even a small coprolite reveals a variety of information. Macroscopically, dropseed caryopses and prickly pear phytoliths dominate. Microscopically, there is a diversity of starch. Both cooked and uncooked maize starch is present. In addition there are two other starch forms from unknown plants and a variety of anatomical elements of prickly pear structures and grass. This represents as many as three dietary episodes of prickly pear, maize, and dropseed. The pollen spectrum was dominated by wild grass, and many wild-grass pollen aggregates were noted.

Coprolite laboratory number 23, FS 244-2256, is an association of fragmented small-animal bone and very finely ground cheno-am. Cheno-am seed coats and a variety of starch granules are evident microscopically. Nearly 70,000 cheno-am pollen grains were recovered per gram of coprolites, some of which were aggregates. Again, this appears to be an association of seed and meat in a stew or soup.

Table C1. Definition of terms applied to microscopic remains

Term	Definition
Lycopodium	Exotic spores of arctic clubmoss added for quantification
Animal hair	Nonhuman hair
CaC_2O_4 druse	Calcium oxalate phytolith probably from cactus
CaC_2O_4 opuntioid druse	Calcium oxalate phytolith from prickly pear
Cheno-am macrofossils and nonpollen microfossils	Seeds that could be from plants in either the genera *Chenopodium* or *Amaranthus* or less likely *Cycloloma*
Cheno-am pollen	Pollen grains that could be from either the family Chenopodiaceae or the genus *Amaranthus*
Cell containing starch	Starch granules found within isolated plant cell
Clump of mineralized plant structures in ash	Curious association of any type of plant remain, primarily from CaC_2O_4 or silicified origins. They represent the most durable plant structures
Glochidia	Stellate, microscopic, recurved spines associated with cactus areoles and specific to cacti
Glochidium fragment	Glochidia are fragile and break into their component spines. These are individual spines
Helianthus achene fibers	Achenes are the simple fruits produced by the sunflower family and a few other families. These are consistent with very small sunflower fruits
Arthropod fragment	Fragments of exoskeleton of insects or other small arthropods
Leaf epidermis fragment	Segments of plant epidermis with stomata
Phloem sieve-tube element	Isolated sieve-tube members from the phloem that conduct food materials in plants
Phloem with sieve-tube element	Segment of phloem with sieve-tube elements, companion cells, and other phloem components
Phytolith, unknown	Phytolith that cannot be identified to plant or plant structure
Plant epidermis, unknown	Epidermis that shows unknown morphology
Plant fiber	Long tapered fibers from xylem or phloem
Plant fiber bundle	Fibers arranged parallel in plant-tissue sections

Plant hair	Small hair-like structures called trichomes derived from plant epidermal cells
Plant hair, mineralized	As above but mineralized into phytoliths
Poaceae epidermis	Epidermis from grass
Poaceae leaf epidermis	Grass epidermis with stomata
Poaceae long cell	Long dendritic epidermal cell phytolith from grass
Raphide	CaC_2O_4 needle-shaped phytolith found in several plant families
Raphide bundle	Mass of raphides arranged in parallel
Ring structure with interference cross	Birefringent doughnut-shaped structures arranged in columns within tubes and here found only in cactus and specifically prickly pear
Seed coat fragment	Seed testa unidentifiable to plant taxon
Seed coat (cheno-am?)	Seed coats from many species of the goosefoot family or some species of the pigweed family
Seed testa, light color	Seed testa perhaps from ground grass or maize
Starch, indeterminate	Very small starch grains with no distinct features
Starch, cheno-am	Faceted granules 5 μm in diameter with hila and found in aggregates
Starch without interference cross	Medium-sized spheroidal granules 10–20 μm in diameter that are not birefringent. All other starch are birefringent
Starch, 15 μm, round, no hilum	Distinctive starch of an unknown source
Starch, 15 μm, round, monocolpate	Distinctive starch of an unknown source that has a single groove on the surface
Starch, 15 μm, faceted, with hilum	Distinctive starch of an unknown source
Starch, 18 μm, round, with hilum	Distinctive starch of an unknown source
Starch, 11 μm, round, with large hilum	Distinctive starch of an unknown source
Starch, *Zea* cooked	Maize starch that is altered by heat. The stellate hila widen in these examples, and some are partly destroyed
Starch, *Zea* uncooked	Maize starch that retains pristine characteristics of irregular spheroid shape, stellate hilum, and birefringency
Starch, *Zea* cooked, large clump of 200+ granules	Mass of cooked maize starch
Starch, tuber aggregate	Aggregate of faceted starch granules of various sizes 5–15 μm that are most consistent with starch from tubers
Xylem section	Columns of conductive tissue with identifiable tracheids and vessel elements. These are not identifiable to taxon. Their abundance reflects how much plant stem and leaves were eaten
Xylem tracheid	Helical, often mineralized, structures. These conduct nutrients in plants
Xylem tracheid, double helical	As above except that the tracheids are paired in double helices
Opuntia cuticle	Fragments of the waxy coating covering prickly pear pads
Yucca phytolith	Wedge-shaped CaC_2O_4 phytoliths consistent with the Agavaceae family of which *Yucca* is best represented in the Antelope Cave area
Unidentified plant tissue	Plant residue with no distinctive features

Table C2. Definitions of terms applied to macroscopic remains

Component	Definition
<.5-mm category	Very finely ground material
>.5–<1.0-mm category	Finely ground material
>1.0-mm category	Ground material
Aggregates of macroscopic remains	Masses of consolidated seeds, bones, and fibers that did not disaggregate during coprolite processing. The percent composition of the aggregates was estimated
Ant	An ant head, probably a cave contaminant
Ash mixed with plant residue	Residue of food preparation, possibly from the use of parching trays, which mixes food with ash
Black granular material	Apparently charcoal
Bone	Bone from human coprolites was highly fragmented and eroded from preparation and digestion
Cactus glochidia	Stellate arrangements of recurved spines from cacti
Cactus thorn	Modified leaf from a cactus
Charcoal	Small charcoal fragment from tree or shrub
Cheno-am	Seeds of the goosefoot family or pigweed genus. These seeds are most likely from the goosefoot genus *Chenopodium*

Claws, rabbit	Claws from jackrabbit, not a contaminant
Cottonwood?	Unusual white plant fiber attached to a woody matrix
Dropseed	Seed morphology consistent with *Sporobolus* caryopses
Feather	Down feather
Feather calami	Bases of feather quills
Fiber	Undistinct masses of fiber
Fiber, <.5 mm in smallest dimension	Finely ground fiber, which indicates that plant stems were ground and eaten
Fur tuft, *Lepus*	Microscopic examination shows that these tufts are from jackrabbit
Spider beetle	From the Ptinidae family of beetles, which are general scavengers of dry substrates. Found commonly in coprolites and mummies. They burrow into coprolites and leave long, narrow holes that allow for contaminants to enter the coprolite matrix
Grass stem	A whole stem fragment
Hair	Nonhuman hair
Maize	Corn kernel testa
Prickly pear	Two or more prickly pear anatomical parts adhered together, including glochidia, phytoliths, epidermis, and fiber
Prickly pear epidermis	Thick, brittle epidermis with classic pattern of CaC_2O_4 opuntioid druses in each cell. Color ranges from light tan to white
Prickly pear phytoliths	CaC_2O_4 opuntioid druses exceeding .25 mm in diameter
Sunflower seed	Actually the ground achenes of sunflower or related genus including the outer fruit wall and seed
Tick	*Dermacentor andersoni* exoskeleton
Twig fragments	Woody stem fragments
Unidentifiable seed	Seed that is so finely ground that no identifiable morphology is visible to make an identification
Unidentified arthropod	Curved, spiny, exoskeleton similar to an isopod
Unknown seed	Highly fragmented seeds similar to four-winged saltbush (*Atriplex* species, but this is not a positive identification). May also have an arboreal origin
Whole dropseed	Caryopses similar but smaller than sand dropseed *Sporobolus cryptandrus*
Whole wolfberry seeds	Seeds from wolfberry fruits, probably *Lycium pallidum*
Yucca fiber	Fiber with distinct groove consistent with *Yucca*

Table C3. Microscopic counts from human coprolites

	Lab no.								
Material	1	2	3	4	5	7	9	10	11
Lycopodium	5	9	2	23	7	1	1	4	34
Animal hair									2
CaC_2O_4 druse					5*				
CaC_2O_4 opuntioid druse	93						1		
Cell containing starch									
Clump of mineralized plant structures in ash									
Enterobius egg fragment?									1
Glochidia, mineralized								55	
Glochid fragment, mineralized					6	4			
Helianthus achene fibers			∞	5			54		
Insect fragment									
Leaf epidermis fragment				25					1
Phloem sieve-tube element		1						6	4
Phloem with sieve-tube element						7			2
Phytolith, unknown		3							
Plant epidermis, unknown						1			
Plant fiber									78
Plant fiber bundle									12
Plant hair				28					15
Plant hair, mineralized									
Poaceae epidermis		3		16	16				
Poaceae leaf epidermis									3
Poaceae long-cell phytolith		6						2	
Raphide									4
Raphide bundle									1
Ring structure with interference cross	84	6		2					1
Seed coat fragment			∞						
Seed testa, light color							128		
Starch, 15 μm, round, no hilum							1		

Starch, 15 μm, round, monocolpate								1		
Starch, 15–20 μm, round, with hilum				297						6
Starch, 11 μm, round, with large hilum	1									
Starch, *Zea* cooked							1			
Starch, Zea uncooked		22								
Xylem section		1			28		5	61	6	
Xylem tracheid	56	10		16	2		1	89	62	
Xylem tracheid, double helical								2		
Opuntia cuticle									6	
Yucca phytolith									1	
Unidentified plant tissue						201				

Note. Samples 6 and 8 are excluded because they are canid in origin. ∞ = masses observed, too numerous to count; * = square plate projections on druses.

Table C4. Microscopic counts from human coprolites

	Lab no.										
Material	12	13	14	15	16	17	18	19	20	21	23
Lycopodium	2	6	3	19	4	2	13	2	32	32	6
Animal hair	10			12				2			
CaC_2O_4 opuntioid druse				2		1		14			
Cell containing starch	1										
Clump of mineralized plant structures in ash				137			92				
Glochid, mineralized	1						7	2			
Glochid fragment, mineralized							88	48		2	
Helianthus achene fibers			180		175				7		
Insect fragment				1							
Leaf epidermis fragment		1									
Phloem sieve-tube element				2			5	6			
Phloem with sieve-tube element				24			6			5	
Plant epidermis, unknown				4			2		4		1
Plant fiber						1				10	
Plant fiber bundle											6
Plant hair						3					
Plant hair, mineralized		23		13							
Poaceae epidermis		177	5			5			14	57	
Poaceae leaf epidermis		1						10			
Poaceae long-cell phytolith		2						2	1	1	
Raphide bundle				2			1			6	
Ring structure with interference cross		3		4			4			105	
Seed coat fragment		5	29								
Seed coat, cheno-am?			12						10		212
Seed testa, light color									173	1	1
Starch, indeterminate				2							3
Starch, cheno-am				1							
Starch without interference cross						215					
Starch, 10–15 μm, round, no hilum		1									
Starch, 10–15 μm, faceted, with hilum							3			1	
Starch, 18–22 μm, round, with hilum										1	
Starch, 10–15 μm, round, with large hilum					2						
Starch, *Zea* cooked	219			1			1			1	
Starch, *Zea* uncooked	1						1		1	4	
Starch, *Zea* cooked, large clump (200)	1										
Starch, tuber aggregate	2										
Xylem section				1		7	5	10	6	8	
Xylem tracheid	1		2	9			12		2	18	
Xylem tracheid, double helical								192			
Opuntia cuticle				1						1	

Note. The two tuber starch aggregates from sample 12 were composed of 11 and 13 individual starch grains.

Table C5. Microfossil concentration values from human coprolites

	Lab no.				
Material	1	2	3	4	5
Lycopodium spores per gram of coprolite	13,661	14,044	6,341	11,737	6,137
Lycopodium	5	9	2	23	7
CaC_2O_4 druse					4,384
CaC_2O_4 opuntioid druse	253,164				
Glochid fragment, mineralized					5,260
Helianthus achene fibers			∞	2,552	
Leaf epidermis fragment				12,758	
Phloem sieve-tube element		1,560			
Phytolith, unknown		4,681			
Plant hair				14,289	
Poaceae epidermis		4,681		8,165	14,027
Poaceae long-cell phytolith		9,363			
Ring structure with interference cross	229,504	9,363		1,021	
Seed coat fragment			∞		
Starch, 15–20 μm, round, with hilum				151,560	
Starch, 11 μm, round, with large hilum	2,732				
Starch, *Zea* uncooked		34,330			
Xylem section		1,560			24,548
Xylem tracheid	153,003	15,604		8,165	1,753

Note. ∞ = incalculably high.

Table C6. Microfossil concentration values from human coprolites

	Lab no.				
Material	7	9	10	11	12
Lycopodium spores per gram of coprolite	7,049	7,143	6,499	14,648	13,587
Lycopodium	1	1	4	34	2
Animal hair				860	67,935
CaC_2O_4 opuntioid druse		7,164			
Cell containing starch					6,794
Glochidia, mineralized			88,841		
Glochid fragment, mineralized	28,163				6,794
Helianthus achene fibers		386,845			
Leaf epidermis fragment				430	
Phloem sieve-tube element			9,692	101	
Phloem with sieve-tube element	49,285			860	
Plant epidermis, unknown	7,041				
Plant fiber				33,546	
Plant fiber bundle				5,161	
Plant hair				6,451	
Poaceae leaf epidermis				1,290	
Poaceae long-cell phytolith			3,231		
Raphide				101	
Raphide bundle				430	
Ring structure with interference cross				430	
Seed testa, light color		914,304			
Starch, 15 μm, round, no hilum		7,164			
Starch, 15 μm, round, monocolpate			1,615		
Starch, 15–20 μm, round, with hilum				2,580	143,555
Starch, *Zea* cooked	7,041				6,794
Starch, Zea uncooked					6,794
Starch, *Zea* cooked, large clump (200)					13,587
Xylem section		35,819	98,533	2,580	
Xylem tracheid		7,164	143,761	26,665	6,794
Xylem tracheid, double helical			3,231		
Opuntia cuticle				2,580	
Yucca phytolith				430	
Unidentified plant tissue	1.42×10^6				

Table C7. Microfossil concentration values

	Lab no.				
Material	13	14	15	16	17
Lycopodium spores per gram of coprolite	14,940	6,234	12,214	12,658	6,406
Lycopodium	6	3	19	4	2
Animal hair			7,714		
CaC_2O_4 opuntioid druse			3,214		3,203
Clump of mineralized plant structures in ash			12,214		
Helianthus achene fibers		374,040		553,788	
Insect fragment			643		
Leaf epidermis fragment	2,490				
Phloem sieve-tube element			1,286		
Phloem with sieve-tube element			15,428		
Plant epidermis, unknown			2,571		
Plant fiber					3,203
Plant hair					9,609
Plant hair, mineralized	57,270		8,357		
Poaceae epidermis	440,730	10,390			16,015
Poaceae leaf epidermis	2,490				
Poaceae long-cell phytolith	4,980				
Raphide bundle			1,286		
Ring structure with interference cross	7,470		2,571		
Seed coat fragment	12,450	60,262			
Seed coat, cheno-am?		24,936			
Starch, indeterminate			1,286		
Starch, cheno-am			643		
Starch without interference cross					688,645
Starch, 10–15 μm, round, no hilum	2,490				
Starch, 10–15 μm, round, with large hilum				6,329	
Starch, *Zea* cooked			643		
Xylem section			643		22,421
Xylem tracheid		4,156	5,786		
Opuntia cuticle			643		

Note. The two tuber starch aggregates from sample 12 were composed of 11 and 13 individual starch grains.

Table C8. Microfossil concentration values

	Lab no.				
Material	18	19	20	21	23
Lycopodium spores per gram of coprolite	14,423	12,626	12,906	62,500	6,098
Lycopodium	13	2	32	32	6
Animal hair		12,626			
CaC_2O_4 opuntioid druse		88,382			
Clump of mineralized plant structures in ash	102,070				
Glochid, mineralized	7,766	12,626			
Glochid fragment, mineralized	97,633	303,024		3,906	
Helianthus achene fibers			2,823		
Phloem sieve-tube element	5,547	151,512			
Phloem with sieve-tube element	4,555			9,766	
Plant epidermis, unknown	1,518		1,613		1,016
Plant fiber				19,531	
Plant fiber bundle					6,098
Poaceae epidermis			14	111,328	
Poaceae leaf epidermis		63,130			
Poaceae long-cell phytolith		12,626	403	1,953	
Raphide bundle	759			11,719	
Ring structure with interference cross	3,036			205,078	
Seed coat, cheno-am?			4,033		215,463
Seed testa, light color			69,773	1,953	1,016
Starch, indeterminate					3,049
Starch, 10–15 μm, faceted, with hilum	2,277			1,953	
Starch, 18–22 μm, round, with hilum				1,953	
Starch, *Zea* cooked	759			1,953	

Starch, *Zea* uncooked	759		403	7,813
Xylem section	3,796	12,626	2,420	15,625
Xylem tracheid	9,109		807	35,156
Xylem tracheid, double helical		1.21×10^6		
Opuntia cuticle				1,953

Table C9. Macroscopic remains (weight in grams)

	Lab no.			
Component	1	2	3	4
Bone, <.5 mm				
Bone, >.5–<1.0 mm				
Bone, >1.0 mm		.34	Trace	.67
Charcoal		.02		
Cottonwood?		Trace		
Feather calami				.01
Ground dropseed, <.5 mm				
Ground dropseed, >.5–<1.0 mm				
Ground dropseed, >1.0 mm	.3			
Ground maize, <.5 mm				
Ground maize, >.5–<1.0 mm		.77		1.1
Ground maize, >1.0 mm		.07		1.27
Ground sunflower seed, <.5 mm				
Ground sunflower seed, >.5–<1.0 mm			7.51	
Ground sunflower seed, >1.0 mm		.01	1.24	
Ground unidentifiable seed, <.5 mm				
Ground unidentifiable seed, >.5–<1.0 mm				
Ground unidentifiable seed, >1.0 mm				
Ground unknown seed, <.5 mm				
Ground unknown seed, >.5–<1.0 mm				
Ground unknown seed, >1.0 mm				
Prickly pear, >.5–<1.0 mm				
Prickly pear, >1.0 mm	.94			
Prickly pear phytoliths, <.5 mm	.4			
Spider beetle		Trace		
Tick		Trace		
Twig fragments			Trace	
Whole dropseed	Trace			
Whole wolfberry seeds				.5
Yucca fiber		Trace		

Table C10. Macroscopic remains (weight in grams)

	Lab no.			
Component	5	7	9	10
Aggregates of macroscopic remains	4.06[a]	.81[b]		
Bone, <.5 mm				
Bone, >.5–<1.0 mm	.19		.04	
Bone, >1.0 mm	1.71	.1	.76	
Cactus glochidia	Trace			Trace
Charcoal	Trace			
Cottonwood?				
Fiber, >.5–<1.0 mm				.85
Fiber, <.5 mm				1.82
Fiber, >1.0 mm				.28
Fruit skin or corn testa				Trace
Ground dropseed, <.5 mm	6.43			
Ground dropseed, >.5–<1.0 mm	1.67			
Ground dropseed, >1.0 mm				
Ground maize, <.5 mm		.56		
Ground maize, >.5–<1.0 mm		.42		
Ground maize, >1.0 mm		.28		

Ground sunflower seed, <.5 mm				
Ground sunflower seed, >.5–<1.0 mm				
Ground sunflower seed, >1.0 mm				
Ground unidentifiable seed, <.5 mm			.41	
Ground unidentifiable seed, >.5–<1.0 mm			.38	
Ground unidentifiable seed, >1.0 mm			1.83[c]	
Ground unknown seed, <.5 mm				
Ground unknown seed, >.5–<1.0 mm				
Ground unknown seed, >1.0 mm				
Prickly pear, >.5–<1.0 mm				
Prickly pear, >1.0 mm				
Prickly pear epidermis	.1			
Prickly pear phytoliths, <.5 mm				

[a]Mostly dropseed.
[b]Mostly maize.
[c]Unidentifiable seed.

Table C11. Macroscopic remains (weight in grams)

	Lab no.			
Component	11	12	13	14
Aggregates of macroscopic remains				
Bone, <.5 mm	.05			
Bone, >.5–<1.0 mm				Trace
Bone, >1.0 mm		.13		
Cactus glochidia				
Crushed unknown seed, <.5 mm	.36			
Crushed unknown seed, >.5–<1.0 mm	.42			
Crushed unknown seed, >1.0 mm	.76		.12	
Fiber, >.5–<1.0 mm				
Fiber, <.5 mm				
Fiber, >1.0 mm				
Fruit skin or corn testa				
Grass stem				Trace
Ground cheno-am, <.5 mm				
Ground cheno-am, >.5–<1.0 mm				Trace
Ground cheno-am, >1.0 mm				
Ground dropseed, <.5 mm			.18[a]	
Ground dropseed, >.5–<1.0 mm			1.04[a]	
Ground dropseed, >1.0 mm			.21[a,b]	
Ground maize, <.5 mm		.06		
Ground maize, >.5–<1.0 mm		.07		
Ground maize, >1.0 mm		.67		
Ground sunflower seed, <.5 mm				.04
Ground sunflower seed, >.5–<1.0 mm				.93
Ground sunflower seed, >1.0 mm				3.59
Ground unidentifiable seed, <.5 mm				
Ground unidentifiable seed, >.5–<1.0 mm				
Ground unidentifiable seed, >1.0 mm				
Prickly pear, >.5–<1.0 mm				
Prickly pear, >1.0 mm				
Prickly pear epidermis				
Prickly pear phytoliths, <.5 mm				
Spider beetle		Trace		Trace
Tick				
Whole dropseed				
Wolfberry seeds				
Yucca fiber				

[a]Composed of ground seed, bracts, and stem.
[b]Aggregates of ground seed, bracts, and stem.

Table C12. Macroscopic remains (weight in grams)

	Lab no.			
Component	15	16	17	18
Aggregates of macroscopic remains				
Ash mixed with plant residue, <.5 mm				.14
Ash mixed with plant residue, >.5–<1.0 mm				.17
Ash mixed with plant residue, >1.0 mm				.35
Black granular material, <.5 mm	.14			
Black granular material, >.5–<1.0 mm	.31			
Black granular material, >1.0 mm	.9			
Bone, <.5 mm				
Bone, >.5–<1.0 mm		.02	1.46	
Bone, >1.0 mm	.24[a]		2.73	.17
Cactus glochidia				
Cactus thorn			Trace	
Charcoal				
Claws, rabbit			.06	
Cottonwood?				
Feather	Trace		Trace	
Fiber, <.5 mm in smallest dimension	.11			.05
Fur tuft, *Lepus*	Trace			
Grass stem	Trace			
Ground cheno-am, <.5 mm				
Ground cheno-am, >.5–<1.0 mm				
Ground cheno-am, >1.0 mm				
Ground dropseed, <.5 mm			5.9[b]	
Ground dropseed, >.5–<1.0 mm			1.24[b]	
Ground dropseed, >1.0 mm			3.7[b,c]	
Ground maize, <.5 mm	.03			.05
Ground maize, >.5–<1.0 mm	.08			.02
Ground maize, >1.0 mm	1.01			.17
Ground sunflower seed, <.5 mm		.84		
Ground sunflower seed, >.5–<1.0 mm		.39		
Ground sunflower seed, >1.0 mm		.37[d]		
Ground unknown seed, <.5 mm				
Ground unknown seed, >.5–<1.0 mm				
Ground unknown seed, >1.0 mm				
Hair			.05	
Spider beetle	Trace		Trace	Trace
Termites ($n = 3$)				Trace
Tick	Trace			
Unidentifiable			1.16	

[a]Apparently juvenile or embryonic.
[b]Mixed seed, bracts, and stem.
[c]Weight estimated from aggregates.
[d]In the form of aggregates.

Table C13. Macroscopic remains (weight in grams)

	Lab no.			
Component	19	20	21	23
Aggregates of macroscopic remains		1.12[a]		
Ant				
Bone, <.5 mm				
Bone, >.5–<1.0 mm				
Bone, >1.0 mm	.11			.13
Feather				
Fiber	.1			
Fiber, <.5 mm in smallest dimension		.03		
Fur tuft, *Lepus*	.19			
Grass stem		Trace[b]		
Ground cheno-am, <.5 mm		.65		3.82

Ground cheno-am, >.5–<1.0 mm		.15		.44
Ground cheno-am, >1.0 mm				1.03
Ground dropseed, <.5 mm		1.43[c]		
Ground dropseed, >.5–<1.0 mm		.15	.01[c]	
Ground dropseed, >1.0 mm				
Ground maize, <.5 mm				
Ground maize, >.5–<1.0 mm				
Ground maize, >1.0 mm				
Ground sunflower seed, <.5 mm				
Ground sunflower seed, >.5–<1.0 mm				
Ground sunflower seed, >1.0 mm				
Ground unidentifiable seed, <.5 mm				
Ground unidentifiable seed, >.5–<1.0 mm				
Ground unidentifiable seed, >1.0 mm				
Ground unknown seed, <.5 mm				
Ground unknown seed, >.5–<1.0 mm				
Ground unknown seed, >1.0 mm				
Hair				
Prickly pear, >.5–<1.0 mm	.27[d]			
Prickly pear, >1.0 mm	.17			
Prickly pear phytoliths with fiber, <.5 mm	.68		.05[e]	
Spider beetle				
Tick				
Unidentifiable		.54		.07
Whole dropseed	Trace			

[a]Aggregates of crushed seed and fiber.
[b]Cut grass stem.
[c]Includes seed, bracts, and fibers.
[d]Phytoliths and fiber.
[e]Includes epidermis.

Table C14. Pollen counts from coprolites

	Lab no.				
Material	1	2	3	4	5
Lycopodium spores	134	876	123	84	35
Ambrosia type	6	8	2	3	
Artemisia	10	6	32	5	10
Celtis		5			
Cheno-am	22	10	32	10	6
Ephedra sp.		1	1	2	1
Ephedra viridis					1
Ephedra torreyana	3				
Eriogonum				1	
Fabaceae	2				
Helianthus type		4			
High-spine Asteraceae			1	1	
Juniperus	6	3	1		
Low-spine Asteraceae	7	7	18	5	1
Maize, torn		5		1	
Maize, whole	1	3		1	
Onagraceae		1			
Pinus	3	6	1	1	1
Poaceae	140	10	123	167	173
Polygonum				1	
Populus type	2	13			
Quercus		1			
Rhus		1			1
Salix	1		2		1
Solanaceae type	2	1		1	
Unidentified		4	3		3
Unknown		2			1
Unknown striate stephanoporate	1				
Yucca		1			

Table C15. Pollen counts from coprolites

	Lab no.				
Material	7	9	10	11	12
Lycopodium spores	159	27	106	100	100
Ambrosia type	1		7	2	
Artemisia	2	182	23	1	
Cheno-am	4		8		
Ephedra torreyana					1
Ephedra nevadensis			1		
Fabaceae			1		
Helianthus type			16		
High-spine Asteraceae			3		
Juniperus			1		
Low-spine Asteraceae		1	2		
Maize, torn		1	1		
Maize, whole	1				
Pinus	5		3		1
Poaceae		31	5	1	1
Populus type			1		
Rosaceae	1				
Salix			2		
Sarcobatus		1			
Sphaeralcea			1		
Unidentified	1	9			

Table C16. Pollen counts from coprolites

	Lab no.				
Material	13	14	15	16	17
Lycopodium spores	17	102	150	100	35
Ambrosia type	1	8			
Artemisia	3	40	1		7
Cheno-am	1	57			2
Ephedra sp.				1	
Ephedra torreyana		1			
Ephedra nevadensis		1			
High-spine Asteraceae		3			1
Low-spine Asteraceae		10			1
Maize, whole			1		
Pinus		1	3		
Poaceae	306	80	1		196
Quercus			1		1
Unidentified		3			2
Unknown			1		

Table C17. Pollen counts from coprolites

	Lab no.				
Material	18	19	20	21	23
Lycopodium spores	259	25	140	93	18
Ambrosia type		2	1		3
Artemisia	1	6	1	2	1
Celtis					1
Cheno-am	3	1	3	2	206
Ephedra viridis				1	
Fabaceae		1			
Helianthus type		5		1	
High-spine Asteraceae		2			
Juniperus					1
Low-spine Asteraceae	1		1		

Maize, torn	172	40			
Maize, whole	26	59			
Pinus		2			
Poaceae	1	113	215	105	13
Quercus	1		1		
Solanaceae type	3				
Unknown striate stephanoporate		1			

Table C18. Pollen concentration values expressed in numbers of pollen grains per category per gram of coprolite

	Lab no.				
Material	1	2	3	4	5
Lycopodium spores per gram	13,661	14,044	6,341	11,737	6,137
Lycopodium counted	134	876	123	84	35
Ambrosia type	612	128	362	419	
Artemisia	1,019	96	5,798	699	1,754
Celtis		80			
Cheno-am	2,243	160	5,798	1,397	1,052
Ephedra sp.		16	181	279	175
Ephedra viridis					175
Ephedra torreyana	306				
Eriogonum				140	
Fabaceae	204				
Helianthus type		64			
High-spine Asteraceae			181	140	
Juniperus	612	48	181		
Low-spine Asteraceae	714	112	3,261	699	175
Maize, torn		80		140	
Maize, whole	102	48		140	
Onagraceae		16			
Pinus	306	96	181	140	175
Poaceae	14,273	160	22,284	23,334	30,337
Polygonum				140	
Populus type	204	208			
Quercus		16			
Rhus		16			175
Salix	102		362		175
Solanaceae type	204	16		140	
Unidentifiable		654	544		526
Unknown		32			175
Unknown striate stephanoporate	102				
Yucca		16			

Table C19. Pollen concentration values expressed in numbers of pollen grains per category per gram of coprolite

	Lab no.				
Material	7	9	10	11	12
Lycopodium spores per gram	7,049	7,143	6,499	14,648	13,587
Lycopodium counted	159	27	106	100	100
Ambrosia type	44		429	293	
Artemisia	89	48,149	1,410	147	
Cheno-am	177		490		
Ephedra torreyana					136
Ephedra nevadensis			61		
Fabaceae			61		
Helianthus type			981		
High-spine Asteraceae			182		
Juniperus			61		
Low-spine Asteraceae		265	123		
Maize, torn		265	61		

Maize, whole	177				
Pinus	222		182		136
Poaceae		8,201	307	147	136
Populus type			61		
Rosaceae	177				
Sarcobatus		265			
Salix			182		
Sphaeralcea			61		
Unidentifiable	177	2,381			

Table C20. Pollen concentration values expressed in numbers of pollen grains per category per gram of coprolite

	Lab no.				
Material	13	14	15	16	17
Lycopodium spores per gram	14,940	6,234	12,214	12,658	6,406
Lycopodium counted	17	102	150		35
Ambrosia type	879	489			
Artemisia	2,636	2,445	81		1,281
Cheno-am	879	3,484			366
Ephedra viridis				127	
Ephedra torreyana		61			
Ephedra nevadensis		61			
High-spine Asteraceae		183			183
Low-spine Asteraceae		611			183
Maize, torn			81		
Pinus		61	244		
Poaceae	268,920	4,889	81		35,874
Quercus			81		183
Unidentified		183			366
Unknown			81		

Table C21. Pollen concentration values expressed in numbers of pollen grains per category per gram of coprolite

	Lab no.				
Material	18	19	20	21	23
Lycopodium spores per gram	14,423	12,626	12,906	62,500	6,098
Lycopodium spores	259	25	140	93	18
Ambrosia type		1,010	91		1,016
Artemisia	56	3,030	91	1,344	339
Celtis					339
Cheno-am	167	505	277	1,344	69,788
Ephedra viridis				672	
Fabaceae		505			
Helianthus type		2,525		672	
High-spine Asteraceae		1,010			
Juniperus					339
Low-spine Asteraceae	56		91		
Maize, torn	9,578	20,202			
Maize, whole	1,448	29,797			
Pinus		1,010			
Poaceae	56	57,070	19,820	70,566	4,404
Quercus	56		91		
Solanaceae type	167				
Unknown striate stephanoporate		505			

Table C22. Pollen aggregates counts

	Lab no.				
Material	1	2	3	4	5
Artemisia					
Cheno-am					
Low-spine Asteraceae				(3)	
Maize	(2)	(2)			
Poaceae	12(2), 6(3), (4), (5), (7), 2(8), (9), (12)	(14)	7(2), 4(3),	4(2), 2(3), (5), (10)	7(2), 2(3), (6), (9)
Populus type		(2), (3), (5)			

Note. Each number in parentheses indicates one clump of the specified number of pollen grains; e.g., (6) = one aggregated clump of six pollen grains. A number in parentheses proceeded by a number without parentheses indicates several aggregated clumps of pollen of the specified number; e.g., 3(6) = three aggregates of six pollen grains each.

Table C23. Pollen aggregates counts

	Lab no.				
Material	9	13	14	15	17
Artemisia	8(2), 2(3), (5), (7)		(3)		(3)
Cheno-am			(4)		
Low-spine Asteraceae					
Maize					
Poaceae		8(2), 5(3), (4), (5), (6), (12)	17(2), 6(3), (4)	(2)	11(2), (3), (5)

Note. Each number in parentheses indicates one clump of the specified number of pollen grains; e.g., (6) = one aggregated clump of six pollen grains. A number in parentheses proceeded by a number without parentheses indicates several aggregated clumps of pollen of the specified number; e.g., 3(6) = three aggregates of six pollen grains each. No aggregates were observed for coprolites 7, 10, 11, 12, and 16.

Table C24. Pollen aggregates counts

	Lab no.				
Material	18	19	20	21	23
Artemisia					
Cheno-am					4(2), (3), (7)
Low-spine Asteraceae					
Maize, torn	(2), 2(3), (4)	2(2), (6)			
Poaceae		2(2), 2(3), (4), (6)	7(2), 3(3), 2(4), (6), (10), (12)	17(2), 3(3), 3(5), (6)	(3), (4), (9)

Note. Each number in parentheses indicates one clump of the specified number of pollen grains; e.g., (6) = one aggregated clump of six pollen grains. A number in parentheses proceeded by a number without parentheses indicates several aggregated clumps of pollen of the specified number; e.g., 3(6) = three aggregates of six pollen grains each.

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