Part III - Parasite Findings in Archeological Remains: a paleogeographic view

21. The Findings in North America

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The Findings in North America

Karl Jan Reinhard

Of Eric Callen, a Canadian botanist, and Thomas Wright Moir Cameron, a parasitologist, launched interest in the study of coprolites. In addition to studies in their specialties, they made pioneering contributions to the study of organic remains preserved in archaeological feces by introducing the technique of rehydration in trisodium phosphate aqueous solution (Callen & Cameron, 1960).

Fry & Hall (1969) compared the rehydration techniques previously used in coprolites, which included distilled water, sodium hydroxide aqueous solution, and others, with trisodium phosphate solution and concluded that the latter was superior. They examined 193 samples dated between 9,500 and 2,000 before present (BP) from Danger Cave, Utah, and found eggs of *Moniliformis clarki* and *Enterobius vermicularis*. The presence of this acanthocephalan species in human feces was discussed by Moore, Fry & Engleert (1969), and Fry & Moore (1969) discussed the ancient dating of coprolites with *Enterobius vermicularis* eggs, reaching close to 10,000 BP. The coprolites found in the Great Basin archaeological region, which covers an extensive area in the Western United States, continued to be an important source of data on diet and parasites and the object of study and reviews, for example Wilke & Hall (1975) and Fry (1977), summarizing the accumulated studies.

Chart 1 shows the parasites found in coprolites in North America. The chart shows that certain parasites are concentrated in specific regions. For example, *Diphyllbothrium* sp. is limited more to the north, while infection with Acantocephalae is limited to the Great Basin. Both infections appear to have been highly common in hunter-gatherers, differing from hookworm infections and *Strongyloides stercoralis*, found in the southern part of North America in agricultural societies, with more favorable environmental conditions for their transmission. However, as shown by Fry & Hall (1969), *Enterobius vermicularis* infection is ancient among hunter-gatherer groups and was ubiquitous among the Ancestral Puebloans of the Southwest and in other regions. Other intestinal helminths, such as *Ascaris lumbricoides* and *Trichuris trichiura*, commonly found in humans at present, were rarer in Prehistoric America.

Chart 1 – Parasites, antiquity, and archaeological sites. Prehistoric North America

Parasite	Date	Site
<i>A. lumbricoides</i>	322-177 B.C.	Big Bone Cave, TN
<i>A. lumbricoides</i>	570-290 B.C.	Upper Salts Cave, KY
<i>A. lumbricoides</i>	A.D. 1075-1140	Antelope House, AZ
<i>A. lumbricoides</i>	A.D. 1100-1250	Elden Pueblo, AZ
<i>A. lumbricoides</i>	A.D. 1127-1207	Adak Island, AK
Ancylostomidae	A.D. 600	Rio Zape, Durango, Mexico
Ancylostomidae	A.D. 1075-1140	Antelope House, AZ
Ancylostomidae	322-177 B.C.	Big Bone Cave, TN
Ancylostomidae (?)	1300-1700 B.C.	Daws Island, SC
Ancylostomidae (?)	A.D. 700-1200	Grenado Cave, Texas
<i>E. vermicularis</i>	c.a. 8000 B.C.	Danger Cave, UT
<i>E. vermicularis</i>	4833-4300 B.C.	Dirty Shame Shelter, OR
<i>E. vermicularis</i>	4010 B.C.	Hogup Cave, UT
<i>E. vermicularis</i>	2100-600 B.C.	Hinds Cave, TX
<i>E. vermicularis</i>	1250 B.C.	Hogup Cave, UT
<i>E. vermicularis</i>	650 B.C.	Hogup Cave, UT
<i>E. vermicularis</i>	322-177 B.C.	Big Bone Cave, TN
<i>E. vermicularis</i>	A.D. 400	Turkey Pen Cave, UT
<i>E. vermicularis</i>	A.D. 600	Antelope House, AZ
<i>E. vermicularis</i>	A.D. 600	Rio Zape, Durango, Mexico
<i>E. vermicularis</i>	A.D. 700-1000	Antelope Cave, AZ
<i>E. vermicularis</i>	A.D. 900-1250	Big Horn Sheep Ruin, Utah
<i>E. vermicularis</i>	A.D. 500-1200	Clyde's Cavern, UT
<i>E. vermicularis</i>	A.D. 920-1020	Pueblo Bonito, NM
<i>E. vermicularis</i>	A.D. 1080-1130	Pueblo Bonito, NM
<i>E. vermicularis</i>	A.D. 1000-1200	Step House, CO
<i>E. vermicularis</i>	A.D. 1000-1200	Glen Canyon, UT
<i>E. vermicularis</i>	A.D. 1075-1140	Antelope House, AZ
<i>E. vermicularis</i>	A.D. 1100-1250	Elden Pueblo, AZ
<i>E. vermicularis</i>	A.D. 1100-1250	Salmon Ruin, NM
<i>E. vermicularis</i>	A.D. 1250-1300	Inscription House, AZ

Chart 1 – Parasites, antiquity, and archaeological sites. Prehistoric North America (continued)

Parasite	Date	Site
<i>S. stercoralis</i>	A.D. 1075-1140	Antelope House, AZ
<i>S. stercoralis</i>	A.D. 1080-1130	Pueblo Bonito, NM
<i>S. stercoralis</i>	A.D. 500-1200	Clyde's Cavern, UT
<i>T. spiralis</i>	A.D. 1550	Point Barrow, AL
<i>T. trichiura</i>	A.D. 600	Rio Zape, Durango, Mexico
<i>T. trichiura</i>	A.D. 1100-1250	Elden Pueblo, AZ
Trematode unknown	A.D. 1250-1300	Glen Canyon, UT
<i>Cryptocotyle lingua</i>	A.D. 400	St. Lawrence Island, AK
Fascioloid	500 BC - 1150 AD	Lovelock Cave, NV
Fascioloid	Unknown	Sudden Shelter, Coahuila, Mexico
<i>Paragonimus</i>	A.D. 600	Rio Zape, Durango, Mexico
<i>Diphyllobothrium</i>	300 BC - 200 AD	Schultz Site, MI
<i>Diphyllobothrium</i>	A.D. 1127-1207	Adak Island, AK
<i>Diphyllobothrium</i>	A.D. 1400 - 1700	Buildir Island, AK
Hymenolepidid	A.D. 1100-1250	Elden Pueblo, AZ
Hymenolepidid	A.D. 1075-1140	Antelope House, AZ
Hymenolepidid	A.D. 600	Rio Zape, Durango, Mexico
<i>Echinococcus granulosus</i>	Precontact	Kodiak Island, AK
<i>Echinococcus granulosus</i>	A.D. 600	North Dakota
Taeniid eggs	4500 B.C.	Hogup Cave, UT
Taeniid eggs	4200 B.C.	Hogup Cave, UT
Taeniid eggs	2000 B.C.	Hogup Cave, UT
Taeniid eggs	330 B.C. – A.D. 200	Schultz Site, MI
Taeniid eggs	A.D. 20	Danger Cave, UT
Taeniid eggs	A.D. 1100-1250	Elden Pueblo, AZ
Taeniid eggs	A.D. 1250-1300	Glen Canyon, UT
Taeniid eggs	A.D. 700-1000	Antelope Cave, AZ
Acanthocephalan	A.D. 460-1500	Clyde's Cavern, UT
Acanthocephalan	A.D. 900-1100	Black Mesa, AZ
Acanthocephalan	A.D. 900-1100	Glen Canyon, UT
<i>Moniliformis clarki</i>	10000-8500 B.C.	Danger Cave, UT

Chart 1 – Parasites, antiquity, and archaeological sites. Prehistoric North America (continued)

Parasite	Date	Site
<i>Moniliformis clarki</i>	8000 B.C.	Danger Cave, UT
<i>Moniliformis clarki</i>	6400-4856 B.C.	Hogup Cave, UT
<i>Moniliformis clarki</i>	4300-5090 B.C.	Dirty Shame Shelter, OR
<i>Moniliformis clarki</i>	4800-4300 B.C.	Dirty Shame Shelter, OR
<i>Moniliformis clarki</i>	2000 B.C.	Hogup Cave, UT
<i>Moniliformis clarki</i>	1869 B.C.	Danger Cave, UT
<i>Moniliformis clarki</i>	A.D. 20	Danger Cave, UT
<i>Moniliformis clarki</i>	A.D. 600-900	Dirty Shame Shelter, OR

B.C. – Before Christ; A.D. – After Death.

Antelope House and Antelope Cave are different sites. Antelope Cave is located in the farthest corner of Northwest Arizona, close to the Great Basin. Antelope House is located in Northeast Arizona, on Colorado Plateau.

CHARACTERISTICS OF PATHOECOLOGY IN THE SOUTHWEST UNITED STATES: APPLICATION OF THE NATURAL DISEASE NIDALITY CONCEPT TO THE STUDY OF HEALTH IN PREHISTORY

One aim of this chapter is to propose that bioarchaeologists adopt the concept of natural nidality of disease (Pavlovsky, s.d.)^{Editor's note} as a tool to reconstitute the pathoecology of infectious diseases in prehistoric communities. The *nidus* is a geographic or other special area containing pathogens, vectors, reservoir hosts, and recipient hosts that can be used to predict infections based on one's knowledge of ecological factors related to infection. Ecological factors include the presence of vectors, reservoir hosts, humans, and a favorable external environment for the transmission of parasites. An individual *nidus* therefore reflects the limits of transmission of a given parasite or pathogen within specific areas of interaction: bedbugs in a bedroom, for example. A *nidus* or a focus of infection can be as confined as a single room containing a bed and with access to the room by rodents carrying plague-infected fleas. Nidality can also be as large as the community and its surrounding area in which there is a transmission of a given helminth species or any other parasite.

Puebloans were a complex of overlapping *nidi*. For example, at Antelope House the grain storage and processing rooms could be identified as a *nidus* for tapeworm infections. The habitation rooms within the shelter formed a *nidus* for pinworm infection. The water sources were *nidi* for whipworm, *Giardia*, and amoeba infections. Finally, the defecation and/or agricultural areas were *nidi* for hookworm and wireworm transmission (Figure 1).

Editor's Note The author of this chapter uses the term “pathoecology” in a somewhat different sense from that of “natural nidus of disease”, proposed by Pavlovsky. A natural nidus of disease exists when there are specific favorable climate, vegetation, soil, and microclimate in regions where there are vectors, infected hosts, and hosts susceptible to infection. In other words, a natural nidus of diseases is related to a specific geographic landscape, such as the taiga with its botanical composition, a hot sand desert, the steppe, etc., i.e., a biogeocenosis (Pavlovsky, s.d.: 19). In the original concept of “nidality”, disease outbreaks occur when persons invade or modify a site where a given parasite circulates in its natural environment (Lemos & Lima, 2002).

Figure 1 – Antelope House, where the cliff on the left shows the dwellings of the Ancestral Puebloans, Chelley Canyon, Arizona, USA

Hymenolepis nana is a tapeworm that has only been recovered from agricultural sites among the Puebloans. The parasite species is found in humans, but other animals such as rats and mice become infected with a very proximate species called *Hymenolepis fraterna*, which however has also been diagnosed sometime in humans. The life cycle and host-to-host transmission occur through the ingestion of eggs eliminated in the feces of infected individuals; these eggs eclode and release the hexacanth embryo, or larva with three pairs of hooks, which attach to the intestinal mucosa in the so-called cysticeroid form. Some ten to 12 days later the cysticeroid larva migrates to the ileum, passing to the adult stage and producing proglottids. This cycle, from egg to egg, takes approximately one month. It is more common in children than in adults, reflecting a certain degree of immunity resulting from the parasite's passage through the intestinal mucosa and the production of serum antibodies. The parasite's eggs in human feces can be ingested by coprophagous insects such as various species of fleas, as well as coleopters. The cysticeroid larva develops in the insects, and infection can occur when the latter are ingested by mammals such as rodents, dogs, and other carnivores. Humans can become infected this way by ingesting small coleopters of genus *Tenebrio*, found in grain, or genus *Tribolium*, found in flour. In these cases, since the cysticeroid is ingested, immunity does not develop and the number of parasites is usually much higher than in infection transmitted by the ingestion of *Hymenolepis nana* eggs.

Thus, among the Puebloans, parasitism by *Hymenolepis nana* must have occurred by direct transmission among humans, as well as autoinfection, but also by ingestion of arthropods inadvertently crushed during the preparation of foods with stored grain.

Hookworm and wireworm larvae penetrate the skin of humans. *Nidi* for these parasites probably were in agricultural fields and/or in or around toilet areas in the sites. The most common method for controlling hookworms is to use

footwear. Ancestral Puebloans wore sandals, but Behnke et al. (2000) document problems in hookworm infection with the wearing of sandals among modern agriculturalists in Mali. They report that the soil sticks to sandals, making them uncomfortable and frustrating to wear when tilling soil, leading people to take them off. As a result, those who wear sandals are infected just as often as those who go barefoot (Behnke et al. 2000).

This same situation may have plagued Puebloan horticulturalists, and larval skin penetration could have occurred in cornfields. Schad et al. (1983) suggest another scenario for hookworm infection that is also applicable to Puebloan pathoecology, when they showed that in West Bengal, villagers defecated in areas around the village peripheries. People used the same areas day after day for this purpose. As a result, hookworm larvae proliferated in those areas and the time spent by humans in the contaminated areas was sufficient to maintain hookworm infection in the population.

At Antelope House, hundreds of small concentrations of coprolites were found within the rock shelter. This pattern of coprolite remains shows that the Antelope House residents had a similar sanitation pattern as the people living in West Bengal, but used abandoned rooms rather than the peripheral regions around the village. Therefore, the *nidi* for hookworm and wireworm infections could have been in the peripheries of the village or in the abandoned rooms, used to defecate. Wireworm larvae were found in Antelope House dog coprolites (Reinhard 1985b, 1985c). Although it has not been proven that the species parasitizing dogs was the same as in humans, experimental infection with *Strongyloides stercoralis* occurs in dogs and rats in the laboratory, suggesting that they may serve as reservoirs or alternative hosts.

By building a multi-room, stone-walled village within a rock shelter, Puebloans at Antelope House established a large *nidus* for pinworm transmission. Pinworms are transmitted both by hand-to-hand contact between humans and by airborne dissemination when a population is occupying a closed space. The apartment-like pueblos with their closed spaces and stagnant air would have been ideal areas for the dissemination of eggs (Hugot et al. 1999; Reinhard 2007a). Proof for this is noted at Antelope House, which has one of the highest prevalence rates of pinworm infection in prehistory due to airborne contamination.

Whipworm, *Giardia duodenalis*, and amoebas are transferred in contaminated water, although hand-to-hand transfer of *Giardia* is known. This would have been a serious problem during a period of drought in the Canyon de Chelly region in Pueblo III times (Morris 1986; Reinhard 1985). During the drought the number of pueblos in the canyon grew as people moved closer to the remaining reliable sources of water in the canyon floor. As a result of overcrowding and poor sanitation, the local water sources became contaminated and thus could be considered as *nidi* for fecal-borne diseases.

PARASITES, DISEASE, AND ANCESTRAL PUEBLOAN PALEOPATHOLOGY

Parasitic infection means the parasite's presence in the host, and parasitic disease does not necessarily result from infection. Disease results from the pathogen's pathogenicity and virulence, associated with the host's characteristics and those of the environment in which both are found. Virulence refers to the parasite's ability to multiply. Pathogenicity refers to the parasite's capacity to cause disease symptoms and mortality in the host population (Araújo et al. 2003). Infection can be transmitted vertically, from mother to child, or horizontally, from one host to another.

Among the various worm types of parasites that infected Ancestral Puebloans, the most virulent included *Trichuris trichiura* (whipworms) which have the potential for each female to lay as many as 20,000 eggs per day, and *Ascaris lumbricoides* (giant intestinal roundworms), which lay 200,000 eggs per day. Perhaps the least virulent

worm parasite was *Strongyloides stercoralis* (wireworm). Female wireworms lay only hundreds of larvae per day. However, the pathogenic potential of these worms is reversed. Whipworms and giant intestinal roundworms rarely cause debilitating long-term problems or death (except intestinal obstruction caused by a bolus of worms in the case of *Ascaris lumbricoides*). In contrast, wireworms are more pathogenic. Wireworms enter the body by penetrating the skin. In their migration toward the intestine they work their way through the heart and lungs and can cause serious pathology in these organ systems. When they enter the intestine they plow through the intestinal mucosa and damage the intestinal tract. Mothers infected with wireworms can potentially infect their nursing babies in vertical transmission via breast milk. Whipworms and giant intestinal roundworms can be transferred only by fecal contamination of the environment. These are “geohelminths”, or parasites whose eggs need to mature to the infective stage in soil.

The number of parasite species infecting a host population relates to their ability to combine into conditions that create a disease. One advantage of coprolite analyses is that they provide the potential for identifying the number and diversity of parasites that are infecting a single host (Reinhard et al. 1988; Reinhard, Ambler & McGuff, 1985).

The level and intensity of parasitic diseases in a population is affected by many conditions. These include the population's past experience with parasitic infection, nutritional and immune status, and the behavioral patterns of the population that increase or decrease risk. Two of these, susceptibility to infection and the nutritional needs of the host, can be assessed through examination of the archaeological record. An example of this can be seen in the studies of sites in the American Southwest. A number of coprolite studies reported that the breadth of Ancestral Pueblo diets were generally nutritionally sound (Cummings 1994; Fry 1980; Minnis 1989). However, beginning in 1992, coprolite evidence emerged for substantial variation in the consumption of wild plants at Ancestral Puebloan sites, suggesting that agricultural failures at some locations may have forced a much higher reliance on wild foods.

To test this assumption, the ancient diets of the populations living at Antelope House and at Salmon Ruin were reconstructed and compared to determine whether clues of starvation could be identified in coprolite data (Reinhard 2008b). These coprolite studies included identification and evaluation of starvation foods based on phytoliths, or silica crystals formed in the epidermis of plants, found in various archaeological remains, such as dental arches (in the spaces between teeth), coprolites, etc. (Reinhard & Danielson 2005), pollen concentrations (Reinhard et al. 2006), and starch and microfossils (LeRoy-Toren & Reinhard 2004; Reinhard 2008b; Reinhard et al. 2006; Sutton & Reinhard 1995). Data from both sites covered the time period during the recorded environmental deterioration in Pueblo III Canyon de Chelly (Reinhard 2004, 2008b). Starvation foods, including yucca leaf bases and prickly pear pads, became very common foods at Antelope House but not so at Salmon Ruin and other Pueblo sites in Utah and New Mexico (Reinhard & Danielson 2005). Pollen concentrations in coprolites reveal that stored maize was eaten less often and in smaller quantities at Antelope House than at Salmon Ruin, and that people at Antelope House were relying more heavily on wild foods like cattail heads and horsetail strobili. Finally, starch grains were much less common in the coprolites from Antelope House than those found at Salmon Ruin. Macrofossil remains show the widest variety of wild plant use at Antelope House. When combined, all of these data support the apparent dietary impact of environmental deterioration in the Antelope House region of Canyon de Chelly, which undermined local agricultural yields and forced the residents to diversify and increase their reliance on wild plant foods (Reinhard 1996, 2008b).

During that same stressful period a greater diversity of parasite species infected the population living at Antelope House. Some of these parasites, like hymenolepidid tapeworms and pinworms, are neither very virulent nor pathogenic but their presence suggests that the population, perhaps already suffering from various forms of malnutrition, was

generally in poor health. Whipworms were also present, and although this parasite is virulent (i.e., it produces an enormous amount of eggs eliminated in the feces), it is not very pathogenic. Hookworm and wireworm infections were also common at Antelope House during this period. Neither of these is particularly virulent, but they both have the capability of vertical transmission from mother to fetus or newborn and the ability to infect the most susceptible portion of the population (infants) with regard to helminths. In addition, two species of diarrhea-causing protozoan parasites were found that are both highly virulent and pathogenic, *Entamoeba histolytica* and *Giardia lamblia*. Overall, the image that emerges of the people living at Antelope House during this period is one of a physiologically stressed, highly infected population among whom some individuals in the poorest health were more susceptible to infection by many parasites.

The widespread infection levels indicated by the Antelope House coprolites raise other important questions, such as the level of interaction between the host's nutritional needs and parasitism and at what point those levels become critical or even life-threatening. One example of this important relationship between nutritional needs and parasitism was discussed by Crompton & Whitehead (1993). In their discussion they constructed a model predicting the effects of hookworm infection on a non-pregnant versus a pregnant woman. Their model predicts that hookworm infection will deplete stored iron in the host's body because of the hookworm's destruction of red blood cells thus reducing their density per milliliter of blood. Thus the effect of this iron depletion becomes much more acute in pregnant women because they must also provide iron for their growing fetus. Each hookworm in a person's body can consume 0.27 ml of blood per day (MacLeod 1988). After only 20 weeks of hookworm infection the host may show symptoms of hypochromic and macrocytic anemia.

A major problem among pregnant women is that the minor symptoms of hookworm infection are often indistinguishable from normal complaints of pregnancy such as epigastric pain, heartburn, etc. When the hookworm infection is more severe, the pregnant woman may show symptoms of low-grade fever, fatigue, dyspnea, heart palpitations, flow murmurs, and anemia. In cases of heavy infection, constipation or diarrhea, jaundice, emaciation, cardiac failure, or preeclampsia can occur. If an infected woman survives labor, she often cannot recover easily from postpartum hemorrhage, which can contribute to maternal death. Overall, in hookworm-infected populations, the increased physiological needs of pregnancy put women at much higher risk.

When multiple infections occur in a pregnant woman, as they most probably did at Antelope House during this period of severe stress, serious consequences result. Of the parasites at Antelope House, hookworm, *G. lamblia*, and *E. histolytica* were the most serious challenges to maternal and infant health. In pregnant women, hookworm causes severe iron deficiency anemia, nutrient malabsorption, alimentary bleeding, fatigue, diarrhea, preeclampsia, and heart failure during labor. *E. histolytica* and *G. lamblia* cause iron deficiency anemia, nutrient malabsorption, diarrhea, dehydration, and shock.

These parasites cause problems for mothers and fetuses, leading to major effects on the population.

The presence of these three parasites in nutritionally stressed Puebloan populations is an important factor in the prevalence of porotic hyperostosis in Ancestral Puebloan skeletal assemblages, especially in concert with nutritional stress when changing environmental conditions resulted in reduced food and nutrient intakes (Reinhard 1992). Long-term droughts, such as recorded in the Antelope House region, resulted in an aggregation of human populations around the dwindling water sources. This in turn led to a proliferation of crowd diseases and diseases associated with contaminated water and inadequate sanitation. Bioarchaeologically, this suite of phenomena are expressed as elevated levels of porotic hyperostosis in skeletal remains.

INSECTS AND PARASITISM IN THE PREHISTORIC SOUTHWEST

Some of the most intriguing pathoecological data come from areas and archaeological sites where ancient people ate the intermediate insect hosts that were carrying acanthocephalans and tapeworms. In these cases, specific aspects of prehistoric diet or hygiene resulted in human infection, but which should be distinguished from false parasitism. Parasites of animals can infect the human host and sometimes cause parasitic disease, which is called zoonosis. However, some parasites are unable to establish themselves in the host, and their ingested infective forms, larvae or eggs, cross the intestinal tract and are eliminated in the feces. In such cases, so-called false parasitism occurs.

Acanthocephalans rarely parasitize humans in the modern world. We know that ancient Americans were infected because we have found acanthocephalan eggs in human coprolites. These finds are most common in the Great Basin from coprolites found at archaic sites including Dirty Shame Rockshelter in Oregon (Hall 1977), Clyde's Cavern in Utah (Hall 1972), and Danger and Hogup Caves in Utah (Fry 1977) (for review see Reinhard 1990). Acanthocephalan eggs have also been recovered from Ancestral Pueblo coprolites found in sites located in the Glen Canyon, Utah, and Black Mesa Arizona (Fry 1977; Gummerman et al. 1972:191; Reinhard 1990). The Ancestral Pueblo infections probably resulted from accidental or purposeful consumption of flour beetles, camel crickets, roaches, and perhaps other similar insects.

A different type of infection may have resulted from eating ectoparasites (parasites outside the body such as lice, fleas, and ticks). Fry (1977) and Napton & Heizer (1970) found lice in human coprolites recovered from Danger Cave, Utah, and Lovelock Cave, Nevada. Recently, Johnson et al. (2008) found a tick in a human coprolite from Antelope Cave, an Ancestral Pueblo Site in northwestern Arizona near the Virgin River. Apparently, the tick had been bitten and swallowed and then became part of a coprolite. Fry (1977) presented a case suggesting that prehistoric people ate ectoparasites as a hygienic measure. This assumption makes good sense and we believe that Fry made a good case for this type of behavior.

Taeniid tapeworm eggs have been found in coprolites from Danger Cave, Hogup Cave, Glen Canyon, and Antelope Cave. The exact species of taeniid that is represented by these finds is unknown. In the modern world, humans are most commonly infected by two species, *Taenia solium* from pork and *T. saginata* from beef. These species of taeniids were almost certainly absent in the prehistoric New World because the host animals are native to the Old World. There is one other known taeniid that can infect humans, although it is much more common to find it as a parasite of dogs. This is *Dipylidium caninum* (cucumber tapeworm). *D. caninum* uses fleas and lice as intermediate hosts. Therefore, if a person ate fleas and lice in an effort to prevent the ectoparasites from feeding on humans, it is possible they could have eaten an ectoparasite (*Ctenophalides canis*) that had fed on an infected dog. Since there is coprolite evidence that prehistoric people did eat fleas and lice, we suspect that the taeniid eggs found in Southwestern human coprolites may be from *D. caninum* infections.

SOUTHWEST PALEOPARASITOLOGY, THE GENERAL PICTURE

The origin for Pathoecology studies in the Southwest was to gain an understanding of the relation of human cultural evolution to parasite evolution. The central question has related to the difference in parasitism between hunter-gatherers, simple horticulturalists, and complex horticulturalists or agriculturalists. For the studies of western North America, the data are robust enough to draw some generalities. First, parasitism by intestinal helminths was a very rare event for hunter-gatherers. Indeed, of some 150 archaic coprolites from the Colorado Plateau, none have convincing evidence of infection. Of some 200 coprolites from the Chihuahuan desert of Texas, only one was positive

for pinworm. In the Great Basin, hunter-gatherer coprolites are often positive for acanthocephalan and taeniid eggs but rarely positive for pinworm eggs. This indicates that for hunter-gatherers, regionally specific subsistence habits opened or closed the opportunity for zoonotic parasitism.

The earliest horticultural site, Turkey Pen Ruin, had one of the highest pinworm prevalence rates in coprolites (29%). Pinworm was present in almost all subsequent Ancestral Pueblo horticultural sites. One general conclusion that we can draw is that human-specific parasitism, which was rare in hunter-gatherer times and absent in the region of the Ancestral Pueblos, became a significant problem for horticulturalists. In evolutionary time, this happened very suddenly, and the paleoparasitological data can contribute to new studies on the theme.

Some Ancestral Pueblos developed more complex methods of food production and apartment-style buildings. The Chaco Canyon Ancestral Pueblos had these developments. Hookworm and *Strongyloides stercoralis* emerged as health problems for these agriculturalists. These parasites spread to more distant sites such as Antelope House. It thus appears from the coprolite data that each advancing stage in agricultural production added species of parasites to human populations. This increasing spectrum of parasites included fewer zoonotic species and more human-specific species.

TRACING THE PATTERN TO NORTHERN MEXICO

This also seems to be the pattern for northern Mexico. Analysis of 32 hunter-gatherer coprolites from Frightful Cave, Coahuila, Mexico, revealed just one positive for a fascioloid fluke. No other contained parasite eggs. In contrast, current analysis of agricultural coprolites from the Cueva de los Chiquitos Muertos reveals pinworm, whipworm, and hookworm. There is also potential evidence of hymenolepidid and fluke infection of a zoonotic origin. The hymenolepidids could be false parasitism. The pattern of hunter-gatherer zoonosis followed by horticultural human-specific infection holds for the arid region of Northern Mexico.

COLONIAL IMPACT ON NEW WORLD PARASITISM

Since the beginning of paleopathology in the Americas, researchers have posed the question of how European colonization of the Americas affected health. This is a pathoecological question on a global scale. Among early 20th-century parasitologists, the general consensus was that most or even all parasite species arrived in the Americas after 1492. There was a consensus that the Americas before colonization were largely free of parasites that were prevalent in the Old World.

This changed in the latter part of the 20th century when analysis of prehistoric coprolites showed that the most common human roundworm and protozoan parasites arrived in the Americas millennia before Columbus. In addition, endemic zoonoses infected prehistoric Indian populations.

The question was modified to: "How was the pathoecological spectrum of parasite infection affected by Colonial settlements?" Long-standing research with prehistoric coprolites showed that fecal-borne parasitism was relatively rare in the prehistoric Americas. In contrast, extensive studies of Medieval and Renaissance latrines in Europe by many authors showed that fecal-borne parasites were an unavoidable aspect of European pathoecology. The answer to this question awaited the analysis of Colonial American sediments.

In the 1990s several analyses of colonial sites were conducted. These included a 1620s-1673 latrine from Newfoundland (Horne & Tuck, 1993); barrel latrines from the Meadows site, an early colonial 1600s Swedish colony

in Philadelphia (see below); surface sediments from the mid-1600s Dutch Colony of Albany, New York (see below); and latrines from 1720 Colonial Williamsburg (Reinhard, 1990). Researchers focused on the recovery and quantification of geohelminth eggs that have direct anal-oral life cycles. Geohelminths are parasites that produce eggs and larvae that are laid in an uninfected state. The eggs need several days to weeks in the open environment to reach infective stage. The two geohelminth species of particular interest are *Trichuris trichiura*, the whipworm, and *Ascaris lumbricoides*, sometimes called the maw-worm or the giant intestinal roundworm. Mature *Trichuris trichiura* worms are whip-shaped and the tiny adults burrow into the intestinal mucosa with only the posterior portion projecting into the intestinal lumen. In contrast, *A. lumbricoides* adults are around a foot in length and a quarter inch in width. The adults live in the intestinal lumen and maintain their place against peristaltic movement by their own muscular exertions.

All of these studies showed the presence of fecal-borne parasites. *Ascaris lumbricoides*, which is especially rare in the prehistoric Americas, was present in all of these analyses (see the chapter on molecular diagnosis in *Ascaris lumbricoides*). *Trichuris trichiura* was found in all of the latrines. As shown in Table 1, this pathoecological association persisted in all Colonial cities and villages studied by Reinhard. These data show that the Colonial period introduced fecal-borne parasitism as a public health hazard and this persisted for many years after initial colonization.

Table 1 – North American archaeological sites, maximum concentration of *Ascaris* and *Trichuris* eggs per milliliter of sediment

Site	Ascarid	Trichurid	Author
Albany River Walk, NY	12,432	1,243	Reinhard **
Caltrans, CA	3,374	3,552	Reinhard **
Colonial Williamsburg, VA	144	1,056	Reinhard **
Fayette, MI	*	*	Faulkner et al. 2000
Five Points, NY	3,896	5,340	Reinhard **
Frederick Douglas, NY	512	73	Reinhard **
Gateway Mall, PA	51,422	8,779	Reinhard **
Greenwich Village, NY	*	*	Reinhard **
Howard Street, NY	33,561	1,243	Reinhard **
Independence Mall 1, PA	4,754	12,639	Reinhard **
Lincoln, NE	0	0	Reinhard **
Meadows Site, PA	6,700	4,800	Reinhard **
Pearl Street 1, NY	207	2,900	Reinhard **
Pearl Street 2, NY	12,153	6,145	Reinhard **
Picotte-Dec, NY	223,248	3,763	Reinhard **
Providence, RI	*	*	Reinhard et al. 1986
Quackenbush Square, NY	38,947	829	Reinhard **
Queen Anne Square, RI	*	*	Reinhard **

Table 1 – North American archaeological sites, maximum concentration of *Ascaris* and *Trichuris* eggs per milliliter of sediment (continued)

Site	Ascarid	Trichurid	Author
Raritan Landing, NJ	8,997	18,112	Reinhard **
Ravensford, NC	400	100	Reinhard **
Rural Farms, IA	0	0	Reinhard **
Sleepy Hollow, NY	6,500	300	Reinhard **
SUFC Site, NY	310,999	12,181	Reinhard **
Troy, NY	746	497	Reinhard **
Tweed Courthouse, NY	118	335	Reinhard **
Wheeling Annex, VA	2,072	2,072	Reinhard **

* Eggs present but not quantified; ** new data.

CONTROL OF PARASITE INFECTION

The emergence and control of parasitic disease has been a central theme in historic pathoecology (Jones 1985; Herrmann, 1986; Reinhard 1994). We can conclude that geohelminth species emerged as public health hazards in the squalid urban conditions of Medieval Europe (Bouchet, Harter & Le Bailly, 2003; Jones, 1985; Herrmann, 1986). Until colonial times, they were relatively rare parasites in the Americas. However, they are ubiquitous in historic colonial and post-colonial sites (Gonçalves, Araújo & Ferreira, 2003; Horne & Tuck, 1996; Reinhard, 1990, 1994, 2000; Reinhard et al., 1986). The new question in historic pathoecology regarding geohelminths is: “When did they become controlled?”

The analysis of well-dated sediment series from historic sites offers an answer to this question. Recent excavations in New Brunswick, New Jersey, and Albany, New York, provided such contexts.

New Brunswick

New Brunswick represents control of disease in the post-Colonial period. The ascarid egg counts are presented in Table 2. It is clear that through the 1860s, there was a large variance in parasitism. This indicates that parasitism was controlled at the household level. Some households were very successful in controlling parasitism and therefore had very few eggs per milliliter of latrine sediment. However, other households were more heavily parasitized and exhibited tens of thousands of eggs per milliliter of sediment. In humans, a number of household-level factors influence the degree of parasitism (Herrmann & Schultz 1986). The demographic nature of the household is very important. Parasites, especially those that have direct life cycles (e.g., *Enterobius vermicularis*), tend to infect children more than adults. Therefore, households with more young children have greater levels of parasitism than those with few young children.

Economics also play a major role in the level of household parasitism. Part of this is obvious. Households that can afford medicine and medical visits will have a greater chance of controlling parasitism. Other factors are more subtle. For example, Reinhard, Mrozowski & Herrmann (1986) found that the artisan class of the Revolutionary Period in

Providence, Rhode Island, had household gardens and open latrine pits compared to the merchant class which had closed privies and no gardens. The open latrine near gardens promoted the contamination of food plants with parasite eggs.

Crowding is more associated with poorer classes. Since direct life cycle diseases are density-dependent, then poorer crowded families are trapped in the parasite life cycles. Hygiene is a final consideration. For households in which hand washing is customary, parasitism is reduced, according to the findings of remains.

After 1860, it appears that parasitism was controlled at a community level.

The five latrines that date to the first third of the 19th century have an average of 13,920 ascarid eggs per milliliter of night soil sediment. The five latrines that date to the middle third of the century have an average of 10,260 ascarid eggs per milliliter of night soil sediment. In contrast, the four latrines that date to the last third of the century have an average of 894 ascarid eggs per milliliter of night soil sediment.

These data indicate that in the latter third of the 19th century, fecal-borne helminth parasites came under control. This implies a community level of parasite control. It is very likely that sanitation measures such as supplying clean water to the population, channeling and sequestering sewage, or increasing restrictions on building and maintaining latrines occurred late in the century. This level of community control, combined with the preexisting household control, served to reduce fecal-borne disease. This does not mean the worms were eliminated, for trichuriasis and ascariasis still occur today. However, they were reduced to a level that produced very little overt disease.

Table 2 – Night soil helminth egg counts in New Brunswick, USA, in the 18th and 19th centuries

Sample #	Stratum	Date	<i>A. lumbricoides</i>	<i>T. trichiura</i>
7	3	1790	150	150
26	6	1805	28,950	3,100
29	3	1805	17,050	3,750
25	5	1823	13,300	4,800
9	2	1830	5,400	2,850
28	4	1830	4,900	750
19	4	1835	22,650	1,000
21	6	1849	1,000	150
17	5	1850	14,400	1,850
5	9	1853	9,050	350
14	2	1860	4,200	2,150
3	7	1870	2,800	650
20	4	1887	450	300
12	7	1890	325	25
10	4	1898	0	0

Albany

The sediments from Albany were recovered from many different contexts including latrines, drains, roads, yards, and wells (Tables 3 and 4). Therefore, we can get an idea of the general level of town contamination with parasite eggs. Seven years of study of Albany resulted in the accumulation of the largest data set for any historic site. The data show that geohelminths arrived with colonization. It appears that parasitism grew rapidly with the population growth. Indeed the 1700s and early 1800s show a growing concentration of parasite eggs in latrines. The concentrations of eggs exhibit a sharp decline after 1810 and then after 1860 most latrines are negative for parasite eggs.

The non-latrine contexts (Table 4) explain these trends. Surface refuse was positive for parasite eggs from the 1600s and 1700s. Nine of 21 non-latrine contexts and over half of the surface contexts are positive for parasite eggs. This shows that infected feces were scattered with trash in the area. One of the highest concentrations comes from a street in the 1740s to 1760s, suggesting that feces contaminated the streets.

In the 1800s, drains and culverts were established in the city. Parasite eggs are commonly found in these as well, but this signals a more successful way of sequestering human waste from the population.

Over all, the average concentration of eggs in latrines declines through time at Albany (Table 3). For *A. lumbricoides*, the average concentration of eggs from the latter half of the 18th century is 51,460 eggs per milliliter of latrine sediment. This declines to 7,890 for the first half of the 19th century and 3,979 for the latter half of the 19th century. Similarly, for *T. trichiura*, the average concentration of eggs for the latter half of the 18th century is 2,492 eggs per milliliter of latrine sediment. This declines to 399 for the first half of the 19th century and 185 for the latter half of the 19th century.

Table 3 – Parasite egg concentrations from latrines in Albany, New York, 18th and 19th centuries

Site	Feature	Date	<i>A. lumbricoides</i>	<i>T. trichiura</i>
Picotte-DEC	7/42 privy	1740	0	0
Pearl Street north	Surface privy	1740 -1760	12153	6145
Picotte-DEC	4/112 privy	1760	62,710	2,508
State Univ. Const.	surface privy	1760	2,019	621
Pedestrian Bridge	below stockade	1760s	1,249	0
Lutheran Church Lot	3	1770 -1790	266	444
Lutheran Church Lot	1	1780 -1790	207	2900
Picotte-DEC	5/126 privy	1785	223,248	3,763
Picotte-DEC	1/96 privy	1790	89,675	3,763
Picotte-DEC	6/148 privy	1800	1,254	314
State Univ. Const. 1/20	Stone-lined privy	1800	4,972	104
State Univ. Const. 5/9	Well, reused as privy	1800	310,999	12,181
State Univ. Const. 7/38	Wooden box privy	1800	5,150	1,598
116 Sheridan	Privy, barrel	1800	6,550	550
Court of Appeals 13	Unlined cesspit	1800 -1830	0	0

Table 3 – Parasite egg concentrations from latrines in Albany, New York, 18th and 19th centuries (continued)

Site	Feature	Date	<i>A. lumbricoides</i>	<i>T. trichiura</i>
Court of Appeals 15	Wood-lined privy	1800 -1830	0	0
State Univ. Const. 3	Stone-lined privy	1810s	25,199	678
116 Sheridan	Privy, wooden vault	1820s-1840s.	5,250	700
Court of Appeals 14	Unlined cesspit	1825	497	
40 Howard Street	2	1830	1709	444
40 Howard Street	3	1830	11311	1119
40 Howard Street	6	1830	249	0
40 Howard Street	8	1830	124	62
Picotte-DEC	3/113 privy	1830	251	0
Quackenbush Square	Barrel privy	1830s	31,607	829
40 Howard Street	5	1840	33561	1243
112 &114 Sheridan	Privy, wooden vault	1840s-1860s	100	50
40 Howard Street	10	1850	13851	888
Picotte-DEC	2/108 privy	1850	1,505	250
Picotte-DEC	12/147 privy	1850s	1,026	114
116 Sheridan *	Privy, wooden vault	1850s-1890s	2,750	200
Picotte-DEC	11/97 privy	1855	60,202	2,090
Picotte-DEC	9/40 privy	1860	448	0
Picotte-DEC	10/122 privy	1860s	228	0
State Univ. Const. 6/31	Large, wood-lined privy	1860s	2,260	0
Troy	69	1864	39	0
112 Sheridan	Privy vault, Concrete	1870s-1890s	0	0
114 Sheridan	Privy, wooden vault	1870s-1890s	0	0
114 Sheridan	Privy, wooden vault	1870s-1890s	0	0
Troy	34	1870s-1890s	0	0
Troy	38	1870s-1890s	207	41
Quackenbush Square	Wood-lined privy	1880s	179	0
Troy	77	1881	249	99
Troy	89	1885	249	497
Troy	71	1895	97	129
Troy	87	1896	0	0
Troy	74	1903	746	99

Table 4 – Parasite egg concentrations from non-latrline sediments in Albany, New York, 18th and 19th centuries

Context	Date	<i>A. lumbricoides</i>	<i>T. trichiura</i>
Surface, Brickyard	1600s	0	0
Surface, Brickyard	1600s	0	0
House yard	1600s, mid-	37	0
Surface refuse near house	1640-1700	60	0
Surface refuse near house	1640-1700	10	1
Surface refuse near house	1640-1700	0	0
Surface refuse near house	1650-1670	0	0
Street, beneath surface	1740-1760	12,153	6,145
distillery, below vat	1750-1800	0	0
distillery, vat sediment	1750-1800	0	0
distillery, vat sediment	1750-1800	0	0
Surface, dismantled stockade	1750s	113	0
Surface near stockade	1760	2,019	621
Dog burial, pelvic area	1760	1,065	355
Surface, dismantled stockade	1760s	1,249	0
Ground Surface 2	1780	0	0
Ground Surface 3	1780	0	0
Surface along wharf	1780s	219	0
cleaned log drain	1780s	75	0
stone culvert	1790s	70	0
Surface, dismantled stockade	1790s	0	0
stone culvert	1800	0	0
stone culvert	1805	14,918	1,243
Ground Surface 1	1820	155	0
Wooden drain	1820s	5	0
Drain	1830	124	62

IMMIGRATION AND SPREAD OF EXOTIC PARASITES

The data from Albany and New Brunswick show that common roundworm parasites were introduced into the Americas and persisted until the latter part of the 19th century when they were largely controlled. More exotic parasites were introduced, but because of the absence of intermediate host, they could not become established in North America. One of these is the Chinese liver fluke (*Clonorchis sinensis*), found in Chinese historic latrines in California.

I summarize the data from the Chinese property in San Bernardino California, where there is evidence of transcontinental introduction of the Chinese liver fluke to California with historic migrations. This study confirms an earlier, unpublished report of Chinese liver flukes from a historic Chinese community in Sacramento, CA (Hall, personal communication, 1982).

Chinese moved to San Bernardino in 1867 (Costello & Hallaran, 2004). By 1880, the county-wide Chinese population was about 150. Initially, they lived in various places throughout the town of San Bernardino. They farmed, operated laundries, worked in restaurants and hotels, and were employed as domestic servants or farm laborers. In 1878, the city prohibited laundries within the town limits, and subsequently a Chinese quarter was established. By the turn of the 20th century, as many as 600 Chinese lived in Chinatown. Chinatown was virtually all male. It was composed of shops, boarding houses, gambling parlors, a temple, labor contractors, and other establishments. With regard to modernization and sanitation, Chinatown had electricity by 1893 and piped water by 1900. Human waste disposal was managed by construction of backyard latrines.

Three artifact-filled latrines were discovered during excavations. They were located on property purchased by California-born Wong Nim in 1900. Wong Nim was born in Alameda County, California, and moved to San Bernardino about 1875. He was successful. He first worked as a laundryman, but eventually opened a mercantile shop and acted as a labor contractor. He also opened a temple. Wong remained on the corner of Third and B streets until his death at age 89 in 1941. At that time he had earned the honorary title of "Mayor of Chinatown".

When the State purchased Wong Nim's property in 1943, all of the remaining buildings on his property were demolished. At least one latrine (number 1035) was filled at this time with debris from the abandoned buildings. The privies were used by people who built residences and businesses on Wong's original property. However, Wong's house, store, and temple were located a half block away from the latrines and associated houses.

Most interesting was the discovery of the delicate eggs of *Clonorchis sinensis*, the Chinese liver fluke. The discovery of these eggs shows that the Chinese immigrants in California brought with them at least one species of parasite from Asia. Latrine 1035 contained 710 *C. sinensis* eggs per ml and 1056 contained 533 eggs per ml.

The three latrines were used at different times by the same Chinese community. It is noteworthy that the earliest latrine deposits (1880-1900) and the latest latrine deposit (1910-1941) were positive for parasite eggs but the 1900-1910 latrine sediment contained no eggs. The Chinese liver fluke, like many flukes, has a multi-host life cycle including fish and snails. These intermediate hosts have important roles in the life cycle of the parasite. The parasite undergoes asexual reproduction in the snails. Thus, the number of parasites produced by a single egg is amplified by the snail stage of the life cycle. The fish is important in conveying the parasites to their definitive host, a human. The definitive host is the animal that harbors the sexually active stages of the parasite. If the parasite survives the culinary preparation of the fish, it will eventually migrate to the liver of the definitive host and live there for many years, mating and laying eggs. The eggs pass through the bile duct into the digestive tract and then onward to the open environment.

However, the introduction of this parasite to California was a dead end. The intermediate snail hosts to which it is adapted in Asia are absent in the Americas. The archaeological identification of parasite eggs in latrines that date from the late 19th century to the early 20th century shows that the parasite was possibly introduced by immigrants during this period that may have lived long lives with their infections. If infections were light, the human hosts probably had no symptoms or mild indigestion with light abdominal pain. If they had heavy infections, then they could have suffered from pronounced abdominal pain, diarrhea, jaundice, enlarged and tender livers, and/or anorexia. In chronic cases, liver cancer could have resulted from infection. No traditional Chinese remedies for this ailment are known to us. However, many bottles from various medicines were found in the Chinese latrines (Reinhard et al., 2008). These may be related to the symptoms of parasitic disease.

Asia is home to many parasites that did not exist in the New World, even after European colonization. These parasites included the Chinese liver fluke (*C. sinensis*), the intestinal fluke (*Fasciolopsis buski*), the oriental lung fluke (*Paragonimus westermanni*), and the Asian blood fluke (*Schistosoma japonicum*). These parasites were present in Asia in ancient times as indicated by paleoparasitology in Korea, China, and Japan. They infected many people and undoubtedly some immigrants entered the Americas with these parasites. For this reason, the analysis of sediments from the San Bernardino Chinatown latrine is particularly important in demonstrating the cross-continental introduction of parasites into North America. For Chinese liver flukes, this was a pathoecological dead end.

WHERE TO FIND PARASITE EGGS IN HISTORIC SITES

The studies of Albany show that any area in a historic site can be contaminated with parasite eggs. For ideal pathoecological study, many samples should be taken to identify “hotspots” for transmission. In Albany, streets and surface trash were such hotspots as well as drains leading to the streets and to rivers. How parasite eggs are distributed stratigraphically in latrines was explored in analyses of latrines from Philadelphia.

The paleoparasitological analysis of 35 archived sediment samples excavated from historic Philadelphia was undertaken. The analysis of these samples had several goals. First, I wanted to assess various proveniences for parasite egg abundance to determine the prevalence of parasite eggs in sediments from the site. Secondly, the fact that several samples were stratigraphically controlled provided an opportunity to explore how parasite eggs are vertically distributed in archaeological features. Third, the presence of samples recovered from inside vessels allowed assessing the value of such samples with regard to parasite egg recovery.

One interesting result was that the concentration of eggs from the two parasite species did not always correlate. As the concentration of eggs declined towards the center for one species, the concentrations declined for the other. This can be explained by the relative ease of treatment for *A. lubricoides* which lives in the intestinal lumen versus *T. trichiura* which burrows into the mucosa of the intestine. There are more effective remedies for lumen-dwelling nematodes, especially *A. lubricoides*, which is a noticeable parasite. People are much more likely to be aware of their ascarid infection when they pass foot-long white worms. Therefore, decline in ascarid egg count could easily be explained by medical treatment. Another factor to be considered is relative egg production. *Ascaris lubricoides* females lay about 200,000 to 240,000 eggs per day versus *T. trichiura* females which lay an estimated 20 thousand eggs per day.

Therefore, elimination of even one ascarid female will result in a dramatic drop in ascarid eggs relative to trichurid. I think that the strata, features, and rooms that have relatively low ascarid counts represent people who have access to vermifuges.

This analysis provided me with the first opportunity to evaluate the content of vessels for parasite eggs. Vessels were found in the sediment, ranging from a pitcher to a 600 mil bottle. The pitcher contained three thousand *Ascaris lumbricoides* and 3,300 *Trichuris trichiura* eggs. These are among the highest egg concentrations. A redware vessel contained 150 *Ascaris lumbricoides* and 400 *Trichuris trichiura* eggs, relatively low levels in this area of the excavation. A green bottle contained 1,350 *Ascaris lumbricoides* and 3,400 *Trichuris trichiura* eggs. These are very interesting concentrations because sediment from the same stratigraphic level contained only 550 *A. lumbricoides* and 900 *T. trichiura* eggs per ml.

These three vessel samples suggest that sampling sediment from inside of ceramic or glass vessels provides good archaeological data, especially if the vessels have narrow apertures such as the pitcher and bottle. Apparently with the glass bottle, the sediment inside the bottle retains higher parasite concentrations, perhaps because sediment outside the bottle was altered by post-depositional processes that removed or destroyed eggs. However, the eggs that entered the bottle mixed with the original contents of the bottle such that the eggs were trapped in a brown, organic matrix and ended up being preserved in this medium.

The stratigraphic distribution of eggs was first explored by Reinhard, Mrozowski & Oloski (1986) and by Reinhard et al. (1986). In these articles, but especially in the latter, it was discovered that the vertical distribution of parasite eggs is highly concentrated in the upper or lower levels of latrines. This is in part because deposition of infected feces oversaturates confined areas with parasite eggs. This oversaturation becomes even more extreme as latrine sediments decompose and compress in the post-depositional phase of archaeological site formation. However, I have had little opportunity to explore the distribution of eggs in the past four years because archaeologists generally send night soil deposits identified in the field without samples from above or below the night soil. This project allowed me to look at the distribution of parasite eggs in stratigraphic association.

In one area, total concentration of eggs is highest in the uppermost stratum (29,250 eggs per ml), declines in the next lowest stratum (26,334 eggs per ml), and is lowest in the bottom of the feature (2,750 eggs per ml).

In another room, total concentration of eggs has the reverse pattern in relation to the previous area, in that the eggs are most concentrated in the lowest level. There were no eggs in the uppermost level and 5,375 eggs per ml in the lower level.

For still another room, the data are most interesting because of the depth of the feature. There is a general congruence of egg concentration for the two parasite species. The maximum concentration is at the top of the feature. However, there is a spike of parasite eggs in a lower level. Whether this represents secondary deposition of eggs to a lower level by post-occupation, archaeological site formation processes, or an actual early use of the feature as a latrine is unknown.

In general, the stratigraphic distribution of the eggs follows previously reported observations in which eggs are concentrated in well-defined areas. It is important for archaeologists to collect samples from every 10 cm in a stratigraphic column within latrines. It is also important to collect samples from water sources for the community, from household drains, community drains, and from yards and streets.

The measures discussed in this chapter increase the possibilities for a more plausible nosological picture of parasite infections at different moments in the past, with a better observational basis, more differentiated and closer to reality. The picture is developed little by little, with an increasingly clear and solid basis in the parasite records from archaeological material.

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