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Comment on Reinterpreting the Pollen Data from Dos Cabezas

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Abstract

The published pollen analysis of the Dos Cabezas giants, Geyer *et al.* ([2003]), lists a variety of purported dietary pollen types. The paper also hypothesizes that the giants were poisoned with plant toxins. We have severe reservations about the pollen evidence of diet and poisoning. We suggest that the analysts made several errors in their interpretation. Firstly, some of the discovered pollen types are not prehistoric endemics to the Dos Cabezas region of coastal Peru. These include the pollen of fava beans (cultivated in the Old World), and specified species of agave and sage. We believe that some or all of the identifications of pollen from arracacha, maca, yuca, oca, potato, peanut, ciruela and tarwi are in error based on the distance they grow from Dos Cabezas and/or their ecological/pollination requirements. We think that it is unlikely that the giants were poisoned because the poisons made from six poisonous plants are not made from the flowers and five of them grow on the opposite side of the Andes from Dos Cabezas. We present an alternative dietary interpretation of the Dos Cabezas giants and suggest methods by which palynological analysis could be improved.

Keywords: palynology, Moche, Peru, theory, method, debate, burial sediments

Introduction

During the summer of 1994, Donnan (2001) began excavations in the northern coastal region of Peru at the site of Dos Cabezas. His objective was to learn more about the beginning of Moche civilization and about the diets and lifestyles of those who occupied the large site of Dos Cabezas. After his initial field season, he returned to work at the site many times. During the late 1990s, Donnan uncovered a complex of four tombs. In one of the tombs, Tomb 3, he found three burials. The project's osteologist, Alana Cordy-Collins, collected soil samples from the pelvic regions of all three burials in hopes that these remains of fecal residues would provide valuable information about the ancient diets of the Moche people. The samples were then given to Geyer, who analyzed them for fossil pollen and then reported his findings (Geyer *et al.*, 2003). Herein lies the problem. In our opinion, some of his conclusions are incorrect and we fear they will continue to haunt the interpretation of the archeological record of Dos Cabezas until corrected.

Geyer *et al.* (2003) identified 34 pollen types from the three pelvic samples and presented interpretations which we believe are in error. We hope to demonstrate this by a thorough and critical review of the paper and a reevaluation of the pollen identifications and interpretations.

Reinterpreting the dietary pollen evidence recovered from the Moche giants

Geyer *et al.* (2003) presented a confusing description of the material they analyzed. They stated: "In obtaining a coprolite sample, sediment is taken from the pelvic girdle, specifically where the colon would have descended" (Geyer *et al.*, 2003: 276). It is unclear whether they analyzed formed coprolites (feces) or loose sediment derived from an area which once held feces. This is not a trivial concern. Although many techniques of coprolite analysis can be applied to burial sediments, such sediments are more prone to be contaminated with pollen from other sources that can potentially filter into the burial. Therefore, control samples from the site must be examined to sort out the influence of contamination. We assume that Geyer *et al.* analyzed burial sediments based on their methods description (2003: 281–2).

The methods for analysis of burial sediments were established many years ago (Bryant & Morris, 1986; Shafer *et al.*, 1989; Reinhard *et al.*, 1992; Berg, 2002). All researchers emphasized the importance of control samples to establish the background pollen spectrum. These researchers established that macrofloral and faunal remains are commonly found in burial sediments. The identification of the macrofloral remains in burials provides insight into the dietary source of recovered pollen. If faunal remains are found, pollen in the intestinal tract could have been introduced by the consumption of entire rodents, lizards, or nectar and pollen feeding insects. These salient references are not cited by Geyer *et al.* (2003). Furthermore, they did not process control samples, nor did they search for macrofossil remains.

The types of error that can occur in palynological reports are listed in Table 1. Chaves & Reinhard (2006) present guidelines for the interpretation of economic use of pollen taxa regarding medicines, based on reviews of archeopalynology (Bohrer, 1981; Hevly, 1981; Bryant and Holloway, 1983; Dimbleby, 1985) (Figure 1). The guidelines are equally applicable to questions of dietary use of plants and poison consumption. These guidelines refer mostly to the pollen found in human coprolites, but they also apply to the identification of economic plant usage from the pollen in burial sediments. The following questions should be considered for each discovered pollen type. Is the pollen type of a food taxon endemic to the study area or of a food product that could have been traded to the site? Is it likely that pollen from the source plant will be attached to, or included in, the part of the plant that is ingested? Is it likely that pollen from the parent plant will be retained when the plant is prepared as medicine or food? Is the pollination strategy of the plant in question (*i.e.* wind vs. insect pollination) likely to result in the pollen being distributed over the landscape in the normal pollen rain? Is the morphology of the pollen in question so unique that it can be identified to the species level? Can the pol-

Table 1. Types of common errors in palynology

Type 1—Endemicity	When a purported pollen type is not endemic to study area and time
Type 2—Use	When a purported pollen type does not match purported use of the species
Type 3—Preparation	When a plant's pollen is not present in economic preparation from the plant
Type 4—Consumption	When a plant's use does not include ingestion
Type 5—Pollination	When a pollen type has a widely dispersed pollination such that the natural pollen rain could be its source
Type 6—Uniqueness	When a purported pollen type is not distinct to a specific taxon
Type 7—Abundance	When a pollen type is not abundant enough to warrant economic interpretation
Type 8—Lab error	When laboratory facilities do not prevent contamination, and/or microscopy facilities are inadequate, and/or the palynologist has insufficient experience or reference collections for the research area or temporal period

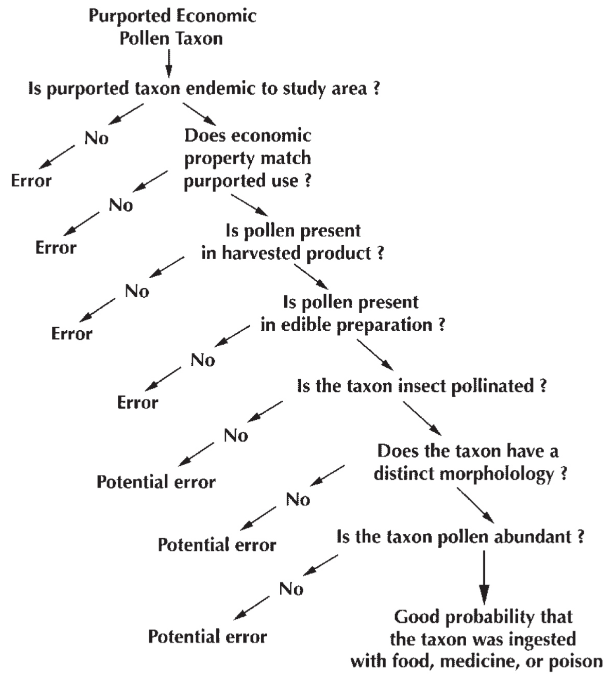

Figure 1. This chart illustrates the decisions a palynologist must make to determine if a discovered pollen type in coprolites resulted from the economic use of a properly-identified source plant. If the decision process leads to an "error" at any point, then the palynologist should reconsider the identification and/or interpretation of the pollen type. If the process leads to "potential error" then he/she must proceed very cautiously and rely on control samples and pollen concentration studies to estimate the probability that recovered pollen reflects dietary use. Only when all criteria are met can the palynologist be confident that the pollen type is identified correctly and that it resulted from economic use of a source plant.

len be used to infer the medicinal/dietary use of the plant at the genus or species level? Is the amount of pollen recovered from the plant in question abundant in the sample, or does the pollen type occur only as a trace occurrence of only one or a few pollen grains?

All of the above questions should be applied to any discussion of economic plant usage at any archeological site. Thus, these questions are relevant to an examination of the pollen data recovered and reported by Geyer *et al.* (2003), and especially to their hypothesis that some of the pollen types recovered from the coprolites at Dos Cabezas represent the use of plant poisons.

Dietary pollen types

One of the first points of concern in the Geyer *et al.* (2003) study is their identification of the use of fava beans (*Vicia faba*) and the inference that these beans were being cultivated by the Moche culture. We believe that their identification of fava bean pollen is in error and that the cultivation of these beans was beyond the subsistence potential of the Moche. The major problem is that fava beans are native to the Old World where they were cultivated in the Near East (Miller, 1992: 44–5). Therefore, we find it highly unlikely that fava bean pollen could have been recovered from the pre-Columbian-age deposits at Dos Cabezas. However, fava beans have been introduced into Peru in historic times. Perhaps the purported fava bean pollen is either misidentified or it is modern contaminant pollen that filtered into the burials.

There are other pollen identifications in the Geyer *et al.* (2003) report that also concern us. For example, they identified pollen at the Dos Cabezas site as coming from the century plant (*Agave americana*). This species has its origins in Mexico and was later introduced into Peru during the historic period (Irish & Irish, 2000). We believe that they may have found agave pollen, but that it is from one of the indigenous species in the Agavaceae plant family or it is from modern sources that filtered into the burial. In addition, they reported finding only one agave pollen grain, which may have come from any source and is unconvincing as solid evidence of dietary use.

We are also skeptical of the claims made by Geyer *et al.* (2003) that they recovered and identified a number of pollen grains from plant species that are grown for their tubers in the Andes regions as primary starch sources. These include their identifications of: (1) arracacha (*Arracacia xanthorrhiza*); (2) maca (*Lepidium meyenii*); (3) oca (*Oxalis tuberosa*); and (4) potato (*Solanum tuberosum*). The altitude at which the root and tuber plants in question grow is generally much higher than the near sea-level elevation of the Dos Cabezas site (National Research Council, 1989; CONDESAN–CIP, 1997; Hermann & Heller, 1997). Oca grows at elevations between 2,500–4,000 masl (meters above sea-level). Arracacha grows between 1,000 and 3,100 masl, and maca grows at elevations of 4,000 masl. Many of the species of potatoes are also high-elevation crops. Geyer *et al.* (2003) also report yuca (*Manihot esculenta*), which does grow at low elevations. All of these plants are propagated by vegetative plantings, not seeds dependent on flowers. Indeed, arracacha does not normally flower (Knudsen, 2003), and maca is a self-pollinating biennial (Quirós & Cárdenas, 1997). There were two types of ancestral, wild arracacha, a biennial form and a perennial form. Ancient people in the Andes domesticated the perennial form and not the biennial, seed-propagating one (Hermann, 1997). Maca grows from seed in the first year, but the roots grow in the second year, when no flowering occurs (CONDESAN–CIP, 1997; Quirós & Cárdenas, 1997).

We have spent considerable time researching the pollen found in archeological sites in Peru. From our past research, we have found that it is highly unlikely or nearly impossible to recover pollen in diets that result from the consumption of these tuber and root plants. During the early 1970s, one coauthor (VMB) worked at the high-elevation Andean site of Ayacucho with Richard MacNeish. During that period we found nearly 100 human coprolites, which were thoroughly examined first by Eric O. Callen, and then by VMB. Although those coprolite data were never published due to the untimely deaths of both Drs. Callen and MacNeish, none of the coprolites contained any pollen from the list of root and tuber types found by Geyer *et al.* (2003). In a second study from 1990–1994, we conducted additional pollen analyses of coprolites recovered in low-elevation Peruvian mummies from the Osmore drainage (Reinhard, 1993; Reinhard & Bryant, 1994; Reinhard *et al.*, n.d.). Although we knew that roots and tubers were a starch source used by prehistoric groups in the region, we found no pollen evidence for the use of these starch sources. This was even true during the examination of coprolites from mummies that were found buried in tombs where roots and tubers were present as offerings.

To develop a method for tuber root identification in coprolites, one co-author (KJR) spent two months during 1996 in the high Andes town of Huancayo, Peru, collecting a diversity of native roots and tubers that were being grown as crops. The samples examined included species reported by Geyer *et al.* (2003). Using those Andean tuber reference collections, Vinton (1997) and Nelson (1997) found that the distinctive starch grains of these plants did preserve through human digestion and could be recovered in the digestive tracts of mummies. The starch grains were also recovered from burials and coprolites. However, during these studies no arracacha, maca, yuca, oca or potato pollen was ever recovered. In an analysis of 46 coprolites, examined primarily for starch and pollen remains from the Lluta Valley of Chile, Vinton (1997) found yuca starch grains in seven coprolites, oca starch grains in four coprolites, and various types of potato starch grains in four coprolites. Nevertheless, even though there was proof that these foods had been eaten, none of the coprolites contained the pollen from any of these species (Vinton, 1997). Similarly, our analysis of 25 Chiribaya mummies from southern Peru commonly revealed yuca starch grains, but no yuca pollen (Reinhard & Bryant, 1994; Reinhard *et al.*, n.d.).

One reason for the absence of these root and tuber plant pollen types in coprolites is quite simple. These plants are insect-pollinated and therefore produce very little pollen. By the time the roots and tubers have matured for harvest and are then prepared as food, the flowers, which are above ground, have withered and disappeared. Even if some of the pollen from these root and tuber crops might have fallen to the ground and become part of the soil, when the tubers were cleaned, washed, or prepared as food, attached soil pollen would have been lost. Therefore, it seems to us that it would be nearly impossible to have attached pollen from these plants included as part of the food when these roots and tubers were eaten.

What about the possibility that some of the pollen from these plants might have been present in the atmosphere and settled on prepared foods about to be eaten? We suspect that pollen control samples from the Dos Cabezas site would have resolved that question, but those studies were not done. Nevertheless, we believe this scenario is unlikely. All of these root and tuber crops are insect-pollinated plants. As mentioned earlier, it is rare for such pollen to be represented in the normal pollen rain of an area, even in regions where those types of plants grow abundantly.

Another point to consider regarding the use of potatoes is that the type of potato grown and traded in pre-Inca times (chuño) was prepared for storage by taking the harvested potatoes up to the treeless Puno regions of the Andes and then freeze-drying the tubers. Freeze-drying methods included soaking potatoes in cold, high altitude streams, and then squeezing out the water and finally drying the potatoes in specially vented structures. This process reduces even more the probability that pollen from these plants would be present on these widely-traded potatoes.

As we have already pointed out, we remain skeptical regarding Geyer *et al.*'s (2003) identifications of the pollen from various root and tuber crops at the Dos Cabazes site. Most of the pollen types they found from root and tuber plants are non-endemic to the lowland regions of Peru. Furthermore, if these items were obtained in trade, it is not likely that pollen grains would have been carried on the roots or tubers. Lastly, it is unlikely that pollen would have persisted in the preparation of food from the tubers or that any of the pollen could have come from the local pollen rain.

The pollen identifications reported by Geyer *et al.* (2003) include ciruela (*Bunchosia armeniaca*) and tarwi (*Lupinus mutabilis*), both of which come from plants that are known to be high-elevation cultigens. Ciruela grows between 1,500 and 2,400 masl (National Research Council, 1989). Tarwi can be grown as low as 800 masl but it is more commonly grown at higher elevations up to and higher than 3,000 masl (National Research Council, 1989). These are insect-pollinated plants which would leave very little or no pollen contamination on the food product. Tarwi is a bean, so the actual food product is removed from the pod and the consumed portion is never exposed to pollen. Because of the natural ecology of these two plants, and because they are endemic to higher-elevation habitats, we think that it is probable that these pollen identifications from the Dos Cabezas site are also in error.

Geyer *et al.* (2003) also noted that they found peanut (*Arachis hypogaea*) pollen. If this identification is correct, then the discovery is remarkable. Peanut flowers produce small amounts of insect-pollinated pollen, which must be fertilized while the flowers are above ground (McGregor, 1976). The developing seed pod is then shoved underground by growing stems. We cannot conceive of a way in which pollen from the above-ground flowers would persist on the underground forming pods. Usually, the peanuts would first be washed to remove dirt, which would also remove any attached pollen. Next, if the seeds inside the pods were then removed before being eaten, then it would be impossible for any pollen from the plant to be on the seeds or to become part of the pollen contents of a coprolite. Even when entire peanut pods were chewed and eaten it is unlikely that pollen would be introduced into the intestinal tract this way. During a modern experiment, no peanut pollen was found in the feces of a volunteer who ate 25 whole peanuts, including the outer shells. The peanuts were purchased in a five-pound bag from a commercial source and the volunteer's fecal samples were examined for three days after eating the peanuts.

Geyer *et al.*'s (2003) discovery of other pollen types in the Dos Cabezas remains may not reflect dietary usage of those plants, even though that point is stated as one of their conclusions. They found one cholla cactus grain (*Cylindropuntia*) in one burial. Similar to the single agave pollen grain, we do not believe that this is sufficient evidence of the intentional consumption of any part of the cholla plant. Similarly, the low pollen counts of other insect-pollinated types they found could be suggestive, but are not proof of dietary use. These include: (1) squash (*Cucurbita maxima*); (2) pacay (*Inga feuillei*); (3) cucuzzi (*Lagenaria siceraria*); (4) lucuma (*Lucuma bifera*); (5) palta (*Persea americana*); and (6) pallar (*Phaseolus lunatus*). We believe that the authors need to produce additional verification of the potential dietary use of these plants. Complementary evidence could be additional analyses of the soils from these sites, or data from additional studies of burial sediments that included a search for macroscopic remains, starch, phytoliths, or further verification in the form of ample concentrations of these pollen types recovered in coprolites.

Several of the pollen types found and reported by Geyer *et al.* (2003) could accurately reflect dietary use. These pollen types include aji (*Capsicum baccatum*), achocha (*Cyclanthera pedata*) and guava (*Psidium guajava*). These plants were available to coastal Peruvians either through trade or from local production. Pollen grains are especially abundant in the flowers of achocha and guava. The larger numbers of pollen grains that they found from these plants suggest consumption, and it would allow for comparative studies with modern reference pollen to ensure that their identifications to the species level are indeed possible for these pollen taxa.

We are also concerned by the Geyer *et al.* (2003) report regarding their identification and interpretation of kiwicha (*Amaranthus caudatus*) and quinoa (sic. "Chenopodiaciea"). We are not sure how they were able to be certain that the pollen they recovered actually represents the parent plants of kiwicha and quinoa. Both of these plants produce pollen grains that are morphologically nearly identical to the pollen from more than a thousand other species and close plant relatives, all of which are weeds and not cultigens. Because of the morphological similarities among the pollen types in more than 100 genera and 1,300 species of plants in the Chenopodiaceae, and their overall similarity with the pollen of more than 50 species in the genus *Amaranthus* in the Amaranthaceae, Martin (1963) suggested lumping all of them into the general category "Cheno-Am." Only through detailed studies of all the different Cheno-Am pollen types within a given geographical region (McAndrews & Swanson, 1967), or through extensive pollen studies using the scanning electron microscope (SEM), can one be certain of the precise identification of certain species of these plants.

Vinton's (1997) study shows how important it is to analyze macroscopic seed remains to establish a basis for Cheno-Am pollen interpretation, which is a lesson that should be transferred to burial sediment analysis. Vinton (1997) noted in her coprolite studies that she often found complementary evidence of both Cheno-Am pollen and *Chenopodium* seeds. She also found that there was on average about 2674 Cheno-Am pollen grains per gram of coprolite, when the same coprolite also contained the macrofossil remains of *Chenopodium* seeds. Reinhard *et al.* (1992) found the same to be true of burial sediments. If Geyer *et al.* (2003) had analyzed seeds from the burial sediments in addition to pollen, they may have been able to support their claim that the chenopod or amaranth pollen they found actually had a dietary origin.

Geyer *et al.* (2003) reported high numbers of maize (*Zea mays*) pollen, which is not unexpected for this site. Maize is wind-pollinated, but the pollen is large and heavy and does not travel far from its source (Hevly, 1981). Nevertheless, in the harvesting and preparation of maize for food, maize pollen was often consumed unintentionally with maize-based foods. Vinton (1997) found as many as 1903 maize pollen grains per gram of coprolite for Chilean Late Intermediate Period and Late Period coprolites, with the average concentration value for *Zea* pollen being 696 grains per gram. She also found the pericarp of maize kernels in the macroscopic analysis of the coprolites. Based on previous studies, it is quite likely that the maize and Cheno-Am pollen found by Geyer *et al.* (2003) do reflect dietary use. However, their conclusions are weakened by the absence of supporting macroscopic analysis of the burial soils, and the absence of pollen data from control samples that might have shown how abundant this pollen type could be in the normal pollen rain of the Dos Cabezas region.

Background pollen types

Geyer *et al.* (2003) identified four types of background pollen. One of these is identified as the thistle *Cirsium altissimum*. This plant is insect-pollinated and thus its pollen is rare in the normal pollen rain. In addition, the pollen in the genus *Cirsium* can be confused easily with other genera of thistles and their relatives. Therefore, we are concerned that this pollen identification might also be in error and we wonder whether the pollen might actually have come from related types, some of which have economic importance. The authors also noted finding small amounts of wormwood (*Artemisia tridentata*). This plant is native to North America and grows mostly in cool and semiarid, high-elevation environments above 1,500 meters (Whitson, 1996). We think it is unlikely that this plant was in the Moche region.

Some of the other background pollen they found includes sedges (*Cyperus eragrostis* and *Scirpus californicus*). We have found that it is nearly impossible to use pollen to distinguish the various species of these two genera without SEM analyses. Often it is nearly impossible even to assign pollen of these two types to the proper genus because of similar morphologies, and both *Cyperus* and *Scirpus* are easily degraded in soils, thereby making precise identifications even more uncertain. We would suggest that it might be prudent to combine all of the sedge pollen (*i.e. Cyperus eragrostis* and *Scirpus californicus*) into one large, family-level category called the Cyperaceae. There are some plants in this family that are associated with dietary use, such as *Schoenoplectus*. If all of the sedge pollen from the Dos Cabezas site currently listed as *Cyperus* and *Scirpus* were combined into the one larger, family-level group, then we are struck by the variation in abundance of this type between the three samples from the Moche giants. We maintain that it is possible that the Cyperaceae pollen grains may not necessarily be part of the background pollen rain, but instead might reflect dietary use of plants in this family.

Reinterpreting pollen evidence of poisoning of the Moche giants

Geyer *et al.* (2003) identified pollen from six poisonous and/or medicinal plant species in the remains from Dos Cabezas. These include one high-altitude plant species, coca (*Erythroxylon coca*), four tropical Amazonia plant species (Brunfelsia grandiflora, *Cassia reticulata*, *Lonchocarpus nicou*, *Nealchornea yapurensis*) and one plant species that is endemic to the tropical environments in both North and South America (*Sapindus saponaria*). If these pollen grains were identified correctly, then this information might indeed suggest that the death of the Moche giants could have been caused by poisoning. Geyer *et al.* (2003: 278) write that the Moche "purposely incorporated them in the last meals of these individuals with the intent of causing a premature death. The researchers ask that this hypothesis at least be considered."

To test this hypothesis, we can follow the logic presented by Chaves & Reinhard (2006). Firstly, with regard to endemicity, none of these plants are endemic to the Dos Cabezas region. However, coca was traded to the lowlands by cultures living at higher elevations in the Andes. The four Amazonian plant species are tropical and endemic to the east side of the Andes (Schultes & Raffauf, 1990; Plotkin, 1993). They are not endemic to the arid, Pacific Ocean side of the Andes. This means that these plants would have had to be traded from the Amazonian region across the Andes to the Moche region in the Peruvian lowlands. Soapberry (*Sapindus saponaria*) is a tropical plant, but it is not endemic to the Dos Cabezas region of coastal Peru. The knowledge that all five of the tropical plants just mentioned grow in areas very distant from the Peruvian Pacific coast immediately begs the question of whether these plants were actually used by the Moche culture. Since the only recorded use of these plants by the Moche culture rests on the pollen recovered and identified by Geyer *et al.* (2003), we feel their interpretation is premature.

Geyer *et al.* (2003) also suggested that these plants were used as poisons. It is true that *B. grandiflora, C. reticulata, L. nicou, N. yapurensis,* and *S. saponaria* were used as poisons in the tropical regions of Amazonia. However, these plants were used to make dart-tip (curare) poisons, not poisons that were designed to be taken internally. The poisons are made from the leaves, bark and roots of these plants, not the flowers (Schultes & Raffauf, 1990; Plotkin, 1993). Also, all of these plants are insect-pollinated. For pollen grains to be included in the poison preparations, flowers or flower buds would need to be used, which is inconsistent with the reported preparation method. Finally, we cannot be confident of the correct identification of these pollen types because no descriptions or photographs of the pollen are included in the Geyer *et al.* (2003) report.

We remain highly skeptical that these pollen types were actually present in the remains reported from the Dos Cabezas site. As noted, none of these species are endemic to the Moche study area, five of the reported types are endemic to the east side of the Peruvian Andes, and all are tropical. Five of the reported types are from plants that are poisonous, but the poisons that are made from those plants do not include the flowers and are not taken internally.

We do know that coca leaves were traded down to the coastal areas from the Andes, and it is possible that the Moche giants chewed coca leaves. However, coca is not a poison and only becomes poisonous after the alkaloids from the leaves are removed and concentrated, as is done in modern types to produce cocaine. Leaves from the coca plant were chewed in prehistory, but because coca plants are insect-pollinated, there would rarely be even a small trace amount of coca pollen on any of the ingested coca leaves. It is also noteworthy that in analyses of dental calculus and mummy coprolites from the Andean region, coca pollen has never been found (Reinhard & Bryant, 1994; Vinton, 1997; Nelson, 1997; Reinhard *et al.*, 2001, n.d.).

Summary

We believe that at least some of the types of errors presented in Table 1 may have been made during the Geyer *et al.* (2003) analysis. We have listed and tabulated those potential errors in Table 2. As detailed above, in our opinion there could be at least one error in each of 28 of their identifications. Because Geyer *et al.* (2003) did not use reference collections, and because they did not specify laboratory conditions or microscopy used in their analysis, it is difficult to rule out possible laboratory or identification errors.

Beyond these common errors, we believe that there are some serious flaws in the reported pollen data presented by Geyer *et al.* (2003) that go beyond laboratory analysis. Firstly, the analysis of burial sediments and remains should be conducted in conjunction with controlled paleoethnobotanical field excavation sampling. Secondly, pollen control samples should be collected from within the burial features, from the surrounding fill, and from the habitat surrounding the site (Adams &

Table 2. Types of potential errors in the Geyer *et al.* (2003) interpretations: potential errors are indicated by an X in the corresponding error type box

Taxa	Error types from Table 1							
	1	2	3	4	5	6	7	8
Agave americana	X				X	X		?
Artemisia tridentata	X							
Amaranthus caudatus					X	X		?
Arachis hypogaea	X		X	X		X	X	?
Arracacia xanthorrhiza	X		X					?
Brunfelsia grandiflora	X	X	X	X				?
Bunchosia armeniaca	X							?
Cassia reticulata	X	X	X	X				?
Cucurbita maxima							X	?
Cylindropuntia species							X	?
Cyperus eragrostis						X		
Erythroxylon coca			X					?
Inga feuillei							X	?
Lagenaria siceraria							X	?
Lepidium meyenii	X		X					?
Lonchocarpus nicou	X	X	X	X				?
Lucuma bifera							X	?
Lupinus mutabilis	X							?
Manihot esculenta			X					?
Nealchornea yapurensis	X	X	X	X				?
Oxalis tuberosa	X		X					?
Persea americana							X	?
Phaseolus lunatus							X	?
Sapindus saponaria	X	X	X	X				?
Scirpus californicus						X		
sic. "Chenopodiaciea"					X	X		?
Solanum tuberosum	X		X					?
Vicia faba	X		X					?

Mehringer, 1975; Reinhard *et al*., 1992). Collected control samples should be processed either before or at the same time as samples from the burial samples, because the control samples offer the best way to determine which pollen types are potential background contaminants and which resulted from intentional usage.

The analysis of burial sediments and coprolites should be multidisciplinary. Interpretation of the pollen record is compromised if complementary studies of the macroscopic remains are not conducted. If one wants to gain the greatest amount of data from burial sediments and coprolites, one should analyze pollen grains, examine phytoliths, search for starch grains, look for other microscopic plant fragments, search for parasites, examine the seeds, identify the stems and fibers present, look for mussel and bird-egg shell fragments, examine recovered hair samples, identify bones, and try to identify all of the other macroscopic animal and plant remains in a sample (Reinhard & Bryant, 1992). If this type of comprehensive analysis is not done, then potential data are lost and analysis of the samples can become a wasted effort.

In the Andean region, the importance of searching for starch remains cannot be overemphasized (Vinton, 1997). Starch grains present a wonderful source of dietary information because the grains are distinctive and the types from oca, chuño, maca, manioc, and other sources such as achira (*Canna edulis*) can be identified.

In fossil pollen studies, and especially in coprolite and mummy digestive tract analyses, pollen concentrations are an essential element (Maher, 1981; Sobolik, 1988; Reinhard *et al*., 1991, 2002, 2006; Vinton, 1997). This method is based on the quantification of pollen grains per unit weight or volume of an analyzed sample. Most often, the quantification is possible because fossil pollen numbers are compared with a known quantity of introduced, tracer spores, usually those of *Lycopodium*. Quantification of pollen in samples adds additional interpretative data to the relative percentages of pollen in a sample.

There are four essential parts of a pollen study of archeological materials, and each must be done thoroughly to produce reliable interpretations. Firstly, the archeological samples and control samples must be collected carefully to ensure against potential pollen contamination. Secondly, laboratory pollen extraction must be done in a contamination-free facility, and techniques that are used must not destroy or damage the pollen. Thirdly, recovered fossil pollen should be compared with modern pollen reference samples to ensure correct identifications. In some cases where adequate reference materials are not available, fossil pollen should be tentatively assigned at the family and/or genus level. For example, it is wise to include the designation "cf." (compares favorably) for those fossil types where positive identification is not certain. Furthermore, in the absence of SEM studies, it is rare that fossil pollen types can be identified and confirmed as belonging to only one species of a plant genus, unless the pollen grain's morphology is unique at the level of light microscopy. Fourthly, once the pollen analysis is complete, it is critical that the resulting data be interpreted as logically and correctly as possible, making assumptions only about those pollen types which seem to fit logically into patterns of either background or economic categories.

Our discussion in this paper has focused on some of the problems related to the published pollen data from archeological sites. We have used the pollen study by Geyer *et al.* (2003) as an example of some of the problems that currently exist in the published literature. In our critique of the published pollen record from Dos Cabezas, we have drawn examples from our own experiences working with similar types of deposits from sites in Peru and elsewhere in South America. In this regard, we hope that the reader will find our discussions and comments helpful, keeping in mind that these are our opinions based on specific first-hand experience at other Andean sites.

References

Adams DP, Mehringer PJ. 1975. Modern pollen surface samples: an analysis of subsamples. *Journal of Research of the US Geological Survey* **3**: 733–736.

Berg GE. 2002. Last meals: recovering abdominal contents from skeletonised remains. *Journal of Archaeological Science* **29**: 1349–1365.

Bohrer VL. 1981. Methods of recognising cultural activity from pollen in archeological sites. *Kiva* **46**: 135–142.

Bryant VM, Holloway RG. 1983. The role of palynology in archaeology. In *Advances in Archaeological Method and Theory* Volume **6**, Schiffer MB (ed.). Academic Press: New York; 191–219.

Bryant VM, Morris D. 1986. Uses of ceramic vessels and grinding implements: the pollen evidence. In *Archaeological Investigations at Antelope House*, Morris D (ed.). National Park Service Publications in Archaeology No. 19: Washington, DC; 489–500.

Chaves SM, Reinhard KJ. 2006. Critical analysis of prehistoric evidence of medicinal plant use, Piauí, Brazil. *Journal of Palaeogeography, Palaeoclimatology and Palaeoecology* **237**: 110–118.

CONDESAN-CIP (Consorcio para el Desarrollo Sostenible de la Ecorregión Andina-Centro Internacional de al Papa) 1997. *Pocket Guide to Nine Exotic Andean Roots and Tubers* Centro Internacional de al Papa: Lima.

Dimbleby G. 1985. *The Palynology of Archaeological Sites*. Academic Press: New York.

Donnan CB. 2001. Moche burials uncovered. *National Geographic* **199**: 58–73.

Geyer PS, Larson TS, Stroik L. 2003. University of San Diego palynological investigation of the Dos Cabezas giants. *International Journal of Osteoarchaeology* **13**: 275–282. doi: 10.1002/oa.685.

Hermann H. 1997. Arracacha (Arracacia xanthorrhiza Bancroft). In *Andean Roots and Tubers: Ahipa, Arracacha, Maca and Yacon; Promoting the Conservation and Use of Underutilized and Neglected Crops*, Hermann M , Heller J (eds). Institute of Plant Genetics and Crop Plant Research: Gatersleben; 75–172.

Hermann M, Heller J. 1997. *Andean Roots and Tubers: Ahipa, Arracacha, Maca and Yacon; Promoting the Conservation and Use of Underutilized and Neglected Crops*. Institute of Plant Genetics and Crop Plant Research: Gatersleben.

Hevly RH. 1981. Pollen production, transport, and preservation: potentials and limitations in archeological palynology. *Journal of Ethnobiology* **1**: 39– 54.

Irish M, Irish G. 2000. *Agaves, Yuccas, and Related Plants*. Timber Press: Portland.

Knudsen SR. 2003. Reproduction Biology of the Andean Root Crop Arracacha (*Arracacia xanthorrhiza* Bancroft var. *xanthorrhiza*) and the Taxonomic Status of the South American *Arracacia* Bancroft Species with Special Emphasis on the Position of the Cultivated Arracacha and Related Wild Species. PhD dissertation, Botanical Section, Department of Ecology, the Royal Veterinary and Agricultural University, Copenhagen, Denmark.

Maher LJ Jr. 1981. Statistics for microfossil concentration measurements employing samples spiked with marker grains. *Review of Palaeobotany and Palynology* **32**: 153–191.

Martin PS. 1963. *The Last 10,000 Years: A Fossil Pollen Record of the American Southwest*. University of Arizona Press: Tucson.

McAndrews JH, Swanson AR. 1967. The pore number of periporate pollen with special reference to Chenopodium. *Review of Palaeobotany and Palynolology* **3**: 105–117.

McGregor SE. 1976. Insect Pollination Of Cultivated Crop Plants. Agriculture Handbook No. 496. United States Department of Agriculture, Washington, DC.

Miller NF. 1992. The origins of plant cultivation in the Near East. In *The Origins of Agriculture: An International Perspective*, Cowan CW , Watson PJ (eds). Smithsonian Institution Press: Washington, DC; 39–58.

National Research Council. 1989. *Lost Crops of the Incas: Little-Known Plants of the Andes with Promise for Worldwide Cultivation: Report of an Ad Hoc Panel of the Advisory Committee on Technology Innovation Board on Science and Technology for International Development*. National Academy Press: Washington, DC.

Nelson GA. 1997. Sex Related Occupation and Dental Attrition in a Formative Population. MA thesis, Department of Anthropology, University of Nebraska, Lincoln.

Plotkin MJ. 1993. *Tales of a Shaman's Apprentice*. Penguin Group: New York.

Quirós CF, Cárdenas RA. 1997. Maca (Lepidium meyenii Walp.) In *Andean Roots and Tubers: Ahipa, Arracacha, Maca and Yacon; Promoting the Conservation and Use of Underutilized and Neglected Crops*, Hermann M, Heller J (eds). Institute of Plant Genetics and Crop Plant Research: Gatersleben; 173–197.

Reinhard KJ. 1993. The utility of pollen concentration in coprolite analysis: expanding upon Dean's comments. *Journal of Ethnobiology* **9**: 31–44.

Reinhard KJ, Bryant VM Jr. 1992. Coprolite analysis: a biological perspective on archaeology. In *Advancesin Archaeological Method and Theory 4*, Schiffer MB (ed.). University of Arizona Press: Tucson; 245–288.

Reinhard KJ, Bryant VM Jr. 1994. Investigating mummified intestinal contents: reconstructing diet and parasitic disease. In *The Proceedings of the First World Congress on Mummy Studies*. Museo Arqueologico y Ethnografico de Tenerife: Tenerife; 403–408.

Reinhard KJ, Sandness K, Ghazi M, Dendy J. n.d. Dietary analysis of corporeal remains: coprolites and bone chemistry. Unpublished report of dietary analyses of Chiribaya Culture Mummies from the Moquegua Valley, Peru (manuscript available at request from KJR).

Reinhard KJ, Hamilton DL, Hevly RH. 1991. Use of pollen concentration in paleopharmacology: coprolite evidence of medicinal plants. *Journal of Ethnobiology* **11**: 117–134.

Reinhard KJ, Geib PR, Callahan MM, Hevly RH. 1992. Discovery of colon contents in a skeletonized burial: soil sampling for dietary remains. *Journal of Archaeological Science* **19**: 697–705.

Reinhard KJ, Souza SMF, Rodrigues CD, Kimmerle E, Vinton SD. 2001. Microfossils in dental calculus: a new perspective on diet and dental disease. In *Human Remains: Conservation, Retrieval, and Analysis*, Williams E (ed.). British Archaeology Research Council: London; 113–118.

Reinhard KJ, Danielson DR, Daniels M, Miranda SC. 2002. Multidisciplinary coprolite analysis. In *Bighorn Cave: Test Excavation of a Stratified Dry Shelter, Mojave County, Arizona*, Geib PR , Keller DR (eds). Bilby Research Center Occasional Papers 1, Northern Arizona University: Flagstaff; 135–152.

Reinhard KJ, Edwards S, Damon TR, Meier DK. 2006. Pollen concentration analysis of Ancestral Pueblo dietary variation. *Journal of Palaeogeography, Palaeoclimatology, and Palaeoecology* **237**: 92–109.

Schultes RE, Raffauf RF. 1990. *The Healing Forest*. Dioscorides Press: Portland Oregon.

Shafer HJ, Marek M, Reinhard KJ. 1989. Mimbres burial with associated colon remains from the NAN Ranch Ruin, New Mexico. *Journal of Field Archaeology* **16**: 17–30.

Sobolik KD. 1988. The importance of pollen concentration values from coprolites: an analysis of Southwest Texas samples. *Palynology* **12**: 201–221.

Vinton SD. 1997. Dietary analysis of coprolites from the Lluta Valley in Arica, Chile. MA thesis, Department of Anthropology, University of Nebraska, Lincoln.

Whitson TD. 1996. *Weeds of the West*. Western Society of Weed Science/Cooperative Extension Services, University of Wyoming: Laramie.