USE OF POLLEN CONCENTRATIONS IN COPROLITE ANALYSIS: AN ARCHAEOBOTANICAL VIEWPOINT WITH A COMMENT TO REINHARD ET AL. (1991)

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INTRODUCTION

To judge from the phrasing of their article's title, "Use of pollen concentration in paleopharmacology: Coprolite evidence of medicinal plants," Reinhard et al. (1991) proposed to demonstrate prehistoric medicinal plant use in their analysis of pollen spectra from human coprolites by means of pollen concentrations. In actuality, the pollen data were presented in two forms: pollen concentrations and relative frequencies (relative percentages).

Two brief but technical discussions will explore the implications of the choice of pollen analytical method, and some of the perhaps lesser-known aspects of coprolite analysis, before undertaking a re-examination of selected pollen data and some of the authors' original conclusions.

POLLEN ANALYTICAL TECHNIQUES

Relative frequencies were used by Reinhard et al. (1991) to display and analyze their coprolite pollen data, despite the title of their article. This technique is based on the work of Barkley (1934), Dimbleby (1957), Martin (1963), von Post (1918, 1967), and others. Relative frequencies are obtained by counting the pollen grains in a preparation to a total of 200 (or more), and then dividing the number of grains of each pollen type seen by the total and multiplying by 100. Converting pollen data to relative frequencies has two major effects. One, the conversion of raw data to a standard percentage masks variations of total pollen abundance in the samples being compared. Two, all pollen taxa in a sample increase or decrease in relative frequency in response to a decrease or increase in any other taxon in that sample (Birks and Gordon 1985:11).

Pollen concentrations were cited by the authors only for the total concentration of each sample; these data were not used in any of the analyses they reported. Although not referenced in the article, the concept of determining the concentration of pollen grains/unit of sample is based primarily on the work of Benninghoff (1962) and Maher (1981). The method depends on the addition of known numbers of exotic marker grains (commonly called "spike grains") to samples prior to laboratory extraction; both pollen grains and spike grains are tallied separately during microscopy. Estimation of the actual number of pollen grains present in a unit of sample uses the equation:

$$\text{\# pollen grains/unit sample} = \frac{\text{\# fossil pollen counted}}{\text{\# spike grains counted}} \times \frac{\text{\# of spike grains added}}{\text{weight (or vol) of sample}} \qquad (1)$$

The method can produce large numbers if pollen in the samples is abundant. The unique strength of the pollen concentration approach is exactly this ability to spotlight different amounts of pollen/unit sample, especially for individual taxa in the pollen spectrum. These numbers can be reduced to percentages, but will round to the same values as when raw pollen counts are divided by the total pollen count to produce relative frequencies, thus losing the particular advantages of scale provided by pollen concentrations.

Both relative frequencies and pollen concentrations are in use today among palynologists to express pollen data. Data from both approaches can be presented for the same set of samples, as done by Reinhard et al. (1991), although this practice may be more common for environmental samples than for archaeological samples.

Generally speaking, three factors influence the pollen spectrum recovered from a sample: rate of pollen production of the contributing vegetation, rate of pollen (and sediment) accumulation at the sampled locus, and rate of degradation at the sampled locus (Stephen A. Hall, personal communication, 1991). Two of

these events, pollen production and accumulation, are crucial to the present discussion.

Environmental palynologists have used relative frequencies to study diachronic vegetation trends in samples from bogs and other open-air sites since the earliest days of palynology, under the fundamental assumption that the pollen rain falling on a given locality is basically uniform from year to year (Birks and Gordon 1985:3–4). Relative frequencies smooth over minor variations in a larger environmental pattern, and are the traditional method of choice for analyzing environmental samples under this theoretical construct. Critical to the success of this approach, however, is the taking of the environmental samples from areas undisturbed by human activities, especially archaeological sites. This is because environmental palynologists recognize that human activities, past and present, disturb the record of environmental pollen rain. Disturbance can take the form of physical turbation of sediments, for example, which can often be seen in the wall of a trench dug for the purpose of sampling. Other past human disturbance may be invisible, such as an alteration of the localized pollen rain as the result of agricultural activities.

Archaeological palynologists, in contrast, take samples to answer research questions about prehistoric human behavior. Archaeological palynology strives to pinpoint past human interference in an otherwise natural pollen rain: differences in rate of pollen accumulation are one clue to such human interference; another is presence of pollen grains of cultivated plants. The best archaeological samples for studying prehistoric human behavior come from enclosed sampling loci such as floors, pits, vessels, and the like. These are sampling loci specifically excluded from environmental pollen rain (commonly viewed as "contamination" or "noise") falling on the open ground. Total numbers of pollen grains in such samples often vary wildly from sample to sample, because human behavior is the primary source of the pollen selectively captured by these sampling loci.

For example, a pit was used to store pollen-dusted seeds or plant parts, in effect accelerating the rate of pollen accumulation there. An adjacent pit was used to store other items, in effect retarding the rate of pollen accumulation there. Both events took place within a pit structure, the roof of which protected the interior from the natural pollen rain of the site area. Samples scraped from the bottom of both pits will yield pollen spectra skewed not only in terms of total pollen abundance, but also in favor of individual pollen taxa. This is the beginning of a picture of prehistoric human behavior in connection with the two pits, but the choice of data presentation, relative frequencies or pollen concentrations, will determine what patterns are actually seen by the analyst.

Pollen concentrations will highlight differences in pollen accumulation between the samples in this example. These differences in pollen accumulation will be lost if data are expressed as relative frequencies. Perhaps more importantly, rare pollen taxa can be analyzed as real numbers/unit of sample when expressed as pollen concentrations because the data need not sum to a predetermined total such as 100%. Rare pollen taxa can only reflect 1% or less of a 200-grain count when expressed as relative frequencies. It is this lack of ability to highlight rare pollen taxa that is the greatest shortfall of relative percentages as applied to archaeological samples taken to answer human behavioral questions.

POLLEN IN HUMAN COPROLITES

Pollen grains enter the body by inhalation from the air and by ingestion via beverages and food. The rate at which pollen grains and other items exit the human system is another matter. Modern experimental data (Alvarez and Freedlander 1924; Kelso 1976; Martin 1965; Williams-Dean 1978) have shown that intestinal motility is not constant from individual to individual, nor in one individual from day to day. In order for coprolite analysis to proceed at all, a number of basic assumptions are made; it is recognized that they are a gross oversimplification of demonstrated variability.

It is assumed that the pollen spectrum passing through a person's system varies from day to day. The recovery of large amounts of pollen from more than one coprolite implies that large amounts of pollen were ingested for more than one day (assuming that all the coprolites under study were deposited over time, and not as one single event). The natural windborne pollen rain should cause a relatively uniform concentration of "background" pollen types, because they are seasonally present in the air for more than one day. The ingestion of windborne and insectborne pollen types with food and drink, on the other hand, should produce a pollen assemblage independent of the windborne pollen rain.

Coprolite analysts are more or less forced to describe pollen from coprolites as resulting from "accidental" or "incidental" ingestion as opposed to "purposeful" or "economic" ingestion because of limitations in the English language. It is assumed that pollen was probably rarely ingested as a recognized substance per se. The distinction to be made is whether pollen was inhaled or ingested in pollen-dusted water or other liquid (incidental ingestion), or whether pollen accompanied the deliberate ingestion of plant material that happened to be pollen-bearing (economic or purposeful ingestion). Pollen resulting from so-called purposeful ingestion is viewed as indicating dietary, medicinal, or other behavior involving the parent plant. Unusual pollen abundance is one clue to an economic use of plants; presence of insectborne pollen types is another, because these types are rare or absent in the atmospheric pollen rain. In order to establish some sort of baseline for comparison, samples from the air or the modern ground surface are analyzed to provide an idea of pollen production in the site area (expressed as pollen con-centration/unit of sample); these figures provide an idea of how many pollen grains are available to be accidentally inhaled by local residents today (and in the past, by extension).

It is apparent that human coprolites are very far removed from the traditional environmental concept of a "uniform pollen rain," and constitute instead an extreme class of archaeological pollen samples influenced by idiosyncratic human behavior. This means that if the ingestive behavior of individual people is to be studied, then a technique which focuses on different pollen accumulation will give better data.

THE BEHAVIORAL ANALYSIS OF HUMAN COPROLITES

Reinhard et al. (1991) chose to analyze the pollen present in coprolites, the ultimate behavioral samples, using methods designed for environmental palynology and its assumptions (for the record, my own work with prehistoric and

TABLE 1.—Approximate pollen concentrations, in number of pollen grains/g of sample, of Bighorn Cave coprolites.

Concentration[1]	Lab No.	Ephedra	%	Salix	%	Larrea	%
0	12	—	—	—	—	—	—
14,300	1	429	3	572	4	143	1
16,100	2	322	2	322	2	—	—
17,100	17	171	1	1,710	10	171	1
20,500	14	410	2	—	—	820	4
26,000	6	—	—	520	2	780	3
26,200	5	524	2	524	2	262	1
29,300	9	879	3	4,395	15	—	—
29,400	3	—	—	1,176	4	588	2
36,300	10	726	2	363	1	1,452	4
53,000	13	530	1	530	1	2,650	5
72,300	4	4,338	6	1,446	2	—	—
114,900	7	—	—	—	—	—	—
129,000	18	3,870	3	2,580	2	—	—
150,000	8	—	—	1,500	1	—	—
224,000	11	—	—	192,640	86	—	—
1,137,000	16	—	—	693,570	61	—	—
2,240,000	20	1,680,000	75	22,400	1	67,200	3
2,340,000	21	1,895,400	81	—	—	46,800	2
4,973,000	15	—	—	4,973,000	100	—	—
5,000,000	19	—	—	—	—	—	—
means of 21 samples		170,838	8.6	280,821	14.0	5,756	1.2

[1]"Total concentration" (column 1) and relative frequencies taken from Reinhard et al. (1991:123). Approximate concentration values for each taxon calculated from relative frequencies as follows: total concentration × relative frequency of a taxon = concentration for that taxon

modern coprolites also used relative frequencies to express the pollen data [Williams-Dean 1978]; this work is slated for revision). It is my position that use of relative pollen frequencies has resulted in behaviorally meaningful patterns being missed in coprolite pollen data.

I converted the relative frequency data presented by Reinhard et al. (1991) to pollen concentrations by multiplying total concentration by the relative frequency for each pollen taxon, yielding a close approximation of the actual pollen concentrations (Table 1, 2). Original relative frequency values are included for sake of comparison; note that low relative frequencies actually mask high pollen concentrations in many instances. As explored in the following discussion, converting the data for each pollen taxon to pollen concentration provides a much richer picture of prehistoric plant use in each sample.

Reinhard et al. (1991) chose to spotlight three genera of plants with known ethnopharmacological uses: *Larrea* (creosote bush), *Salix* (willow), and *Ephedra* (Morman tea). Data on other pollen types recovered from the coprolite specimens were largely omitted. Only the pollen data from Bighorn Cave, Arizona, and the

TABLE 2.—Approximate pollen concentrations, in number of pollen grains/g of sample, of NAN Ranch burial coprolite and burial soil samples.

Taxon	Burial Coprolite	%	Burial Soil 1 °	%	Burial Soil 2 °°	%	Burial Soil 3 °°°	%
Salix	117,000	26	93	tr	—	—	—	—
Apiaceae	2,250	tr	93	tr**	—	—	—	—
Artemisia	—	—	—	—	63	tr*	—	—
Brassicaceae	238,500	53	—	—	—	—	—	—
Cactaceae	—	—	186	1	63	tr	—	—
Cucurbita	4,500	1	—	—	—	—	—	—
Cheno/Am	36,000	8	13,020	70	7,056	56	3,886	58
Fabaceae	—	—	—	—	—	—	34	tr
high-spine aster	—	—	—	—	63	tr*	—	—
low-spine aster	2,250	tr	—	—	63	tr	67	1*
Pinus	—	—	744	4	63	tr	201	3
Poaceae	4,500	1	2,046	11	2,142	17	804	12
Typha	4,500	1	—	—	—	—	—	—
unidentifiable	2,250	tr	744	4	63	tr***	469	7
Zea	45,000	10	1,674	9	2,646	21	1,206	18
TOTALS:								
Pollen counted	1,011		209		211		124	
Concentration	450,000		18,600		12,600		6,700	

tr trace (here assumed to be a uniform 0.5%).
  * trace % reported for Burial Soil 1 by Shafer et al. (1989:22; Sample 2).
 ** trace % reported for Burial Soil 2 by Shafer et al. (1989:22; Sample 3).
*** trace % reported as 5% in Shafer et al. (1989:22); concentration value would equal 630 grains/g.
  ° provenience given as "grave fill" (Shafer et al. 1989:22; Sample 2).
 °° provenience given as "soil from atop left pelvis" (Shafer et al. 1989:22; Sample 3).
°°° provenience given as "soil from beneath pelvis" (Shafer et al. 1989:22; Sample 4).

Values do not necessarily sum to total. Approximate concentration values calculated as in Table 1. "Total pollen grains counted" taken from Shafer et al. (1989:22). "Total pollen concentration" taken from Reinhard et al. (1991:127).

NAN Ranch, New Mexico, are addressed here, since the Texas samples discussed by Reinhard et al. (1991) did not have pollen concentration values available for their pollen spectra. The conclusions from Reinhard et al. (1991) and my reanalysis are summarized and compared in Table 3.

Bighorn Cave data.—The authors stated as an underlying assumption that insect-borne pollen types were to be viewed as signalling ". . . the intentional consumption of dietary or medicinal plants" (page 122) only when present in relative frequencies greater than 4%. To further highlight intentional consumption of pollen grains, the authors calculated the mean occurrence of the three pollen taxa under discussion (*Larrea*, *Salix*, and *Ephedra*) for all 21 Bighorn Cave coprolites; these means were calculated on the basis of relative frequencies, not pollen concentration values.

TABLE 3.—Comparison of conclusions: relative frequencies vs. pollen concentrations

Bighorn Cave Relative Frequencies	**Bighorn Cave Pollen Concentrations**

Bighorn Cave Relative Frequencies

(1) *Larrea* pollen was accidentally ingested in the 10 specimens in which it was seen (mean of relative frequencies was below 4%).

(2) *Salix* pollen frequencies were significant in only three of 16 samples containing *Salix* (relative frequencies were above the mean of 14%).

(3) Relative frequencies of *Ephedra* in samples from the modern ground surface were 8%–45%, suggesting that windborne *Ephedra* pollen was accidentally ingested or inhaled in 10 of 12 samples containing *Ephedra*.

NAN Ranch Relative Frequencies

(1) Control samples from the midden contained more pollen from Cheno/Ams, Poaceae, and low-spine Asteraceae than did the coprolite, indicating that the lower amounts of these pollen types in the coprolite were derived from the natural pollen rain in the site area.

(2) Midden samples contained more pollen from corn than did the coprolite, pointing up the unusual nature of the last meal(s) of the individual.

(3) The pollen spectra of the three midden samples resembled each other more than the coprolite pollen spectrum; these were lumped and interpreted as environmental or non-behavioral control samples. High relative frequencies of *Zea* pollen in samples 2 and 3 were suggested as reflecting ritual preparation of the grave with corn pollen or corn meal by Shafer et al. (1989:27), but not by Reinhard et al. (1991).

Bighorn Cave Pollen Concentrations

(1) *Larrea* pollen was not accidentally ingested (relative frequencies represent from 143 to over 67,000 insect-transported *Larrea* pollen grains/g of sample).

(2) *Salix* pollen concentrations were significant (above an arbitrary 1000 grains/g) in 10 of 16 samples containing *Salix*. Experimental data are needed to suggest the number of *Salix* pollen grains available for accidental ingestion.

(3) Concentration values of *Ephedra* in two New Mexico samples from the modern ground surface suggest that windborne *Ephedra* pollen might have been accidentally ingested or inhaled in only 8 of 12 samples containing *Ephedra*. Better data are needed from modern plant communities.

NAN Ranch Pollen Concentrations

(1) The coprolite sample contained more pollen from Cheno/Ams, Poaceae, and low-spine Asteraceae than did the samples from the midden, despite the midden's exposure to the atmospheric pollen rain, indicating that the coprolite pollen spectrum is behavioral in origin.

(2) The coprolite sample contained more pollen from corn than did the midden samples; no unusual last meal(s) are indicated in the coprolite pollen spectrum.

(3) Burial Soil Sample 2, taken from atop the left pelvis, contained up to twice as many grains of *Zea* pollen as the other two midden samples, suggesting that the sample reflected decomposed intestinal contents. The concentrations of *Zea* pollen in the other two midden samples reflect localized deposition of pollen-bearing plant material which may predate the grave, or may have resulted from ritual use of corn products in the grave as suggested by Shafer et al. (1989:27).

The mean percentage of *Larrea* (1.2%) is below the stated threshold of 4% and all *Larrea* data from the coprolites were dismissed by Reinhard et al. (1991) as ". . . accidentally ingested" (page 125). However, when pollen concentration values of *Larrea* are calculated and the mean determined from these data, samples 20 and 21 (67,200 and 46,800 grains/g, respectively) depart significantly from the mean (5,756 grains/g), suggesting more than accidental ingestion of *Larrea* pollen (Table 1). In fact, most of the calculated concentration values for insectborne *Larrea* pollen grains appear to be high enough to indicate intentional ingestion regardless of departure from the mean concentration value. Pollen concentration data from modern surface samples are needed to establish an "environmental" or "natural" baseline from which to infer "behavioral" departures.

My calculation of concentration values and the mean for *Salix* pollen data from Bighorn Cave coprolites indicates that only two samples (samples 15 and 16), not three (samples 11, 15, and 16) as determined by the authors, depart from the mean concentration value of 280,821 grains/gram (Table 1). The calculated concentration value for Sample 11 (192,640 grains/gram) is still very large; I would definitely pay attention to it if I were conducting this analysis *de novo*. In fact, given the sampling context (coprolites), most of the calculated concentration values for insectborne *Salix* pollen appear to be high enough to indicate possible intentional ingestion.

At this point, I suggest that it is inappropriate to apply analyses of central tendencies and departures from a mean to samples from coprolites precisely because the pollen spectrum originates from within a human body with an idiosyncratic rate of pollen introduction. Given the context, establishment of a mean implies nothing more than an average level of *ingestion*. Coprolites completely lacking pollen are not unknown; one such occurs among the Bighorn Cave samples, raising questions about the implications of both pollen-negative and pollen-positive coprolites. The point of coprolite pollen analysis is to distinguish pollen grains which just "blew into their mouths" from pollen grains which were swallowed more intentionally. A more reasonable approach than analyzing central tendencies is to measure normal ambient pollen levels by means of samples from the modern ground surface or of airborne pollen, using those pollen concentrations as baselines with which to compare coprolite pollen concentrations.

In just such a support of their evaluation of the *Ephedra* frequencies, Reinhard et al. (1991:126) cited the spectra of five modern surface pollen samples taken in an *Ephedra*-dominated ecosystem near Corpus Christi. Those relative frequencies ranged from 8% to 45%; corresponding concentration values were not given. By way of comparison, my own surface sampling of vegetation communities in New Mexico (which include *Ephedra* as a minor member) indicates that the time of year during which the sample is taken is critical. Samples taken during the pollination season for this wind-pollinated plant yield nearly double the calculated pollen concentrations of samples taken at the same locations several months later (Dean 1991; 2723 *Ephedra* grains/g in June 1990; 1528 *Ephedra* grains/g in September 1990). Corresponding relative frequencies for these concentration values are 12% and 7% respectively. If, for the sake of argument, we use my high value as a trial maximum for the normal pollen rain in a vegetation community in which *Ephedra* is present but not dominant (as proposed by Reinhard et al. [1991:125–126] for the West Texas area), four Bighorn Cave samples, not two, contain significant con-

centration values (samples 4, 18, 20, and 21; Table 1). Obviously, more modern pollen samples are needed from well-described vegetation communities in the area of each archaeological site to establish the range of *Ephedra* (and other) pollen concentrations released into the air to be ingested by local residents.

NAN Ranch data.—Reinhard et al. (1991) also presented and discussed pollen data from one coprolite and three soil samples from a midden burial context at the NAN Ranch in New Mexico. The pollen spectra of these four samples had been previously included in discussions by Shafer et al. (1989). I calculated pollen concentration values for the various pollen taxa as described earlier, using data provided in Reinhard et al. (1991; Table 5) and Shafer et al. (1989; Table 1). I assumed that "trace" uniformly indicated 0.5% (1 pollen grain in a 200-grain count) of the stated pollen spectrum. This means that some of my calculations for "trace" percentages probably vary from the actual abundances of rare pollen types. My calculated pollen concentrations are presented in Table 2.

Data given by Shafer et al. (1989:22) indicated that three soil samples were taken from grave fill (here, Burial Soil Sample 1), from atop the left pelvis (here, Burial Soil Sample 2), and from beneath the pelvis (here, Burial Soil Sample 3). This suggests that Burial Soil Sample 2 from atop the pelvis may also contain pollen originating from within the abdomen of the body. Reinhard et al. (1991) lumped all three soil samples together as control samples. These authors observed that pollen frequencies were dominated by Cheno/Am (goosefoot and pigweed) and Poaceae (grass) pollen types, and concluded that these reflected the natural pollen rain of the site area (Reinhard et al. 1991: 126–127), but it should be noted that relative frequencies for Burial Soil Sample 3 are based on an incomplete count (124 pollen grains; Shafer et al. 1989:22). The lower frequencies of Cheno/Am and Poaceae pollen types in the coprolite received no further attention.

Converting relative frequencies of the four samples to concentrations shows that windborne Cheno/Ams and Poaceae are actually more abundant in the burial coprolite than in the control samples. In fact, low-spine Asteraceae (wind-pollinated sunflowers) and *Zea* (corn) pollen types are also more abundant in the coprolite, in contradiction of the pattern yielded by the relative frequencies. The spectrum of Burial Soil Sample 2 from atop the pelvis contains the second highest number of *Zea* pollen grains (up to twice that of the other soil samples), suggesting that it indeed may reflect decomposed intestinal contents. These observations are despite the fact that the sediments into which the grave was dug must have been exposed to the natural pollen rain of the site area while midden deposits were accumulating. The observation that more pollen grains were introduced into a human digestive tract than were accumulated by a midden highlights the special nature of coprolites as data sources; those extra pollen grains may or may not have been knowingly ingested by the individual, but it is very unlikely that they originated from the natural pollen rain of the site area. Concentrations of *Zea* pollen in midden samples 1 and 3 reflect localized deposition of pollen-bearing plant material, and may have resulted from ritual use of one or more corn products in the grave as originally suggested by Shafer et al. (1989:27).

The picture of pollen abundance in the burial coprolite as reflected by concentration values indicates that the individual consumed Cheno/Am, Poaceae,

and *Zea* pollen (probably along with ground chenopod and grass seeds and one or more ground corn products), and the pollen of low-spine Asteraceae (possibly as part of a tea such as made from blooming *Thelesperma* [Navajo tea or *cota*] in the greater Southwest to this day), and the pollen of *Salix* (possibly as a medicinal tea or a fresh food source in the early spring). The burial coprolite had been previously interpreted as reflecting a special diet (Shafer et al. 1989), primarily on the basis of the lack of fiber content. Given that many post-Archaic coprolites were found to be fiber-free in the studies cited by Shafer et al. (1989), there would appear to be little in either the macrofossil or pollen portions of the NAN Ranch coprolite to support the suggestion that it resulted from an unusual diet.

POLLEN EVIDENCE OF MEDICINAL USES OF PLANTS

Reinhard et al. (1991) further concluded that presence of large frequencies of *Salix* and *Ephedra* pollen in some coprolites was the result of intentional consumption of (medicinal) teas (the low frequencies of *Larrea* pollen grains had been dismissed as "accidentally ingested" as noted earlier). This conclusion followed from their observations that the coprolites contained high frequencies of disaggregated pollen grains and lacked botanical macroremains. Because flowers usually contain anthers, and anthers produce pollen, the lack of pollen aggregates in the study coprolites was interpreted to mean that *floral* material was not directly consumed (page 127), but the supporting discussion is confused (". . . *flowers* of this plant were intentionally consumed, probably in a tea derived from the *foliage* of the plant" [page 129], and, "In the process of soaking and possibly heating vegetative and *floral structures* in water, the light pollen grains floated into solution and were then drunk. An aqueous solution derived from *foliage* was the probable source of large amounts of pollen . . ." (page 128, emphasis added). Medicinal use of teas was ascribed to the pollen data because of ethnopharmacological records for these taxa (page 119).

Salix is a dioecious genus (Correll and Johnston 1979:448), with completely separate male and female plants; *Ephedra* is usually dioecious (Correll and Johnston 1979:80). Ingestion of unpollinated female flowers of either *Salix* or *Ephedra* would yield no pollen grains to a coprolite. Ingestion of foliage, bark, or stems from female plants would similarly leave no pollen evidence of the use of these plants, unless pollen from male plants had been deposited on the gathered plant material. Presence of pollen implies the use of primarily male flowers and male plants, and secondarily the use of fertilized female flowers and pollen-dusted female plants. Male and female *Salix* plants produce precocious catkins before or at the beginning of leaf formation, and flowers are unlikely enough to be found in the field that separate keys have been devised for vegetative and floral characters (Correll and Johnston 1979:449–451). Ingestion of male or fertilized female flowers would result in the appearance of *Salix* pollen grains in coprolites. Taxonomic evidence indicates that there is a limited time frame for *Salix* foliage to be produced and still accumulate *Salix* pollen; plant material gathered for use during any other time of year would be very unlikely to convey *Salix* pollen grains in the numbers recovered from either the Bighorn Cave or the NAN Ranch samples. This proposition should be confirmed by laboratory experiments using *Salix* foliage

gathered from male and female plants during the pollination season as well as later in the year.

Why the lack of pollen aggregates which should have been present in the anthers of male flowers and on the fertilized female flowers? At least two possible solutions present themselves. Casual inspection of pollen data from my own work and the work of other palynologists reveals that aggregates of many pollen types are unusual no matter what the sample context. This is to say, pollen taxa such as Cheno/Ams and low-spine Asteraceae are commonly seen as aggregates while most other pollen taxa are rarely seen as aggregates. This suggests that a lack of pollen aggregates is more likely a reflection of plant reproductive biology than human behavior. The presence of pollen aggregates, on the other hand, is cause for scrutiny. Lack of aggregated *Ephedra* pollen grains in the coprolites is a perfect illustration of this point, because it is a wind-pollinated taxon and pollen grains are produced with a minimum of sticky coatings in order to enhance transportation from one plant to another. I can recall seeing aggregates of *Ephedra* pollen only once in 15 years of pollen analysis, but male *Ephedra* flowers should be tested in the laboratory to see whether they yield pollen aggregates.

Secondly, use of a four-minute sonication as part of the pollen extraction procedure may be especially pertinent for *Salix* (sonication ". . . separates the microscopic particles," Reinhard et al.(1991:120). It is entirely possible that this treatment disrupted pollen aggregates from male or pollinated female flowers without causing other damage that would be recognized at the microscope. A simple experiment to extract pollen from male *Salix* flowers with and without a four-minute sonication would shed light on this issue. Disaggregation of pollen aggregates in hot tea water, as suggested by Reinhard et al. (1991:128), is unlikely. Hot water washes are a common part of my pollen extraction procedures and aggregates of other pollen types, both wind- and insect-transported, are common in the final pollen preparation (I have no data specifically for *Salix*). In the final analysis, lack of pollen aggregates does not in and of itself support the interpretation that medicinal teas were the source for the pollen grains under discussion.

Medicinal purposes for *Salix* flowers were lacking in the ethnographic sources I consulted (Castetter and Bell 1951:202–203; Elmore 1976:185; Moore 1979:161; Tierney 1983:70; Vines 1986:95, 104). Only twigs and bark were described for medicinal purposes; these were administered internally as a tea or externally as a wash. Castetter and Bell (1951:203) mentioned that ". . . a fine drink . . ." was formerly made of *Salix* flowers by the Yuma Indians on the Colorado River, but no medicinal effects were mentioned for this drink, nor whether male or female flowering catkins (or both) were selected for use, nor was the preparation (by infusion, fermentation, or another method that might affect the amount of pollen present in the final drink) described. Lack of an ethnographic reference for a particular use for a particular plant does not, of course, mean that the plant never enjoyed such a use. Lack of an ethnographic reference, however, would suggest caution in the conclusion of a "new" use in prehistory.

Salix and *Populus* are closely related members of the same plant family; indeed, some forms cannot be easily distinguished. Food uses of *Salix* flowering catkins were lacking in the ethnographies I consulted, but cottonwood *(Populus)* flowering catkins were eaten during February and March as one of the very ear-

liest spring wild foods in Arizona and New Mexico (Castetter 1935:43). In this dioecious genus, the male catkins are conspicuous but the female catkins are not. Elmore (1943:37–39) states that the Navajo chew *Populus* catkins as gum, alone or mixed with animal fat, and notes that the Navajo words for the flowering catkins of both *Populus* and *Salix* are identical. This observation suggests at least one native taxonomy that lumps uses of both plants together, raising the possibility that such nonmedicinal uses for *Populus* catkins as food or chewing gum could reasonably have extended in the past to include the catkins of closely-related *Salix*.

Finally, Reinhard et al. (1991:130) suggested that *Ephedra* teas may have been used to relieve stuffy noses and colds. However, they stated earlier (page 119) that North American species of *Ephedra* do not contain ephedrine, the compound used to treat such symptoms and found only in Old World species of *Ephedra*.

ACKNOWLEDGEMENTS

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RESPONSE

THE UTILITY OF POLLEN CONCENTRATION IN COPROLITE ANALYSIS: EXPANDING UPON DEAN'S COMMENTS by Karl J. Reinhard,

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Glenna Dean presents a variety of comments on recent research into coprolite evidence of medicinal plants (Reinhard et al. 1991). Some of her comments provide a different perspective on the ethnobotanical significance of our finds. Other comments address methodological issues. The breadth of her comments prevents me from addressing all in a single response; consequently I will focus on those that are more stimulating to me.

Dean comments on two papers, Reinhard et al. (1991) and Shafer et al. (1989); the latter was published in the *Journal of Field Archaeology* and I will largely ignore the comments regarding it. Concerning Reinhard et al. (1991), Dean's comments about plant ecology, pollen dispersion, ecological sampling, and the ethnographic literature were considered by us, and some of these issues were addressed in the original paper. Consequently I will not address them again although I recognize that Dean's alternative interpretations are valid.

Dean's comments of greatest value to me regard the interpretation of pollen concentration data. Dean's observations on this issue provide a stimulating departure for further exploration of the pollen concentration technique. I take this opportunity to place her comments within the perspective of coprolite methodology and to expand upon her observations.

Although pollen analysis of coprolites has long been used for dietary reconstruction, it is a technique that is undergoing continuing refinement (Reinhard and Bryant 1992). A major goal of such analysis is separating the dietary compo-

nent of coprolite pollen data from the nondietary. Using relative frequency data, several researchers have addressed this issue with some success (Bohrer 1981; Bryant 1974a, 1974b; Bryant and Williams-Dean 1975; Clary 1984; Scott 1979; Williams-Dean 1978). Furthermore, the intestinal passage of pollen has been examined experimentally by Kelso (1976) and Williams-Dean (1978) which greatly elucidated the nature of pollen transport and deposition from ingestion to defecation.

Pollen concentration is the latest development of coprolite pollen analysis. The pollen concentration technique was originally devised by stratigraphic palynologists as a means of determining absolute pollen content per unit of sediment and now has recognized potential in paleoethnobotanical analysis (Bryant and Holloway 1983; Holloway and Bryant 1986; Pearsall 1989). Although Kelso (1976) applied the technique in his study of modern feces, Aasen (1984) was the first to apply it to coprolites, followed by Sobolik (1988). Most recently, methods for its application to latrines have been defined by Warnock and Reinhard (1992). Although I had been involved in coprolite pollen analysis since the early 1980s (Reinhard 1985), I did not begin to apply the pollen concentration technique consistently until 1986 with an analysis of Archaic coprolites in southwest Texas (Reinhard et al. 1993). Since then, I have collected pollen concentration data from 155 coprolites from Archaic and horticultural sites in the Southwest and am collecting similar data from Mesoamerican and Peruvian coprolites.

I suspected that application of pollen concentration data to coprolites might provide insight into dietary behavior. In Reinhard et al. (1991) a case was presented that pollen concentrations, when combined with relative pollen frequency data, help shed light on use of medicinal plants, an aspect of plant use which is cryptic in the archaeological record relative to dietary plant use. However, we were conservative in our approach and suggested that pollen concentration be applied as one of a battery of tests, including relative pollen frequency and statistical evaluation, to determine with greater certainty whether human behavior affected pollen recovered from coprolites. Multiple tests of an archaeological problem minimize the possibility of making an interpretive error. Relative frequency data and pollen concentration data both reflect human use of plants, but the magnitude of pollen concentrations from coprolites provide unequivocal evidence of human utilization of economic taxa. We were, however, concerned about applying a stratigraphic technique to archaeological coprolite analysis. There are potentially undefined factors of human behavior and intestinal physiology that may profoundly affect pollen concentration data as has been suggested by Kelso (1976) and Dean (Williams-Dean 1978).

Dean's new comments are significant contributions to the application of the pollen concentration technique. She suggests that pollen concentration data tell us more about plant use than relative frequency data. This suggests that pollen concentration data can be presented independently of relative frequency data. If correct, Dean has made a breakthrough in refining pollen analysis of coprolites. I test her assertion by presenting preliminary statistical evaluation of pollen values from coprolites (further statistical studies are planned). Dean highlights coprolite-specific factors that affect pollen content based on her work with modern feces. I expand on this point by describing recent results of examining mummy intestinal contents which further point to factors of ingestion and food type that affect

pollen concentration. Another issue raised by Dean relates to the utility of pollen aggregates as indicators of pollen consumption. She also suggests that pollen extraction technique may destroy pollen aggregates. I address this issue with data derived from pollen extractions of coprolites using different techniques.

POLLEN CONCENTRATIONS VERSUS RELATIVE FREQUENCY

Pollen data have long been presented by coprolite researchers as relative frequency expressions of a minimum of 200-grain counts. If a new technique is to be useful, it must provide information not available through previous approaches. Statistical analysis of relative pollen frequencies and pollen concentration values should discern whether or not pollen concentration provides different information than relative frequencies.

Dean intuits that pollen concentration values provide a more complete picture of plant utilization than do relative frequencies. Although I agree, I wonder whether the two approaches provide results which are statistically different. Both are measures of pollen abundance and as such may simply represent two different avenues to the same conclusion. For example, if relative frequency shows that a given pollen type makes up 90% of the pollen from a gram of coprolite and the pollen concentration value shows that it occurs in 1,000,000 grains per gram of coprolite, then both expressions indicate a high percentage and high human usage. The difference is the magnitude of pollen variation. Relative frequency data are normalized within 1–100% limits while concentration values typically range between 0 to several million. Thus, the difference, if any, in information conveyed by the two techniques results from differences in magnitude of the different expressions.

To evaluate the difference between the two expressions, I compared relative frequency and concentration value data for 20 coprolites, 10 from the hunter-gatherer site Bighorn Cave, Arizona, and 10 from the horticultural site Salmon Ruin, New Mexico. I selected these sites because of clear differences in the nature of pollen yield between them. Salmon Ruin coprolites tend to contain fewer pollen types, a generally high amount of pollen per coprolite, and lessened background pollen representation. The reverse is true for Bighorn Cave.

The coefficient of variation was determined for each pollen taxon by site. If there is different information being conveyed by pollen concentration as opposed to relative frequency data, then one would expect that when the coefficients are plotted against each other, they would deviate from a linear distribution. As shown in Fig. 1 and Fig. 2, the two sites show variable patterns of coefficient correlation. Salmon Ruin coefficients show poor correlation ($R^2 = 0.50$); Bighorn Cave data show a strong correlation ($R^2 = 0.87$). These results indicate that the two techniques do provide different information, but that the extent of difference is related to site.

Why is this the case? Pollen from Bighorn Cave is largely derived from background taxa, whereas at Salmon Ruin pollen is largely derived from dietary plants. It would therefore appear that human usage of plants could account for the variation. The higher magnitude of variation exhibited by pollen concentration data is probably related to the higher magnitude present in the raw pollen concentration values.
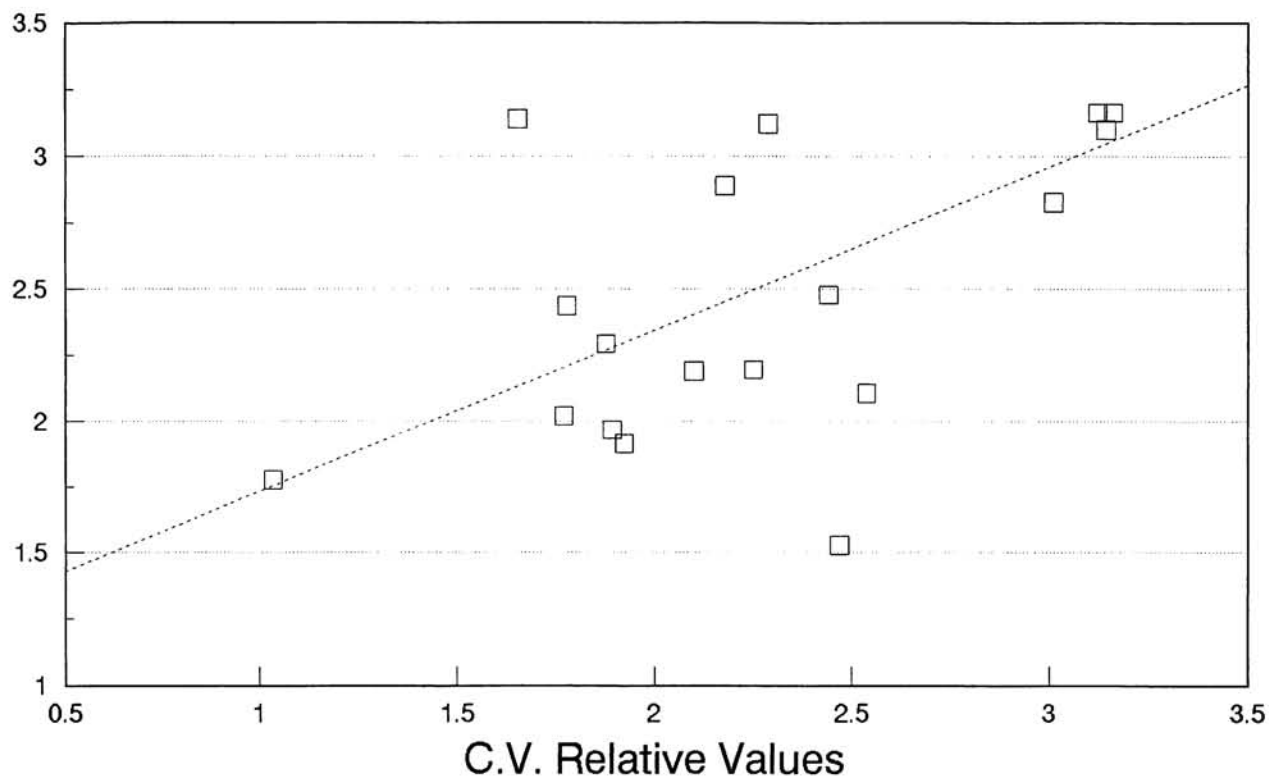
Absolute Pollen Values

Relative Pollen Values
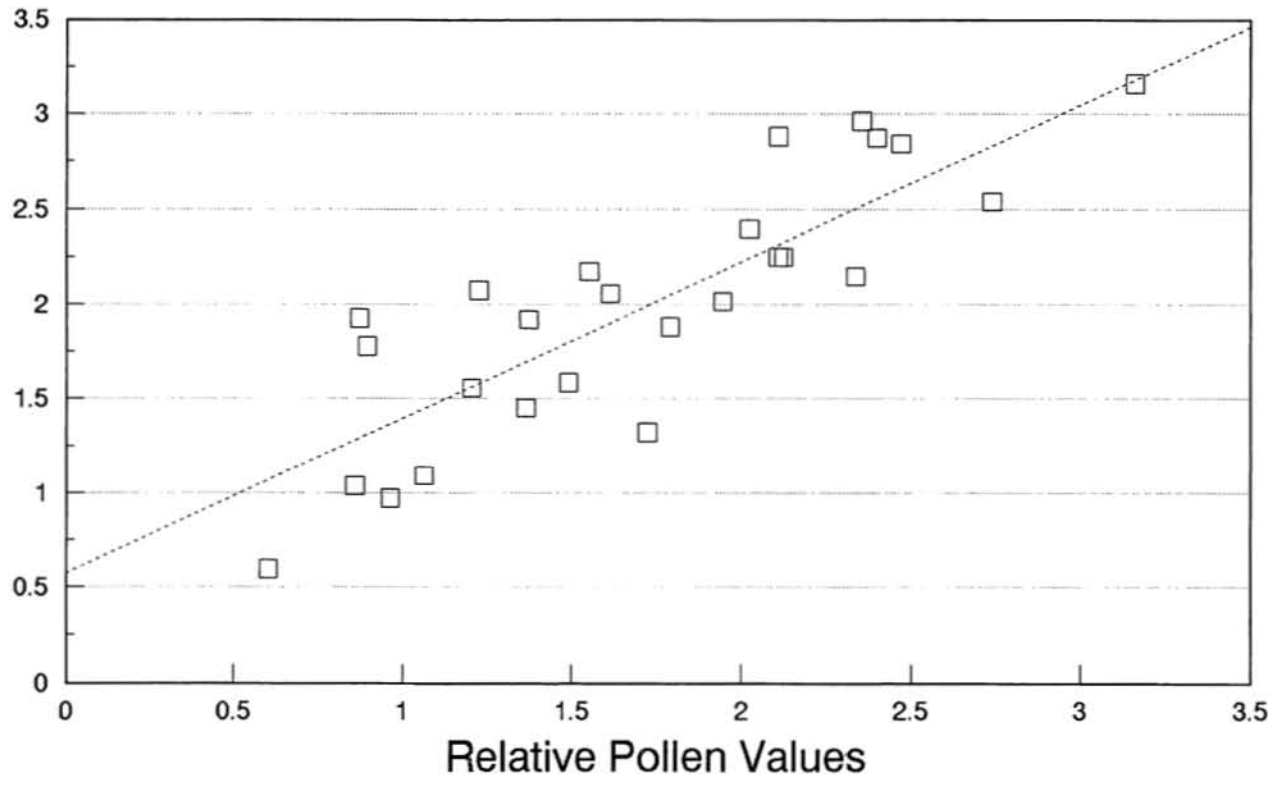
Bighorn Cave
······□······

FIG.1.—Coefficients of variation of pollen concentration and relative frequency values for taxa recovered from Bighorn Cave coprolites. A strong correlation ($R^2 = 0.87$) indicates little difference in the nature of data provided by the two types of pollen quantification.

C.V. Absolute Values

C.V. Relative Values

Salmon Ruin

FIG. 2.—Coefficients of variation of pollen concentration and relative frequency values for taxa recovered from Salmon Ruin coprolites. A poor correlation ($R^2 = 0.50$) indicates substantial difference in the information provided by the two types of pollen quantification.

Finally, to test whether there is different information conveyed on a population level, cluster analysis was performed on pollen concentration and relative frequency data from each site. With regard to Bighorn Cave, the same nine samples sorted into one cluster while one was sorted into another for both concentration and relative frequency data. Clustering differed for Salmon Ruin in that one sample was sorted out in the pollen concentration value analysis but another was sorted out in the relative frequency analysis. This indicates that the different techniques provide different statistical information. Further analysis of the relative significance between pollen frequency and pollen concentration needs to be done; we are continuing to evaluate this problem for the sites mentioned above.

A difference in the information gained by applying the two techniques has been tentatively established by comparative analysis of a small set of coprolite pollen data. Now it is important to ask what factors affect concentration values. We should consider the influences of coprolite substrate and intestinal passage, for example, on pollen concentration values. A recent analysis of mummified intestinal contents is informative in this regard.

POLLEN CONCENTRATION AND MUMMIES

Dean notes that pollen concentration and relative frequency in modern feces are variable among individuals, and vary within one individual from day to day (Kelso 1976; Williams-Dean 1978). Modern studies of coprolites show that pollen is passed up to 32 days after consumption. Pollen is passed most abundantly two to four days after consumption, then in ever-decreasing amounts thereafter.

These studies have been critical in establishing the rate and amount of pollen passage through the digestive tract. My comments are not meant to diminish the contributions of Dean and Kelso. I am, however, concerned with directly applying these data to prehistoric peoples who had a very different diet with respect to fiber consumption, and eating habits that at times probably saturated the intestinal tract with pollen from a few species. Hunter-gatherer coprolites I have examined from Arizona, Utah, and Texas show that the majority of diet comes from a few plant taxa (Reinhard 1992). This probably relates to binge eating of seasonally abundant foods, a phenomenon also reported for modern hunter-gatherers (Cohen 1989). With respect to pollen consumption, it is possible that binging on a polleniferous food may alter the pattern described from modern fecal studies. One might expect the intestinal tract to become saturated with specific pollen types that are passed for many days in large quantities. Prehistoric diets are also high in fiber content. High fiber content accelerates passage through the intestinal tract and therefore may result in defecation of pollen over shorter periods of time but in higher concentrations per unit measure of feces.

Sobolik (1988) provides an example of the error in applying modern studies directly to coprolites. She attempted to ascertain the interval of time lapsed between pollen consumption and defecation based on pollen concentration values. The basic flaw with this study is the unquestioning application of modern studies to a prehistoric, high fiber diet which exhibits considerable evidence of binging. Sobolik presented minimal consideration of these aspects of prehistoric diet. She

also neglected Kelso's (1976) caveats regarding interpreting pollen concentration based on his analysis of modern feces.

Turpin et al. (1986) demonstrated that pollen was recoverable from intestinal contents of mummies. To gain an understanding of pollen passage through prehistoric people, I have initiated study of pollen concentrations in mummified individuals, beginning with mummified or partly mummified individuals from the Southwestern United States, and continuing in Peru. My goal is the recovery of mummified intestinal contents from different parts of the large intestine.

Unfortunately, finding mummies with full intestines is rare; only about 30% of mummies contain mummified intestinal remains and of these, fewer still have feces in various parts of the colon. Since I have not finished the analysis of all Peruvian mummies, my sample size is limited to five individuals. These are nonetheless instructive with respect to variability of pollen concentrations in mummified individuals and therefore relate to interpreting pollen concentrations of coprolites from latrine contexts.

As a study area, the large intestine has several advantages over the stomach or small intestine. First, multiple meals can be recovered from the large intestine. Secondly, the amorphous, more fluid nature of chyme in the stomach and small intestine forms into defined, harder feces after a few hours in the large intestine. Thirdly, the large intestine has well defined areas that are easily identifiable in mummified individuals: the ascending, transverse, descending, and sigmoid portions of the colon. Coprolites can also occasionally be recovered from the rectum. Fourthly, although water content of the feces in the colon is inconsistent (there is greater water absorption on the cecum and ascending colon), it is more consistent than in the small intestine where water absorption is greatest. In the case of analyzing samples, the process of natural mummification results in consistent dehydration of the feces. Pollen concentration of chyme and feces may be affected by water content in living individuals, but this is probably not a factor in dead, desiccated individuals. Thus, in the large intestine, distinct masses of concentrated, dehydrated fecal material can be recovered in anatomical association (reflecting the location and shape of distinct haustra) that are relatively consistent in water content. The study of these remains allows one to evaluate the passage of pollen through the intestine as reflected by pollen concentration values.

Occasionally, partially mummified individuals are excavated, but anatomical association of the large intestine contents are not noted. Two such cases are discussed below. In one of these, it was possible to fit the separate coprolites together to reconstruct their approximate association. However, it was not possible to determine which end of the series was higher in the intestinal tract. It was still possible to sample different regions of the colon.

One of the major factors that affects pollen concentration in feces is the nature of food eaten. Foods vary widely in pollen content and component digestibility. Obviously foods with high pollen content will produce coprolites with pollen. However, prehistoric peoples typically had diets high in nonsoluble carbohydrate (fiber) in the form of vascular bundles, seed testa, epidermis, and other plant structures. Thus, the amount of fiber in the diet will affect the concentration of pollen in feces. The only incorrect assertion in Dean's review is that "many post-Archaic coprolites were fiber free." I have analyzed 373 coprolites from post-

Archaic Southwestern sites (Reinhard 1992) and consistently find fiber to be the dominant component of coprolites. The nature of fiber differs between Archaic and post-Archaic coprolites with vascular tissue being more common in Archaic coprolites and seed testa more common in post-Archaic. Perhaps this is the difference Dean is referring to, not to the general fiber content of coprolites.

Reinhard and Hevly (1991) present the results of a study that illustrates the effects of different pollen and fiber concentrations on mummified feces. Four coprolites were recovered from a partially mummified individual. Two were black and granular and two were light brown and fibrous. One of each type was analyzed. We determined that the dark coprolites came from adjacent haustra and the light coprolites from adjacent haustra, but it was impossible to determine which pair of coprolites was higher in the digestive tract.

Examination of remains from one dark, granular coprolite revealed ground saguaro cactus seed *(Carnegiea gigantea)* and fibers of mesquite pods (*Prosopis* sp.). To quantify the remains, the hila of the ground seeds were counted. A minimal count of 439 saguaro seeds per gram of coprolite was obtained. In addition 11 insect fragments, 13 mesquite pod fragments, 1 grass leaf, and 5 unidentified seeds were observed. In contrast the macroscopic remains of a fibrous coprolite were dominated by mesquite pod fragments. Two peduncles of mesquite pods were found among 46 mesquite pod fragments. We also identified 105 saguaro seeds, mesquite leaf, and a human hair.

Palynological examination revealed a preponderance of cactus pollen in both granular and fibrous coprolites. The pollen concentration value of the granular coprolite was 500,000 grains/gm. Of these, 487,500 were consistent in morphology with saguaro pollen, 11,000 with *Opuntia* sp., and 1,500 were from nondietary, wind pollinated plants. From the fibrous coprolite, only 60,000 pollen grains per gram were recovered, 35,000 of a type similar to saguaro, 6,000 from *Opuntia*, and the remaining from nondietary, wind pollinated plants.

I believe that the dark, granular coprolites are the residue of saguaro seed "cake" and the fibrous coprolite represents a meal of whole mesquite pods. The *Opuntia* sp. pollen is the residue of yet another meal, or the result of indiscriminate pollination of *Opuntia* cactus to saguaro. I believe that the saguaro pollen was probably ingested with the seeds since saguaro flowers are not dehiscent and therefore contamination of seeds with pollen while extracting the seeds and eating mature fruit is a strong possibility.

This mummy, with two meals represented, reflects the effects of dietary pollen and fiber content on pollen concentrations. The mesquite meal was low in pollen and high in insoluble fiber. Although the saguaro seed meal had a high fiber content in the form of seed testa, it was also high in pollen. In this case, the remarkable reduction in pollen concentrations of the mesquite meal (487,500 to 35,000 saguaro-like pollen) is due at least in part to the introduction of large amounts of fiber. The saguaro seed content of the fibrous coprolite was about $^1/_4$ that of the dark, granular coprolite, but the saguaro pollen content was reduced to about $^1/_{14}$. This shows that fiber content of a meal has a pronounced impact on the pollen concentration of the coprolite resulting from that meal.

Examination of coprolites from the Dan Canyon burial (Dominguez et al. 1992) provided an instructive case to evaluate whether pollen concentration in

feces from a single individual varied independently of fiber content. Twenty coprolites were recovered from the excavation of this partially mummified individual. After reconstructing the anatomical order of these coprolites, I sampled three different regions of the colon, probably the ascending, transverse, and descending regions. Three coprolites (A, B, and C) were selected from these areas and processed. Macroscopically, all twenty coprolites were composed exclusively of finely ground grass testa. Thus, in this individual there was consistent dietary residue, and therefore consistent fiber content, between the portions of the colon. This makes it probable that the individual ate several meals of ground grass. Indeed, analysis of foods buried with the individual showed a preponderance of *Oryzopsis* sp. (Indian rice grass). Archaeological reconstruction of the burial also suggests that the individual was buried at a time of low food diversity, probably limited largely to uncultivated grasses. Pollen concentrations derived from this burial should provide an idea of the impact of "binge" eating of a single food source.

It is noteworthy that pollen concentrations varied among coprolites. For sample A, 23,800 grains/gm were recovered, for B 49,500, and for C 19,900. The vast majority of pollen was derived from uncultivated grass (Poaceae). *Ephedra* (Mormon tea) pollen was also present as were trace amounts of *Pinus* (pine) and *Artemisia* (sage brush). Pollen aggregates were noted for Poaceae and *Ephedra*. The variation of pollen concentration was due to variation in grass pollen content. I think it very likely that grass pollen was ingested with the ground grass seed. The occurrence of torn grass grains is consistent with this interpretation: they resemble torn maize grains described by Bryant and Morris (1986) resulting from mechanical breakage on grinding stones.

Despite the fact that food residue was consistent, the pollen concentrations varied. This indicates that consistent diet over a period of time does not result in even distribution of pollen in the intestinal tract. The varying pollen concentrations in otherwise consistent matrices indicate that there is variation due to the influence of undefined factors on pollen concentrations.

Extreme variation in pollen concentration values within a short distance in the intestinal tract is illustrated by the study of mummy T-10, S-241 from the site of Chiribaya Alta, Osmore Drainage, southern Peru. Five samples were recovered: ascending colon, transverse colon, splenic flexure, upper end of the descending colon, and middle of the descending colon (Fig. 3). Five "meals" are present in the colon. In the ascending colon, the coprolite macroscopic residue contains crustacean fragments and manioc tissue in a fine brown matrix composed of ground seed testa. The coprolite in the transverse colon contained possible starch aggregates in a light brown matrix. The splenic flexure contained ground fish bone in a matrix of amorphus, light brown material. The upper descending colon contained crustacean remains and manioc tissue in a dark brown matrix identical to that found in the ascending colon. In the middle of the descending colon, starch aggregates, maize hulls, and crustacean fragments are present. The sequence of foods was consumed in reverse order of that summarized above.

Pollen spectra from the coprolites were dominated exclusively by Cheno/Am grains. Pollen concentrations of Cheno/Am varied between regions of the colon: 9,000 in the ascending colon, none in the transverse, none in the splenic flexure,

ascending colon

rectum

transverse colon

huastra
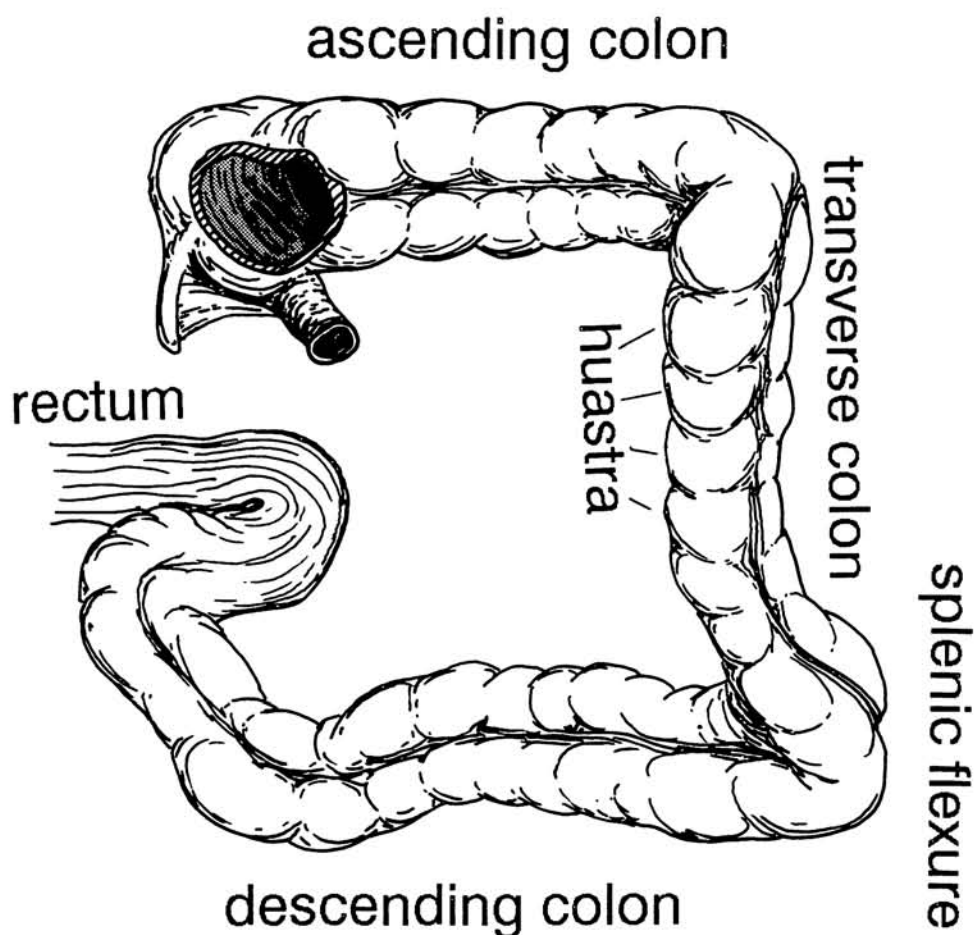
splenic flexure

descending colon

FIG. 3.—Diagram of the large intestine showing anatomical regions sampled for coprolites.

8,200 in the upper end of the descending colon, and 3,400 in the middle descending colon. Higher pollen concentrations are associated with the brown matrix derived from finely ground seeds. The lower concentration in the middle descending colon is probably due to partial mixture of meals between the two descending colon samples. The range in pollen concentration from total absence to several thousand grains per gram which existed in coprolites located a few centimeters apart is not what one would expect based on studies of pollen in modern feces. Gradual voidance of pollen over several days after consumption is indicated by those studies (Kelso 1976; Williams-Dean 1978). The residue from this mummy's large intestine indicates that pollen tended to maintain intestinal position in association with source macroscopic material rather than become dispersed clinally throughout the length of the intestine. Perhaps high bulk diet caused this.

Two other Peruvian mummies from which multiple samples were recovered

contained no pollen at all. One mummy, T-325, S-3763 from Chiribaya Alta, contained coprolites in the sigmoid and descending colon. The sigmoid colon contained maize vascular tissue, other monocot vascular tissue, boiled maize hulls, and spongy fiber vascular tissue. The descending colon contained *guava* seed testa, *molle* leaf tissue, and monocot leaf tissue. The other mummy was recovered from Algonodal, a site near Chiribaya Alta. Coprolites were recovered from the caecum, the ascending, transverse, and descending colon, and rectum. The only identifiable material in the caecum was monocot leaf tissue. All other coprolites from this mummy contained boiled maize hull, woody tissue, and maize leaf tissue. It is unusual for maize hulls to be found without maize pollen in coprolites in the Southwestern United States. The fact that five coprolites from two Peruvian individuals contained macroscopic maize but no pollen suggests that differences in maize preparation techniques between the two regions may have had an impact on the pollen content of consumed maize. Thus, the evidence indicates that food preparation technique, in addition to intestinal action, affects pollen abundance as reflected in pollen concentration values.

Analysis of mummy intestinal samples highlights issues relevant to the interpretation of pollen concentration values from coprolites. Admittedly, the sample of mummies presented above is small. We need to build on this data base, and some of my current research is focused on this problem. Therefore, I present the following observations without generalizing them to pollen concentrations in coprolites. First, there is an interaction between the amount of insoluble fiber and pollen content of foods that affects concentration values. Secondly, even in consistent coprolite matrices from the same individual, pollen is not distributed equally. Therefore, some variation can not be explained on the basis of food texture alone. Thirdly, in the case of one mummy, different foods resulted in differing concentration values in coprolites located very close to each other in the intestinal tract. Contrary to modern studies of fecal pollen content, this indicates that pollen can pass through the intestine in distinct concentrations that do not readily mix between food residues. The most important lesson to be learned from the study of mummies with respect to pollen data is that one must be aware of the macroscopic content of coprolites in order to interpret pollen concentration values.

POLLEN AGGREGATES

Dean raises the issue that pollen aggregates potentially reflect human behavior, and that processing technique affects the integrity of pollen aggregates. Both of these issues need to be addressed.

Since Bohrer (1981) established the importance of pollen aggregates in archaeological analysis based in part on her dissertation research (1968), archaeological palynologists have interpreted the presence of pollen aggregates of some species as evidence of human utilization. Although I have previously used pollen aggregates as evidence of fecal origin (Reinhard et al. 1992), after considering aggregate data from a number of coprolites, I now believe that pollen aggregates are much more common from nonfecal contexts than from coprolites. Furthermore, processing technique does not seem to impact the few pollen aggregates that are present in coprolites.

During the past ten years I have used very different processing techniques on coprolites. From 1981–1984, for example, I was interested in examining parasite eggs, fungal spores, and pollen grains in the same preparation. This necessitated moderating the chemical treatments typically used in palynological processing. My coprolite processing involved rehydration, disaggregation, screening, light acetolysis (3–5 minutes), and brief treatment (30 seconds) in 5% potassium hydroxide. Between 1984 and 1989 my emphasis was on obtaining very clean pollen preparations. Processing involved rehydration, disaggregation, screening, hydrochloric acid, hydrofluoric acid, zinc bromide heavy density separation, sonication, long acetolysis (20 minutes), and potassium hydroxide treatments. Since 1989, I have moderated my processing technique to rehydration, disaggregation, screening, heavy density separation, and moderate acetolysis (5–10 minutes).

Through these years of coprolite study, I have noted the presence of pollen aggregates (pollen clumps of three grains or more). I have not noticed a decrease in the yield of pollen aggregates despite applying different processing protocols. To verify this, I recounted coprolite preparations from two different Anasazi sites, Turkey Pen Cave, Utah, and Salmon Ruin, New Mexico, giving special attention to pollen aggregates. I selected these sites because both are sites with similar diets and pollen representation. Turkey Pen Cave coprolites were processed in 1983; Salmon Ruin coprolites in 1988. These two sites represent the extreme ends of my processing spectrum: Turkey Pen Cave was processed with minimal chemical treatment and no sonication, Salmon Ruin with the most extensive series of treatments.

Of the 10 Turkey Pen Cave coprolites, only five are countable today. The following observations can be made. Sample 263 was dominated by *Cleome*. Two hundred *Cleome* grains were counted of which only one was an aggregate of three grains. Sample 164 was especially rich and over 4,000 grains were counted in three microscope preparations. Of these 3,066 were *Cleome*. Only two aggregates were found, both of *Cleome*, one consisting of four grains, and one consisting of a large aggregate of over 100 grains. Sample 238 was dominated by *Cleome*; 252 grains were counted including two aggregates of three grains and about 50 grains. A *Zea mays* aggregate of five grains was also found. Sample 163 was dominated by high spine composite pollen of which 111 were counted. There were no aggregates. Sample 236 was dominated by Poaceae pollen; 194 were counted, including one aggregate of four grains. Thus, the samples processed with minimal chemical baths and no sonication produced a very sparse representation of pollen aggregates.

The Salmon Ruin counts from 10 coprolites also show low frequencies of aggregates. Twenty-two *Cleome* aggregates larger than three grains were found in five samples. Between 200 and 1,000 grains were counted for each sample. I believe that *Cleome* counts are especially relevant to the question of the importance of pollen aggregates. *Cleome* is an insect pollinated genus and Native Americans used the flowers/buds as seasoning. It should produce pollen aggregates in large numbers. Four Cheno/Am aggregates were also found in two samples. These data indicate that aggregates are recoverable from highly processed and sonicated samples. However, it is clear that pollen aggregates are not abundant, and that more extensive preparation technique does not reduce the number of aggregates. I agree

with Dean that further evaluation of this issue should be made by comparative processing and counting from the same coprolites.

These data illustrate that pollen aggregates are not common in coprolites; pollen goes through mechanical and chemical disaggregation between the time it is obtained from plants and the time it is defecated. Winnowing, grinding, and cooking may impact the presence of pollen aggregates. Food mastication is the beginning of the mechanical disaggregation process that continues through the intestine in the form of peristaltic pressure. Exposure of food to acidic pH in the stomach followed by digestive enzymes in the small intestine are chemical processes that result in further disaggregation. Thus, although pollen exine passes through the intestine intact, aggregates of pollen are broken. Therefore, it is seems that pollen concentration data or even relative frequencies are much more significant than pollen aggregate data in interpreting human use of food plants through coprolite analysis. It is a mistake to emphasize pollen aggregate data.

CONCLUSION

After preliminary evaluation of statistical variation of pollen concentration values and relative frequency values, I agree with Dean that there is different information conveyed by the two expressions of pollen counts. I tentatively agree that pollen concentration values may provide more definitive evidence of plant consumption that relative values. This requires further, intensive statistical evaluation.

Although I recognize Dean's (Williams-Dean 1978) and Kelso's (1976) studies of modern passage of pollen through the intestine as especially insightful work, I believe that considerations of fiber content and binge eating must be incorporated into any model regarding the analysis of prehistoric pollen concentration data. Analysis of mummies demonstrates that these considerations are important in evaluating how pollen passes through the intestine and becomes distributed in coprolites.

I disagree that pollen aggregate data are as significant as pollen concentration data in interpreting prehistoric plant use. I believe that the preingestion processing of plant foods, postingestion mastication and peristaltic pressure, and exposure to digestive acid and enzymes breaks pollen aggregates while maintaining high pollen concentration values.

With regard to differences in ethnographic interpretation of pollen data as reflecting medicinal use of plants, I recognize that Dean presents alternative explanations, but feel most confident in the original assertions presented by Reinhard et al. (1991). This is a case of different researchers coming to different conclusions from evaluation of the same data.

Clearly, the value of pollen concentration data in coprolite analysis requires additional statistical evaluation. The data set I have collected over the past years is large enough for statistical study and this is underway. Since Dean clearly has insights into coprolite pollen data that are different than mine, I have invited her to evaluate these data with me. I anticipate that we will carry out a thorough analysis together. Thus, the productive research into pollen concentration applied to coprolites will continue beyond this exchange of ideas.

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