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USE OF POLLEN CONCENTRATION IN PALEOPHARMACOLOGY: COPROLITE EVIDENCE OF MEDICINAL PLANTS

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ABSTRACT.—Nearly 2,400 plant species have been documented ethnographically as having medicinal value among Native Americans. Therefore, it is not surprising that evidence of medicinal plants appears in some of the over 1,000 coprolites analyzed from the southwestern U.S. Three medicinal species identified in pollen analysis of coprolites are discussed. Willow *(Salix)* is the most common analgesic in the Native American pharmacopoeia. Prehistoric use of this plant is documented in coprolites from Bighorn Cave in the Black Mountains of Arizona and also in a burial from the Mimbres Valley, New Mexico. Historically, Mormon tea *(Ephedra)* served as a diuretic. Prehistoric occupants of Bighorn Cave and the Rustler Hills of far western Texas utilized this plant. Creosote *(Larrea)*, with antidiarrheal properties, has been documented in the Rustler Hills as well. These remains demonstrate the antiquity of folk remedies and provide circumstantial evidence of certain disorders suffered by prehistoric peoples. Also discussed are palynological procedures that are useful in identifying dietary and medicinal pollen types.

RESUMEN.—Se documentaron casi 2400 especies de plantas con valor medicinal usadas por los Indígenas de América. Por eso no es gran sorpresa que la evidencia de las plantas medicinales se hallaron en algunos de los más que 1000 coprolitos analysados del Suroeste de los Estados Unidos. Se discuten tres especies medicinales identificadas por el análisis palinológico de los coprolitos. El sauce *(Salix)* es el análgesico lo más común en la farmacopea de los Indígenas de América. Se documentaron el usado de esta planta en los coprolitos de la Caverna Bighorn de la Sierra Negra de Arizona, y también en una tumba en el Valle Mimbres, Nuevo México. Historicamente, el té mormón *(Ephedra)* ha servido como diurético. Los habitantes prehistóricos de la Caverna Bighorn y del Cerro Rustler del Oeste de Taxes utilisaron esta planta. Se documenta también el creosote *(Larrea)*, que tiene los efectos contra la diarrea. Estos restos muestran la antigüedad de los remedios populares y dan la evidencia circunstancial de algunas enfermadades que afligaron a la gente prehistórico. Se discuten también los métodos palinológicos que son útiles para la identicación de las especies de polen dietético y medicinal.

RESUME.—On a documenté presqu'à 2400 espèces des plantes avec de la valeur medicinale chez les Natifs de l'Amérique. Donc ce n'est pas une grande surprise que la preuve des plantes medicinales apparaît dans quelquesunes des plus que 1000 coprolites analysées de Sud-ouest de l'Etats-Unis. On discoute trois espèces medicinales identifiquées par l'analyse palynologique des coprolites. Le saule *(Salix)* est l'analgésique le plus commun dans la pharmacopée des Natifs de l'Amérique. On documente l'usage de cette plante dans les coprolites de la Caverne Bighorn des Montagne Noires de l'Arizone, et aussi dans une tombe dans la Vallé Mimbres, Nouveau Méxique. Historiquement, le té mormon *(Ephedra)* a servi comme diuretique. Les habitants préhistoriques de la Caverne Bighorn et des Coteaux Rustler de l'Ouest de Texas ont utilisé cette plante. On a documenté aussi le créosote *(Larrea),* qui a des effets contre la diarrhée. Ces restes montrent l'antiquité des remèdes populaires et donnent la preuve circonstancielle de quelques maladies qui ont affligé des gens préhistoriques. On discoute aussi des procèdes palynologiques qui sont utiles avec l'identification des espèces du pollen diétique et medicinal.

INTRODUCTION

A pharmacopoeia was integral in each ancient health care system. Medicinal compounds used were mostly derived from plants. Some have been documented in texts from the Old World (Manniche 1989; Perrot 1987), and at least one codex documents a New World pharmacopoeia (Ortiz de Montellano 1975). However, for most ancient New World cultures, no written record exists of the plants utilized for medicinal purposes. In the absence of textual documentation, ethnographic analysis of extant or historical native Americans has provided the bulk of our knowledge of New World pharmacopoeia (Etkin 1988; Moerman 1986).

Coprolite analysis provides a means to view plants or plant parts directly consumed by humans, including evidence of medicinal plants. The plant remains recovered offer a perspective on ancient plant use that can complement or enhance modern ethnographic data. To date, from the American Southwest macroscopic vegetal analyses of over 1,000 coprolites have been completed. In some cases, evidence of possible medicinal plants has been discovered, including Fry's (1977) find of hallucinogenic *Cornus* bark in a coprolite from Utah, and Reinhard and colleagues's (1985) find of possible use of *Chenopodium* spp. as an anthelmintic.

Psychotropic plants have been recovered from several sites, although not associated with coprolites. Adovasio and Fry (1976) report numerous finds of such plants in the lower Pecos region of Texas and from Coahuila, Mexico. The species found are *Sophora secundiflora* and *Ungnadia speciosa*. These date from 7,500 B.C. to A.D. 1,000.

Microscopic analysis of pollen provides another avenue of examining plant remains in coprolites (Aasen 1984; Adams 1980; Bryant 1974a, 1974b, 1986; Bryant and Williams-Dean 1975; Hevly 1964; Hevly *et al.* 1979; Hill and Hevly 1968; Martin and Sharrock 1964). Pollen analysis of coprolites was pioneered by Hevly, Sharrock and Martin (Martin and Sharrock 1964). Pollen is introduced into the intestinal tract through the consumption of flowers, foliage and seeds of certain species (Adams 1980; Bohrer 1968). Most published pollen analyses document dietary usage of plants. Hevly (1964; Hill and Hevly 1968) was the first individual to identify medicinal plant pollen in fecal remains. In this instance, pollen of *Sphaeralcea* was recovered from an infant burial.

The purpose of this paper is to identify the extent of medicinal plant usage in the southwestern U.S.A. in both time and space. Discussed below are recent palynological examinations of coprolites that have produced possible evidence of medicinal plant consumption. Three medicinal taxa are discussed: *Ephedra* (mormon tea), *Larrea* (creosote) and *Salix* (willow). The coprolites analyzed come from three prehistoric cave sites and one open Mimbres site. Granado Cave and Caldwell Shelter 1 are located in the Rustler Hills of west Texas and contain cultural deposits that date between A.D. 200–1400. Hamilton believes the coprolites are recovered from levels that date to approximately A.D. 700. Bighorn Cave is located in the Black Mountains of western Arizona and coprolites recovered from this cave date to A.D. 600–900. In addition, a coprolite recovered from a Mimbres burial from the NAN Ranch Ruin, New Mexico was analyzed (ca. A.D. 1,000). The Mimbres coprolite represented the colon contents of the burial (Shafer *et al.* 1989). In the case of the burial, control soil samples were taken from the pelvis and knee areas and were analysed to provide a comparative base for the pollen remains from the coprolite.

MEDICINAL VALUE OF PLANT TAXA

The three taxa under study are among the most common plants in the Native American pharmacopoeia (Moerman 1986). We suspect that these plants were used to make tea, as will be discussed below. Strictly defined, 'tea' refers to an aqueous infusion of *Camellia sinensis.* For the purposes of this paper, the term tea refers to an aqueous infusion of the plants considered here.

Salix (willow) contains salicin, an analgesic. Its analgesic use has been documented ethnographically among many New World indigenous cultures (Vogel 1971; Moerman 1986). The compound is typically ingested as a tea.

Moerman (1982) discusses the uses of *Ephedra viridis.* He notes its use as a remedy for venereal disease by traditional hunter-gatherer (Paiute, Shoshone) and agricultural (Zuni, Pima, Hopi) peoples. It is unlikely that this was a cure for venereal disease, but rather used to reduce symptoms of such disease (Kieth Manchester, Mary Lucas Powell, pers. comm.). Moerman also notes that the tea was used as an antidiarrheal by Tewa, Paiute and Shoshone, and as an antirheumatic by the Paiute. In addition, the plant is also used as a burn dressing, a cold remedy, and a treatment for bladder and kidney disorders.

One active compound in at least Asian and Spanish *Ephedra* species is ephedrine. Ephedrine causes "the constriction of blood vessels, rise in blood pressure, dilation of pupils, and relaxation of the intestinal and bronchial muscles" (Moerman 1982:19). Contemporary uses of ephedrine include reduction of nasal congestion due to colds or allergies. Ephedrine is not present in North American

Ephedra species (Norman R. Farnsworth, College of Pharmacy, University of Illinois at Chicago, pers. comm.). Consequently, identification of biologically active compounds in North American species awaits further research.

Larrea also has medicinal value (Lewis and Elvin-Lewis 1977; Moerman 1986). As a hot tea, decoctions of *Larrea* have been used as a treatment for diarrhea. In addition, it is also a Mexican folk remedy for bladder ailments and for removing calcium deposits from kidneys (Holloway 1985).

In the Southwest, *Larrea* and *Ephedra* were used in conjunction for the treatment of disease. Train *et al.* (1982) note that Paiutes boiled the leaves of both plants together to make a tea which was taken internally for gonorrhea. A reduction of the tea, mixed with badger oil, was used as a salve for burns.

The above mentioned plants were used in the treatment of mundane ailments common to most peoples. None of these ailments, except for certain venereal infections, leave osseous traces to be found by paleopathologists. Thus, the find of these medicinal plants provides not only time depth for the study of traditional medicines, but also documentation of minor maladies experienced by prehistoric peoples.

POLLEN PROCESSING PROCEDURE

For Bighorn Cave and the Mimbres burial coprolite analyzed by Reinhard, portions of the coprolites, each weighing 1.0 gram, were rehydrated as described by Bryant (1974b) and Fry (1977) in 0.5% trisodium phosphate for 48 hours. During rehydration, a *Lycopodium* spore tablet was added to the coprolites. Each *Lycopodium* tablet contains 11,200 plus or minus 400 spores. By calculating the number of pollen grains to spores, the approximate number of pollen grains per gram of coprolite can be determined.

After rehydration, the coprolites were disaggregated with a magnetic stirrer. They were then screened through a 300 micrometer mesh screen and the microscopic material passing through the screen was collected in a beaker and concentrated by centrifugation.

After the microscopic remains were washed and again concentrated by centrifugation, they were treated with 72% hydrofluoric acid. This process dissolves fine silicates. The concentrated remains were transferred to 700 milliliter plastic beakers and about 50 milliliters of acid were added to the soil. After stirring, the samples were set aside for 24 hours to allow for completion of the reaction. After 24 hours, the remaining sediments were concentrated by centrifugation. The sediments were then washed with distilled water to remove residual hydrofluoric acid.

After the water washes, distilled water was added to the samples in 50 milliliter centrifuge tubes. The tubes were then placed in a sonicator and sonicated for 4 minutes. This treatment loosens fine organic debris and separates the microscopic particles. After sonication, the remains were transferred to 12 milliliter glass centrifuge tubes and the sediments were concentrated by centrifugation and the supernatant poured off. A zinc bromide heavy density mixture (specific gravity 2.0) was added to the tubes. The samples were then mixed into the zinc bromide and the tubes were spun in a clinical centrifuge at 1,500 rpm for 15 minutes. This process results in the separation of light organic remains, including pollen grains, from heavier organic detritus. The light remains float to the surface of the heavy density mixture and are easily removed. The heavy detritus sinks to the bottom of the tubes. The floating material was concentrated by centrifugation in 12 ml tubes.

The samples were processed further to extract pollen by acetolysis. The samples were washed twice in glacial acetic acid. Then an acetolysis mixture (9 parts acetic anhydride to one part sulfuric acid) was added to the tubes which were then heated for 20 minutes. The acetolysis treatment dissolves several organic compounds, the most important of which are cellulose and chitin. After the acetolysis treatment, the samples were washed once with glacial acetic acid and then with distilled water until the supernatant was clear.

The microscopic remains were then treated for 30 seconds in 5% potassium hydroxide to dissolve humic compounds. After several water washes the supernatant was clear and the microscopic remains were transferred into vials with glycerol.

Microscopic examination was accomplished by placing a drop of glycerol containing the suspended pollen onto a microscopic slide. A coverslip was placed over the drop and sealed with commercial nail polish. After the polish dried, the slides were examined with a binocular compound microscope. The pollen preparations were examined at 400 power. From each slide, a minimum of 200 pollen grains were identified and tabulated. It has been determined that a minimum of 200 grains is necessary for a statistically valid count (Barkley 1934; Bryant and Holloway 1983). The counts provided the basis for percentage expressions of the taxa in the pollen spectra from the coprolites. *Lycopodium* spores were also counted and, as noted above, the ratios of spores to pollen grains were calculated which was then used to calculate the number of pollen grains per gram of coprolite. In addition, pollen aggregates were counted, if present.

The analysis of coprolites from Caldwell Shelter 1 was completed by Holloway (1985) and the analysis of Granado Cave was done by Robert E. Murry (n.d.). Their procedures are similar to those described above with the important exception that *Lycopodium* spore tablets were not added to the coprolites. Holloway examined eight of 20 coprolites and Murry examined 16 coprolites for pollen.

INTERPRETING POLLEN RESULTS

As demonstrated by several researchers (Bryant 1974a, 1974b, 1986; Bryant and Williams-Dean 1975; Hevly 1964; Hevly *et al.* 1979; Martin and Sharrock 1964), pollen analysis of coprolites and latrine sediments is a useful way of obtaining dietary data. Pollen is ingested from dietary sources and also by accidental ingestion. Accidental ingestion includes drinking water containing pollen, eating food on which ambient pollen has settled, and by processing plant materials that carry large amounts of pollen. The focus of coprolite pollen analysis is separating pollen from plants that were intentionally consumed from accidentally ingested ambient pollen.

Two pollen analysis techniques are employed in this study. The first involves calculating the percentages of pollen present in coprolites (Bryant and Holloway

1983), a technique that was first used by Hevly to identify plant pollen from a Puebloan burial (Hevly 1964; Hill and Hevly 1968). This technique is useful in isolating insect pollinated (entomophilous) taxa (Hevly 1964). The second technique is pollen concentration analysis (Kelso 1976; Aasen 1984) which allows for the calculation of the number of pollen grains per gram of coprolite. The latter technique is useful for determining whether or not wind pollinated (anemophilous) types have been intentionally consumed. Wind pollinated taxa are most often incorporated in environmental pollen rain. Of the taxa discussed here, *Ephedra* is anemophilous and *Larrea* is entomophilous. Although *Salix* pollen is derived from catkins like many wind pollinated species, it is largely pollinated by bees.

The different pollen dispersal mechanisms of entomophilous and anemophilous plants result in the differing efficiency levels for the two techniques. As summarized by Bryant and Holloway (1983), anemophilous plants produce an abundance of easily dispersed pollen grains. Anemophilous plants typically produce 10,000 to 70,000 pollen grains per anther. In contrast, entomophilous plants produce about 1,000 grains or less per anther. Entomophilous grains are typically covered with lipids that securely hold them to the anther. Consequently, entomophilous grains rarely appear in percentages greater than about 4% in the natural pollen rain. Thus, the occurrence of large percentages of entomophilous pollen in coprolites (usually 4% or more) signals the intentional consumption of dietary or medicinal plants.

Dietary origin of anemophilous pollen is more difficult to determine. As noted above, pollen of this type is produced in large quantities and is widely dispersed in environmental pollen rain. Consequently, the detection of large percentages of anemophilous pollen does not necessarily indicate the intentional plant consumption. However, accidentally ingested anemophilous pollen should include a variety of taxa. For example, in the prehistoric Southwest, grass pollen, low spine composite, and chenopod/amaranth pollen make up the bulk of the natural pollen rain, with lesser amounts of pine and juniper pollen. A pollen spectrum from a coprolite that is largely dominated by one anemophilous type suggests that this type had a dietary origin. This will be reflected by a high percentage of the total pollen spectrum being composed by a single anemophilous type.

A second means to evaluate anemophilous pollen involves the calculation of concentration, or the number of pollen grains per gram of coprolite. Assuming that environmental anemophilous pollen that is introduced by fortuitous ingestion will appear in relatively low concentrations, then anemophilous types that occur in high concentrations can be inferred as having a dietary origin. The dietary origins of pollen are the consumption of flowers, the consumption of certain seed types, the consumption of foliage which includes buds and flowers, and finally drinking teas derived from foliage or flowers.

Coprolites exhibit a large range of pollen concentration values. In the analysis of Bighorn Cave, most coprolites contained less than 100,000 grains per gram (Table 1). Four samples contained 100,000 to 1,000,000 grains per gram. Five samples exceeded 1,000,000 grains per gram. As pollen concentration increases, there is a tendency for fewer plant taxa to be recovered. For example, of coprolites with pollen concentrations less than 100,000, an average of 16 plant taxa were

TABLE 1.—*Pollen concentration values for all 21 coprolites studied from Bighorn Cave with the number of taxa found in a 200 grain count and percentages of* Salix *and* Ephedra *found in each sample.*

Concentration Value	# taxa	Laboratory #	% *Ephedra*	% *Salix*	% *Larrea*
0	0	12	0	0	0
14,300	14	1	3	4	1
16,100	12	2	2	2	0
17,100	14	17	1	10	1
20,500	18	14	2	0	4
26,000	12	6	0	2	3
26,200	19	5	2	2	1
29,300	16	9	3	15	0
29,400	23	3	0	4	2
36,300	16	10	2	1	4
53,000	19	13	1	1	5
72,300	12	4	6	2	0
114,900	7	7	0	0	0
129,000	18	18	3	2	0
150,00	11	8	0	1	0
224,000	8	11	0	86	0
1,137,000	13	16	0	61	0
2,240,00	11	20	75	1	3
2,340,00	9	21	81	0	2
4,973,000	1	15	0	100	0
5,000,000	2	19	0	0	0

recovered per coprolite. For those ranging from 100,000 to 1,000,000, an average of ten taxa were recovered per coprolite. For those coprolites exceeding 1,000,000 grains per gram, an average of seven taxa were recovered per coprolite. This suggests that as people selectively consume large amounts of polleniferous food, the diverse spectrum of environmental pollen types proportionately decreases. As a subjective criterion for distinguishing intentional consumption, I suggest that pollen concentrations in excess of 100,000 grains per gram signals intentional consumption. Pollen concentrations exceeding 1,000,000 grains per gram definitely indicate selective consumption of polleniferous foods.

Finally, it is useful to evaluate dietary consumption of windborne pollen by calculating deviation from the mean for specific taxa. In this procedure, the mean concentration of a specific taxon from a series of coprolites is calculated. In samples where that taxon significantly exceeds the mean occurrence of the taxon in all coprolites from the site, intentional ingestion is indicated. This is a third method of identifying intentional consumption of foods containing high amounts of anemophilous pollen.

In sum, when concentration data are combined with percentage data and a statistical evaluation of deviation from the mean, one can usually make safe inferences regarding dietary utilization of even anemophilous types. For example, if pollen grains of a specific anemophilous taxon: (1) dominate the percentages, (2) occur in high concentration, and, (3) significantly deviate from the mean, then intentional ingestion is indicated.

RESULTS

All three of the taxa under study were found in coprolites from Bighorn Cave (Table 1). However, only two appear to have been intentionally consumed. *Ephedra* pollen dominates samples 20 (75%) and 21 (81.3%). Pollen concentration shows that samples 20 and 21 contained quantities in the millions of pollen grains per gram (Tables 1 and 2). The pollen from three coprolites from Bighorn Cave sug-

TABLE 2.—*Pollen percentages and concentration values for selected coprolites from Bighorn Cave.*

Taxon	Laboratory Numbers				
	11	15	16	20	21
Salix	86	100	61	1	
Ephedra			1	75	81
Larrea				3	2
Acer	1				
Artemisia			1		
Brassicaceae	8		1	3	2
Cheno Am			7	1	1
Fabaceae	1				
High Spine Asteraceae			3	1	1
Juniperus	1				
Ligulafloreae					2
Liliaceae			3		
Low Spine Asteraceae	2		14	2	6
Onagraceae			1		
Pinus	1		2	1	
Poaceae			4	9	2
Populus			1		
Quercus	2			1	1
Typha latifolia			1		
Unidentifiable			4	6	3
Yucca				1	

gests intentional consumption of *Salix*. In coprolite 11, 86% of the pollen recovered was from *Salix* and the pollen concentration value of 224,000 grains per gram was relatively high (Tables 1 and 2). Very high pollen per gram values were obtained from samples 15 and 16 (4,972,800 and 1,136,800 respectively). Both samples contained large percentages of *Salix* pollen, 61% for sample 16 and 100% for sample 15. In sample 15, the large numbers of *Salix* pollen grains exclude all other types (Tables 1 and 2). It is improbable that *Salix* would normally make up such high percentages of the normal pollen rain or that unintentional ingestion would result in such high pollen concentration values. *Larrea* pollen was present in ten coprolites from Bighorn Cave. The mean percentage occurrence of *Larrea* pollen in all 21 Bighorn Cave coprolites was 1.2. The low percentages of *Larrea* pollen in the Bighorn Cave coprolites indicate that *Larrea* pollen was accidentally ingested.

Ephedra pollen was found in three coprolites from west Texas. From Caldwell Shelter 1, one coprolite, sample 6, contained 11% *Ephedra* pollen (Table 3 and 4). No other coprolite analyzed from this cave contained *Ephedra* pollen. From

TABLE 3.—*Pollen percentages for selected coprolites from Caldwell Shelter 1 (Robert E. Murry, n.d.).*

Taxon	Laboratory Numbers			
	3	6	11	12
Salix			1	2
Ephedra		11		
Larrea	4		2	19
Alnus				1
Artemisia	7		9	3
Brassicaceae		2		1
Cactaceae	2			
Carya	1			
Cheno Am	3	2	3	2
Cornaceae			1	
Fabaceae				1
High Spine Asteraceae	2	1	5	1
Hydrophyllaceae				45
Juniperus	1	1		
Liliaceae	1		1	1
Lamiaceae				3
Low Spine Asteraceae	5	4	11	5
Pinus	3	1	2	2
Poaceae	54	79	48	11
Quercus	6		1	1
Unidentifiable	11		2	

TABLE 4.—*Pollen percentages for selected coprolites from Granado Cave.*

Taxon	Laboratory Numbers 1	11
Ephedra	97	87
Larrea	trace	1
Cheno Am		2
High Spine Asteraceae		1
Lamiaceae	5	
Liliaceae	trace	
Low Spine Asteraceae		1
Pinus	1	
Poaceae	1	6
Unidentifiable		3

Granado Cave, samples 1 and 11 contained 97% and 87% *Ephedra* pollen respectively. Eight other Granado Cave samples contained small amounts of *Ephedra.*

To evaluate the expected percentage of *Ephedra* in normal pollen rain, I sampled soil in *Ephedra* dominated ecosystems at Lake Corpus Christi in south Texas. Five soil samples were taken from points in which *Ephedra* dominated the community and from points where undergrowth plants dominated the community. In plant communities dominated by *Ephedra,* a wide range (8% to 45%) of the pollen rain is from *Ephedra.* The variation in count depends on whether the sample was collected in an area devoid of undergrowth plants, such as species of Apiaceae, Chenopodiaceae, Poaceae, Asteraceae, and Cactaceae, or in areas where undergrowth was thick. Lower *Ephedra* counts were derived from areas of thick undergrowth and high counts were derived from areas of sparse undergrowth.

Clearly, the percentages of *Ephedra* pollen in coprolites from the caves exceed that expected in natural pollen rain. *Ephedra* is not a dominant species in the areas around the caves. The possibility of *Ephedra* making up a large portion of the pollen rain is very remote.

Five of 24 coprolites studied from Caldwell Shelter 1 and Granado Cave contained *Larrea* pollen. From Caldwell Shelter 1, coprolite 12 contained large amounts of *Larrea* (Holloway 1985). Of the pollen recovered from this coprolite, 19% was *Larrea* pollen, a remarkably high amount for an entomophilous species. This high percentage indicates intentional consumption of *Larrea.* The other coprolites from Caldwell Shelter 1 and Granado Cave contained small amounts of *Larrea* pollen that probably have an environmental source (Table 4).

Pollen was abundant and well preserved in the coprolite from the NAN Ranch burial (Shafer *et al.* 1989). Pollen was less abundant in the control soil samples from the burial and represented a different spectrum than that of the coprolite (Table 5). The control samples taken from the midden soils show a predominance of pollen from the Chenopodiaceae and/or the Amaranthaceae, with a strong presence of small sized pollen grains of the Poaceae (grass family). These pollen types probably reflect the natural pollen rain in the vicinity of the village. The small percentages of other pollen types such as the Asteraceae and pine are also environmental types. The next most common type of pollen in the control samples is that of maize (*Zea mays*). This pollen was undoubtedly introduced by human activity. In contrast, the burial coprolite exhibits a dominance of mustard, (Brassicaceae), willow, and maize pollen. *Salix* pollen makes up 26% of the pollen counted in the coprolite sample and the pollen concentration value from the coprolite is 456,000. Thus, the coprolite sample differs from the control sample both in the amount of pollen present and the percentages of different taxa in the pollen spectra. The high percentage and concentration of *Salix* pollen from the coprolite indicates intentional consumption of *Salix,* probably for medicinal purposes (Shafer *et al.* 1989).

The lack of macroscopic evidence of cuticle or fiber of *Larrea, Ephedra,* and *Salix* suggests that vegetative structures of the plants were not consumed. The lack of pollen aggregates is also of interest. Usually, pollen aggregates are found when floral portions of the plants were consumed. The absence of pollen aggregates indicate that flowers were not directly consumed. Yet the high pollen percentages and concentration values indicate intentional consumption of polleniferous substances.

TABLE 5.—*Pollen percentages from soil samples and coprolites recovered from the NAN Ranch burial.*

Taxon	*Coprolite*	*Control Soil Samples*		
		1	*2*	*3*
Salix	26	trace		
Apiaceae	trace	trace		
Artemisia			trace	
Brassicaceae	53			
Cactaceae		1	trace	
Cucurbita	1			
Cheno Am	8	70	56	58
Fabaceae				trace
High Spine Asteraceae			trace	
Low Spine Asteraceae	trace		trace	1
Pinus		4	trace	3
Poaceae	1	11	17	12
Typha	1			
Unidentifiable	trace	4	trace	7
Zea	10	9	21	18
Concentration value	450,000	18,600	12,600	6,700

A parsimonious explanation for the presence of large amounts of pollen with no aggregates and no macroscopic indication of foliage consumption is that the pollen was consumed in an aqueous concoction, i.e. a tea. 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. Thus, consumption of an aqueous solution derived from foliage was the probable source of large amounts of pollen in the coprolites.

DISCUSSION

The presence of the pollen of ethnographic medicinal plants suggests their use in prehistory as medicines (Holloway 1985). However, one cannot assume that plants in prehistory were used to treat the same illness as today or that contemporary uses of medicinal plants can be projected specifically into the past. It is possible that the plant species discussed here were used primarily as food or beverage rather than as medicines. However, this certainly does not negate the medicinal value of the plants. Etkin and Robs (1982), in their study of plant utilization among the Hausa of Nigeria, found that 50% of the medicinal plant species were also classified by the Hausa as dietary plants. Spices especially tend to have medicinal value. The reader should bear in mind these points when reading the discussion below.

There is evidence that the prehistoric inhabitants of Rustler Hills, an area including the Caldwell Shelters, Books Cave, McAlpin Cave, Granado Cave and other sites, were environmentally predisposed to diarrhea. The Rustler Hills are composed of dolomite and lie in the center of the Great Gypsum Plain. The water contains very high levels of magnesium and sulphur (Holloway 1985). As pointed out by Holloway, magnesium is a component of laxatives and the high amount of magnesium in the water probably had a laxative effect on the Caldwell Shelter 1 inhabitants. Hamilton, who excavated the coprolites, is native to this area and verifies that drinking local water, including the spring closest to Caldwell Shelter 1, results in diarrhea. The most direct evidence that diarrhea was a common prehistoric malady is a high percentage of the diarrheal coprolites recovered from Caldwell Shelter 1. Hamilton notes that in the excavation of the cave, formed stools constituted a minority of the coprolites present in the cave deposits. Holloway (1985) estimates that 65% of the coprolites are diarrheal.

In light of these observations, the inhabitants of Rustler Hills may have been in need of antidiarrheal compounds such as *Larrea* and perhaps *Ephedra*. The discovery of *Larrea* pollen in high percentages in two coprolites from the area, and its dietary absence from all other coprolites studied in the Southwest outside of the Rustler Hills of the Great Gypsum Plain, suggests that at least creosote was used in the treatment of diarrhea in this area. The fact that the pollen spectrum of one of these coprolites contains 19% *Larrea* pollen is strongly indicative of intentional consumption. On the average, only 3% of the pollen from Caldwell Shelter 1 coprolites comes from *Larrea*. The fact that 11% of the pollen from Caldwell Shelter coprolite 6 consists of *Ephedra* suggests that the pollen was introduced intentionally. However, in the absence of concentration values from the coprolite, this inference cannot be verified.

The evidence of medicinal plant use at Granado Cave is equivocal. *Larrea* occurs in only two coprolites in low percentages. Therefore, it is impossible to infer intentional use of the species. However, *Ephedra* occurs in eight coprolites and two of those contain high percentages. Sample 1 and sample 11 contain 97% *Ephedra* pollen and 87% *Ephedra* pollen respectively. This is highly suggestive that *Ephedra* was intentionally used at Granado Cave.

There is no indication that the inhabitants of Bighorn Cave in the Black Mountains of Arizona were predisposed to diarrhea or other ailments by their environment; yet there is strong evidence that *Salix* and *Ephedra* were intentionally consumed. Macroscopic evidence of these plants was absent, as were pollen aggregates, which suggests that the pollen was ingested in a tea.

With regard to *Salix* at Bighorn Cave, both the pollen counts and concentration values indicate that flowers of this plant were intentionally consumed, probably in a tea derived from the foliage of the plant. The mean *Salix* pollen percentage for the 21 human coprolites studied from Bighorn Cave is 14%. From samples 11, 15 and 16 pollen percentages from *Salix* are 86%, 100% and 61% respectively. These percentage values deviate significantly from the mean occurrence of *Salix* in all coprolites from Bighorn Cave. The pollen concentration values from samples 11, 15 and 16 are 224,000, 5,000,000 and 1,000,000 grains per gram of coprolite respectively. Thus, the percentages of *Salix* pollen in these coprolites is exceptionally high and the concentration values from these coprolites are also extremely high. These data indicate that a substance, probably a tea, containing large amounts of *Salix* pollen was intentionally consumed.

A similar case can be demonstrated for *Ephedra*. The mean *Ephedra* pollen percentage for the 21 human coprolites was 9%. The *Ephedra* pollen percentages for samples 20 and 21 are 75% and 81% respectively. Both values deviate significantly from the mean. The pollen concentration values for both coprolites exceed 2,000,000 grains per gram. As in the case for *Salix*, the pollen percentages and concentrations for *Ephedra* greatly exceed what would be expected for accidental consumption. Consequently, it is highly probable that a tea derived from *Ephedra* foliage was intentionally consumed, thereby introducing large amounts of pollen into the intestinal tract.

Unfortunately, in the case of the NAN Ranch burial, there is only one coprolite to study. Fortunately, control soil samples were taken from the burial pit to provide an idea of the natural pollen rain in the area.

As noted above, the coprolite from this burial contained 26% *Salix* pollen. The high pollen concentration of 456,000 grains per gram suggests that pollen had a medicinal source when compared to the relatively low concentrations present in the soil control samples. Therefore, the moderate percentage of *Salix* pollen and the high concentration value indicate the intentional consumption of a polleniferous substance. Also, the pollen spectra from the control soils show a minimal amount of *Salix* pollen in the pollen rain at the site. In the case of the burial, it is highly likely that the pollen evidence from the coprolite connotes willow tea administered to a dying individual (Shafer *et al.* 1989).

The origin of medicinal plants has been a topic of recent interest. Moerman (1989) statistically identifies "high use" and "low use" categories for 39 plant families. It is not surprising to find Salicaceae (willow family) classified as a high use taxon. Moerman infers mechanisms by which people originally identified high use plants as medicinal. He points out that many medicinal components are secondary compounds produced in the plants to reduce browsing. Plants signal the presence of the compound and thus experience reduced predation by browsers. The signals may be visual or olfactory. Moerman (1989) and Logan (1988) suggest that people used these signals to identify plants of potential pharmaceutical value. Therefore, the selection of medicinal plants was not random.

It is, of course, impossible to determine if these qualities in *Larrea, Ephedra* and *Salix* were recognized by prehistoric peoples as having medicinal significance. However, the plants discussed here may have attracted human attention in the manner described by Moerman. In the case of *Larrea,* olfactory signals could have stimulated human interest in the plant as a medicine. To a lesser extent this could be true of *Salix* and *Ephedra,* although these plants are not nearly as pungent as *Larrea.* The curious, leafless growth form of *Ephedra* also might have attracted the attention of prehistoric peoples, as it stands out from most other desert plants and is easily recognizable.

This argument is important with respect to the discussion of whether or not medicinal plants originated as dietary plants in prehistory. Reinhard *et al.* (1985) suggests that *Chenopodium* was used first as a dietary plant before the medicinal property of a limited number of its species was recognized. However, at least *Chenopodium graveolens,* an anthelminthic species, produces an intense odor and color change in fall. Perhaps people recognized that there were two varieties of *Chenopodium,* one including many species of dietary value and one including a few species of medicinal value. The difference between the two might have been originally defined from smell and perhaps seasonal color.

Logan (1988) adds another perspective to the origin of medicinal plants. He suggests that the introduction of agriculture resulted in land disturbance with consequent growth of pioneer species. He views agriculture as expanding the variety of plants with which humans were associated. Experimentation with some of these weedy species growing in cultivated fields led to the discovery of medicinal species.

Regardless of whether *Salix, Larrea* and *Ephedra* were first recognized as food, medicine or beverage, the coprolite evidence demonstrates that they were used in the prehistoric Southwest. It is apparent that the use of these plants began among hunter-gatherer cultures. The use of at least *Salix* continued into agricultural times.

The coprolite evidence provides important time depth for the study of the Native American pharmacopoeia. *Larrea* was used in the late Archaic of west Texas. The use of *Salix* and *Ephedra* in western Arizona began by A.D. 600. As coprolite analysis progresses, the antiquity of more medicinal plants will be documented and add an important time dimension to the study of paleopharmacology.

The paleopathological implications of the finds of these plants relate to pathology that will not be preserved in the skeletal record. Stuffy noses and colds may have been treated with *Ephedra* tea. Although the use of *Ephedra* is better known as a treatment for venereal disease, it is unlikely that such disease was common among scattered populations of hunter-gatherers. The various pains resulting from a variety of factors, including degenerative diseases such as osteoarthritis and dental decay, were in all probability treated with *Salix* tea. Diarrhea was evidently a problem in the Rustler Hills. Direct evidence of this malady is not preserved skeletally. However, the presence of *Larrea* in coprolites, combined with modern constitutional effects observed from drinking the local water and the diarrheal form of Rustler Hills coprolites, strongly implicates loose bowels as a chronic problem for Archaic peoples who lived in the area.

The study of pollen remains from coprolites provides the potential for identifying prehistoric medicinal plants. Two aspects of pollen analysis are useful for this purpose: pollen percentages and pollen concentration. As coprolite analysis progresses, we anticipate that more information will be obtained relevant to the development of a Native American pharmacopoeia.

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