PHYTOLITH ANALYSIS OF FEATURE FILL SAMPLES FROM THE EL DORNAJO SITE, ECUADOR.

By

Chad Yost

Paleo Research Institute
Golden, Colorado

Paleo Research Institute Technical Report 08-129

Prepared For

Sarah Taylor
University of Pittsburgh

February 2008

INTRODUCTION

Sediment samples from six different features were submitted for plant opal phytolith analysis from the El Dornajo site, located 10 km inland from the southern coast of Ecuador. This site has two distinct upper and lower occupations, and is affiliated with the Jambeli culture. Previous macrofloral analysis by other researchers failed to identify any economical plant remains. The goal of this analysis is to recover evidence of economic plant use from features associated with the upper and lower occupations.

METHODS

Phytolith Extraction

Extraction of phytoliths from these sediments was based on heavy liquid floatation. Hydrochloric acid (HCL) was first used to remove calcium carbonates and iron oxides from a 15 ml sediment sample. Then sodium hypochlorite (bleach) was used to destroy the organic fraction of the sediment. Once this reaction was complete, a 5% solution of sodium hexametaphosphate was added to the mixture to suspend the clays. Each sample was rinsed thoroughly with distilled water to remove the clays, allowing the samples to settle by gravity. Next, a 10% solution of ethylenediaminetetraacetic acid (EDTA) was added to each sample and throughly mixed. EDTA aids in the removal of organic humic substances. Once most of the clays were removed, the silt and sand size fraction was dried under vacuum. The dried silts and sands were then mixed with sodium polytungstate (SPT, density 2.3 g/ml) and centrifuged to separate the phytoliths, which will float, from most of the inorganic silica fraction, which will not. Because a lot of silt-sized inorganic silica was floated with SPT, each sample was again dried under vacuum and then mixed with potassium cadmium iodide (density 2.3 g/ml). The addition of potassium cadmium iodide greatly improved the recovery and concentration of the phytolith fraction, without which, many of the samples would not have been countable. Any remaining clay that was floated with the phytoliths was removed by centrifugation. Samples were then rinsed with alcohol to remove any remaining water. After several alcohol rinses, the samples were mounted in optical immersion oil for counting with a light microscope at a magnification of 500x. A phytolith diagram was produced using Tilia, which was developed by Dr. Eric Grimm of the Illinois State Museum.

Maize Detection Using Cross Phytoliths and Multivariate Analysis

Wild panicoid grasses and domesticated *Zea mays* (maize) are both members of the grass subfamily Panicoideae and prolific produces of cross-shaped phytoliths in their leaves. Since these samples contained cross-type phytoliths, and are from an area where maize utilization was possible, shape and size analysis of cross-type phytoliths was employed to determine whether these phytoliths were likely to be derived from wild grasses such as *Tripsacum* and teosinte (*Zea diploperennis*), or domesticated *Zea mays* (maize). This method was developed by Dr. Deborah M. Pearsall, University of Missouri, and Dr. Dolores R. Piperno, Smithsonian National Museum of Natural History (Pearsall 1989; Piperno 2006). Cross phytoliths were first assigned a variant type and then measured by visualizing a rectangle around the cross, recording the length (longest side) and the width (shortest side), and then converting to microns (μm). Using multivariate statistics, the resulting cross data for each sample was then entered into two discriminant function equations, one for maize prediction and one for wild grass prediction. The category with the highest canonical score predicts membership in that category. Because multivariate approaches are not 100% accurate, outcomes that predict maize are then subjected to two additional identification rules based on the percent occurrence of variant 1 crosses and large-sized crosses (>16 μm wide). Residues, features and areas directly associated with maize processing and utilization are ideally suited for this type of analysis. Maize signatures from areas and features not directly associated with maize utilization may be diluted by environmental inputs from wild grass decay.

PHYTOLITH REVIEW

Phytoliths are silica bodies produced by plants when soluble silica in the ground water is absorbed by the roots and carried up to the plant via the vascular system. Evaporation and metabolism of this water result in precipitation of the silica in and around the cellular walls. Opal phytoliths, which are distinct and decay-resistant plant remains, are deposited in the soil as the plant or plant parts die and break down. They are, however, subject to mechanical breakage and erosion and deterioration in high pH soils. Phytoliths are usually introduced directly into the soils in which the plants decay. Transportation of phytoliths occurs primarily by animal consumption, gathering of plants by humans, or by erosion or transportation of the soil by wind, water, or ice.

The three major types of grass short-cell phytoliths include festucoid, chloridoid, and panicoid. Smooth elongate phytoliths are of no aid in interpreting either paleoenvironmental conditions or the subsistence record because they are produced by all grasses. Phytoliths tabulated to represent "total phytoliths" include the grass short-cells, buliform, trichome, elongate, and dicot forms. Frequencies for all other bodies recovered are calculated by dividing the number of each type recovered by the "total phytoliths".

The festucoid class of phytoliths is ascribed primarily to the Subfamily Pooideae and occur most abundantly in cool, moist climates. However, Brown (1984) notes that festucoid phytoliths are produced in small quantity by nearly all grasses (mostly rondel-type phytoliths). Therefore, while they are typical phytoliths produced by the Subfamily Pooideae, they are not exclusive to this subfamily. Chloridoid phytoliths (short saddles) are found primarily in the Subfamily Chloridoideae, a warm-season grass that grows in arid to semi-arid areas and require less available soil moisture. Chloridoid grasses are the most abundant in the American Southwest (Gould and Shaw 1983:120). Bilobates and polylobates (lobates) are produced mainly by panicoid grasses, although a few of the festucoid grasses also produce these forms. Panicoid phytoliths occur in warm-season or tall grasses that frequently thrive in humid conditions. Twiss (1987:181) also notes that some members of the Subfamily Chloridoideae produce both bilobate (Panicoid) and Festucoid phytoliths. "According to (Gould and Shaw 1983:110) more than 97% of the native US grass species (1,026 or 1,053) are divided equally among three subfamilies Pooideae, Chloridoideae, and Panicoideae" (Twiss 1987:181).

Buliform phytoliths are produced by grasses in response to wet conditions and are to be expected in wet habitats of floodplains and other places. Trichomes represent silicified hairs, which may occur on the stems, leaves, and the glumes or bran surrounding grass seeds.

Conifers produce opal silica phytoliths in their inner bark and needles. Polyhedral phytoliths are noted to be observed in leaves (Bozarth 1993), while the authors have observed the blocky forms in bark reference samples.

A rapidly growing body of phytolith studies, many of which use three-dimensional typological descriptions, are allowing a much finer resolution of taxa identification, often to the subfamily and genus level. This is especially true with the grass family, where diagnostic forms are now accepted for many additional subfamlies and genera such as: Bambusoideae (bamboo), Erhartoideae (rice), tribe Oryzeae (*Oryza*, *Zizania*), Aristidoideae (threeawn, needlegrass), Arundinoideae (reeds), and *Zea mays* (maize, corn) (Piperno 2006). Determining local and regional levels of diagnostic morphotypes can also greatly improve taxa identification.

Other Siliceous Microfossils

Diatoms and sponge spicules also were noted in these samples. Pennate diatoms are cosmopolitan, occurring in many sediments, and they indicate at least some soil moisture. Sponge spicules represent fresh water sponges. Diatoms are single-celled algae with a siliceous cell wall. They grow in a wide range of aerophilous habitats, including on wet plants and rocks, in damp soils, marshes, wetlands, mudflats, and all types of standing and flowing aquatic habitats. Their silica cells often are preserved in sedimentary deposits. Because individual taxa have specific requirements and preferences with respect to water chemistry, hydrologic conditions, and substrate characteristics, the presence (and subsequent identification to the species level) of diatoms in paleoenvironmental context can provide information about the nature of the local environment. These data, coupled with input about local geology, hydrology, soil characteristics, pollen and phytoliths, provide evidence of the paleoenvironmental setting. In the context of phytolith samples, diatoms are noted, but not usually identified beyond the split of “pennate” and “centric” forms. Centric diatoms often indicate wet conditions, while at least some of the pennate diatoms are cosmopolitan, occurring nearly everywhere. Both diatoms and sponge spicules can be transported with sediment. As an illustration, recovery of sponge spicules in upland soils is noted to accompany loess deposits derived from floodplains in Illinois (Jones and Beavers 1963).

DISCUSSION

Phytolith extraction and analysis was conducted on six feature fill samples from the El Dornajo site, located 10 km inland from the southern coast of Ecuador. The vegetation in the area is described as being dry, thorny scrub forest, situated near the Zarumilla River. The site consists of occupation on three hills (Loma Blasio, Loma Alvarrado, and Loma Segarra) above the Zarumilla River floodplain. Loma Blasio has an artificial platform and associated cemetery. Deposits range from 2.5 to 5 meters in depth and have dense midden refuse. Loma Alvarrado may have been another platform and cemetery area, or it may have been an area of elite residence. Loma Segarra is a residential occupation with dense shell middens. All parts of the site have two distinct occupations, an upper and a lower. This site is culturally affiliated with the Jambeli, and may have an approximate date range of 600 to 1000 AD. It was reported that previous analysis of samples from this site failed to recover any macrofloral botanical remains or storage pits. Thus, very little is known about possible agricultural activities at this site. The goal of this current analysis is to recover evidence of economic plant use from features associated with the upper and lower occupations, and to look for any difference in the phytolith assemblages from these occupations.

All of the samples (Table 1) exhibited a well preserved and highly concentrated phytolith record (Figure 1). All phytolith samples were counted to a total of 301 phytoliths to obtain relative abundance. Additional slides from each sample were scanned for diagnostic food-related phytoliths and cross-type phytoliths used in the maize vs. wild grass discriminant function analysis (Table 2). Results are grouped and discussed by specific location (hill) for this site. Although each of the samples analyzed represents different features, they are paired to represent specific areas of the site for early and late use.

Loma Blasio

Sample 1 was taken from near the bottom of a 50 cm deep pit full of midden deposits including fish bone and shell. This pit was dug into sterile green-gray clay, 3 meters below the ground surface, and is believed to be associated with the initial phase of an artificial platform construction. This sample was meant to represent the period of early platform use. The phytolith record contained several morphotypes diagnostic of potential plant foods, as well as several morphotypes highly distinctive of plant food processing. A seed phytolith diagnostic of cultivated arrowroot (*Maranta arundinacea*) was observed (Figure 2 B) and indicates the likely use of its edible rhizome (Chandler-Ezel, et al. 2006; Piperno and Becker 1996; Piperno 2006). Rectangular phytoliths with irregular short protrusions (IRP phytoliths) were quite notable in this sample (Figure 2 C and D). IRP phytoliths are the product of epidermal silicification in the fruitcase, cupule, glume, and other inflorescence tissues of maize, teosinte, and some non-*Zea* (wild) grasses (Piperno and Pearsall 1993). Wide (> 7.5 µm), rectangular IRP phytoliths were the most common IRP-type observed, and are found primarily in *Zea* species (maize and teosinte), but have been observed in the panicoid grass *Oplismenus setarius* and two bamboo species (*Olmeca* and *Rhipidocladum*). These are very common in *Zea* inflorescences, often occurring in large sheets (Pearsall, et al. 2003). If the possible panicoid and bamboo IRP producing confuser taxa are not likely to have occurred in the study area, such as teosinte, then the presence of the wide rectangular IRP phytoliths may be highly suggestive of the presence of maize. Rectangular IRP phytoliths less than 7.5 wide were observed as well. These IRP phytoliths are produced in *Zea* cob material and in many other panicoid grasses, bamboos, and canes. Globular echinates (Figure 3 A), diagnostic of members of the palm family (Arecaceae), were fairly abundant and may indicate the use of palm fruit or leaf material. Globular echinates occur in the leaf, fruit and bark material of palm family vegetation. If palms are common in this area, the presence of their phytoliths here may likely be derived from the environment or structure construction. A few globular verrucate phytoliths, often in joined chains of two or more, were observed (see Figure 3 B for an example of a charred globular verrucate from sample 6). These are primarily found in leaf material and are diagnostic of families within the order Zingiberales, including the Marantaceae, Cannaceae, Costaceae, and Zingiberaceae.

However, these verrucate globular phytoliths have also been observed in the rhizomes of a number of species within the Marantaceae, including *Calathea* (Piperno 2006:38). Indicators of water use and nearby riparian areas were also fairly abundant. Diatoms (siliceous algae) and freshwater sponge spicules were very common in this sample. Phytoliths diagnostic of the wetland obligate common reed (*Phragmites* sp.), as well as phytoliths diagnostic of bamboo species, were most abundant in this sample, and may be related to structure construction or input from the surrounding environment.

Discriminant function analysis of cross-type phytoliths from sample 1 indicates that the source of the cross-type phytoliths is most likely from wild grasses or non-*Zea* grasses such as *Tripsacum*, bamboos, or other panicoids (Table 2). However, only residues, features and areas *directly* associated with maize processing and utilization are ideally suited for this type of analysis. Maize signatures from areas and features not directly associated with maize utilization may be diluted by environmental or structural inputs from wild grass decay. The presence of wide rectangular IRP phytoliths is suggestive of maize utilization; however, it is not diagnostic and may be derived from use of non-*Zea* grass seeds. In summary for sample 1, phytoliths indicate the utilization of arrowroot (*Maranta arundinacea*) and grass taxa for subsistence purposes during this period of early platform use.

Sample 2 was derived from a posthole in an upper level of platform modification, about 1 meter below ground surface. This sample represents the period of late use of the platform, as compared to Sample 1, which represents early use of the platform. Although not an ideal feature-type to analyze for economic plant remains, the space between a post and its hole can capture and trap food remains from a habitation surface. The most significant find, a single phytolith diagnostic of the tuberous root of *llerén* (*Calathea allouia*) was observed (Figure 2 A). Also important was the recovery of an arrowroot (*Maranta arundinacea*) seed phytolith (Figure 2 B). The diagnostic phytolith from *llerén* tuber material, as well as the seed phytolith from arrowroot, indicates the use of starchy underground storage organs for subsistence during the late occupation of the platform area. An achene (seed) phytolith diagnostic of the sedge family (Cyperaceae) was observed, and may be derived from the genera *Cyperus* or *Kyllinga* (Piperno 1989). With a nearby riparian zone, it is unclear if this phytolith is related to subsistence activities, derived from matting material, or simply part of the environmental signal. As in sample 1, this sample contained palm family (Arecaceae) phytoliths (globular echinate), and Zingiberales phytoliths (globular verrucate), which may be derived from structural material or part of the environmental signature. A few wide-rectangular IRP phytoliths, as well as a dendriform phytolith (Figure 2 E) typical of grass seed glume material, were observed and likely reflect utilization of grass seed for subsistence. Several different thinly silicified epidermal sheet elements were observed, and are often associated with grass seed processing (Harvey and Fuller 2005). It should be noted that this sample, and all of the late-use samples from this site (samples 2,4 and 6) contained trapeziform sinuate phytoliths diagnostic of the cool-season, C3 metabolism, grass subfamily Pooideae. Members of this notable subfamily include wild and domesticated cereal grain producing taxa such as *Hordeum*, *Elymus*, *Triticum*, and *Avena*. Dendriform phytoliths from grass seed glume material were also observed in all of the late-use samples from this site.

Discriminant function analysis of the cross-type phytoliths from sample 2 strongly indicates that the source of the cross-type phytoliths is most likely from wild grasses such as non-*Zea* grasses that might include *Tripsacum*, bamboos, or other panicoids (Table 2). However, it should be mentioned again that only residues, features and areas *directly* associated with maize processing and utilization are ideally suited for this type of analysis. Maize signatures from areas and features not directly associated with maize utilization may be diluted by environmental or structural inputs from wild grass decay. In summary for sample 2, the observation of a phytolith from *llerén* (*Calathea allouia*) tuber material, as well as the seed phytolith from arrowroot (*Maranta arundinacea*), indicates the use of starchy underground storage organs for subsistence during the late use of the platform. Phytoliths also suggest the utilization of non-maize grass, and possibly the use of cool-season grass as part of the subsistence package during late occupation.

Sample 3 was excavated from the bottom of a small hearth-like feature in the lowest levels of the cemetery area, approximately 2.5 meters below ground surface. The feature was dug into sterile green-gray clay and may have accompanied a series of postholes indicating a structure. This sample is meant to represent the cemetery area prior to, or very early in its use. The phytolith record from this sample exhibited the fewest possible food indicators of all the samples analyzed from this site. Phytoliths diagnostic of the sedge family (Cyperaceae), the order Zingiberales, and the palm family (Arecaceae) are most likely derived from the environment or structure construction. Silicified mesophyll cells from a dicotyledonous tree or shrub were commonly observed in this sample, some of which exhibited evidence of being burned (Figure 3 E). The soils in this area at the time of occupation may have been fairly moist and under an arboreal canopy, as sponge spicule (Figure 3 I) relative abundance is fairly high.

Discriminant function analysis of the cross-type phytoliths from sample 3 strongly indicates that the source of the cross-type phytoliths are from non-*Zea* grasses (Table 2). In fact, because of the low concentration of grass phytoliths, only 20 panicoid cross phytoliths were observed and measured. It appears that grass densities at this time were fairly low, again suggesting that a mesic forest may have been the dominant vegetation type at this time. In summary for sample 3, no strong phytolith indicators of possible foods were recovered from this sample, as the phytolith assemblage appears likely to be derived from environmental and possibly structural decay of plant matter.

Sample 4 was taken from a chalky ashy surface 1 meter below ground surface. This surface is only 5 cm thick and has burials excavated into it. It is located near the platform and in a cemetery area. Midden deposits were found both above and below the chalky surface. The sample was taken after scraping the top few cm and was removed laterally. This sample is meant to represent the latter period of cemetery use (sample 3 represents pre or early use). One phytolith diagnostic of the early successional herb genera *Heliconia* (false bird-of-paradise) was observed (Figure 2 F). *Heliconia* used to be placed within the Musaceae, but is now recognized as its own family (Heliconiaceae). These long, narrow phytoliths with the central trough are found in *Heliconia* leaf and rhizome material. *Heliconia* leaves are generally used as wrapping and sometimes as roofing material. The rhizome may also have some edible uses (Duke and Vasquez Martinez 1994). The particular type of *Heliconia* trough phytolith recovered here is more characteristic of those derived from the leaf rather than the rhizome (Piperno 2006:38). An interesting ecological fact about *Heliconia* is that it is an archetypal early pioneer that quickly invades the edges of human clearings and large, natural forest gaps. *Heliconia* is then quickly replaced by woody successional taxa once the disturbance regime has stopped (Piperno 2006:137). A few dendriform phytoliths typical of grass seed glume material, several epidermal sheet elements, and a few trapeziform sinuates diagnostic of cool-season Pooideae grasses were observed. This phytolith combination is suggestive of grass seed processing and utilization, and is found in all of the late-occupation samples. A lack of arboreal phytoliths, along with relatively high proportions of *Phragmites* and bamboo phytoliths suggests that construction materials may have been comprised more of grasses and herbaceous materials than arboreal materials.

An interesting observation in this sample concerns the recovery of several aggregates of rondel grass phytoliths that appear to be slightly melted together (Figure 2 G). Biogenic opal silica has a melting point of about 1000° C (1832° F). However, we have observed phytoliths exposed to lower temperatures (≈500° C) for prolonged periods of time (several days) that have exhibited characteristics of melting such as warping or even complete loss of form. In a study of páramo grassland wildfires in Ecuador, temperatures ranged from 65° C near the ground, to greater than 500° C near the upper leaves of the tussock grass (Ramsay and Oxley 1996). More robust fuels such as woody material can result in temperatures in excess of 1000° C. It's possible that the melting of these grass phytoliths may be related to cremation activities at this site.

Discriminant function analysis of the cross-type phytoliths from sample 4 strongly indicates that the source of the cross-type phytoliths is from non-*Zea* grasses (Table 2). In fact, cross-type phytoliths were rare, as bamboos seem to be responsible for much of the grass phytolith influx. In summary for sample 4, a member of the genus *Heliconia* appears to have been present on site; however, it is unclear if use of this plant was for subsistence (rhizome), wrapping food (leaf), or roofing material (leaves and branches). The *Heliconia* phytolith observed from this sample is most likely derived from leaf material. It is also possible that the presence of *Heliconia* is related to disturbance of the surrounding vegetation, and thus, part of the environmental signature. Phytoliths diagnostic and highly distinctive of bamboos (Bambusoideae) were most abundant in this sample, and may be derived from structure material or environmental inputs. Seed from a cool-season grass(s) may have been utilized for subsistence, as dendriforms, epidermal sheet elements, and trapeziform sinuates were recovered. Melted grass phytolith rondels recovered from this sample may be result of cremation activities or cooking activities involving temperatures in excess of 500° C.

Loma Segarra

Lomo Segarra is a residential occupation with dense shell middens. Sample 5 represents the earlier occupation and sample 6 represents the later occupation of this site.

Sample 5 was extracted from a posthole 1.5 meters below ground surface in the earlier floor of a household area far from the platform and cemetery center. This sample is meant to represent the earlier household occupation of this part of the site. The presence of dendriforms, narrow and wide rectangular IRP phytoliths and many epidermal sheet element fragments suggests that grass seed was utilized for subsistence. One of the epidermal sheet elements appears to exhibit unnatural breaks across the short axis of the long cells, possibly from cutting or processing activities (Figure 2 I). Aggregates of melted rondels, first observed and discussed in sample 4 from Loma Blasio were most abundant in this sample. In fact, some of the aggregates exhibited signs of extreme heat alteration, most likely in excess of 500° C (Figure 2 H).

Sample 5 also exhibited the highest relative abundance of panicoid grass phytoliths, especially cross morphotypes. Discriminant function analysis of the cross-type phytoliths from sample 5 indicates that the source of the cross-type phytoliths is most likely from wild grasses or non-*Zea* grasses such as *Tripsacum*, bamboos, or other panicoids (Table 2). However, the canonical score used to predict membership in either the maize or wild grass category was close (Wild: 0.5505 vs. Maize: 0.4494). As previously stated, only residues, features and areas *directly* associated with maize processing and utilization are ideally suited for this type of analysis. Maize signatures from areas and features not directly associated with maize utilization may be diluted by environmental or structural inputs from wild grass decay. Of the 50 crosses that were measured, 38% were the variant 1 type typically associated with maize, and 30% were variants 2 and 6, which are commonly produced by teosinte and many non-*Zea* grasses (Piperno 2006:60). As a general rule, cross assemblages with less than 50% variant 1 are discounted as resulting from maize decay (Piperno 2006:56). The phytolith assemblage indicates the *possibility* that maize was present at this site; however, the feature-type sampled was not ideal. Basically there were too many non-maize cross types in the assemblage, possibly the result of structure decay or environmental inputs from bamboos and wild panicoid grasses.

Sample 6 was extracted from a posthole, 1 meter below ground surface in the later midden deposits of a household area far from the platform and cemetery center. This sample is meant to represent the later household occupation of this part of the site. Diagnostic phytolith indicators of foods are somewhat lacking from this sample; however, utilization of cool-season grasses cannot be discounted. Dendriforms, a few IRP-types, and epidermal sheet elements, indicators of grass inflorescence processing, were all observed. Discriminant function analysis of the cross-type phytoliths from sample 6 indicates that the source of the cross-type phytoliths is most likely from wild grasses or non-*Zea* grasses such as *Tripsacum*, bamboos, or other panicoids (Table 2); however, a large percentage (58%) of variant 1 crosses typical of maize was observed. Again, the feature -type analyzed here may not be conducive to maize detection using the Pearsall/Piperno discriminant function analysis.

An interesting element of sample 6 is the dominant percentage of saddle phytoliths diagnostic of the grass subfamily Chloridoideae. Chloridoids typically thrive under hot and dry conditions, and their dominance here may indicate that much drier and open conditions existed at this time, and in this particular area. In fact, this is the only sediment sample with no freshwater sponge spicules, typical of soils with some moisture content. Thus, the diatoms observed in this sample, and possibly all the other samples, are likely derived from water transported to this site for various uses, or from storm surges and uncommonly high tides that would have deposited brackish-water tolerant diatoms across the site.

Sample 6 also contained some interesting phytoliths that exhibit evidence of burning. Phytoliths that have been exposed to oxidative fire, particularly an open flame, can exhibit varying degrees of darkening, from dull opaque to completely black; whereas unburned phytoliths are typically transparent or opalescent (Parr 2006). Some phytoliths, such as globular verrucates produced by some members of the order Zingiberales (e.g. *Canna* sp.) are naturally dark. In this sample a few charred perforated sheets diagnostic of sunflower family (Asteraceae) inflorescence material (Figure 3 D), as well as a few charred globular echinates (palm family; Figure 3 B) and globular verrucates (order Zingiberales; Figure 3 C) were observed. Because of the feature type sampled it is unclear if these charred phytoliths are derived from food preparation activities or non-subsistence burning episodes such as cremation activities or wildfires. In summary for sample 6, diagnostic phytolith indicators of foods are somewhat lacking from this sample; however, utilization of cool-season grasses cannot be discounted. Environmental conditions appear to have been hot, dry and fairly open, as shade tolerant bamboo abundance is much reduced and chloridoid grasses are dominant in the phytolith assemblage. Charred phytoliths indicate that members of the sunflower and palm families, as well as a member of the order Zingiberales (e.g. Marantaceae, Heliconiaceae, Zingiberaceae, Cannaceae, Musaceae) were exposed to some type of fire.

SUMMARY AND CONCLUSION

Phytolith analysis of feature fill samples from the Loma Blasio and Loma Segarra areas of the El Dornajo site has documented diagnostic evidence for the utilization of plant resources for subsistence. The most significant find, a single phytolith diagnostic of the tuberous root of *llerén* (*Calathea allouia*) was observed from sample 2 (Figure 2 A). Also important, was the recovery of arrowroot (*Maranta arundinacea*) seed phytoliths from samples 2 and 3 (Figure 2 B), indicating the likely utilization of its rhizome for subsistence. Rectangular IRP phytoliths, produced by maize (cupule) and *Tripsacum* (fruitcase) were observed in samples 1, 2 and 5, and indicate the utilization of grass seed or possibly maize. Use of the Pearsall/Piperno discriminant function analysis on cross-type phytoliths for maize identification did not yield positive results; however, sample 5 was close to indicating maize as the likely source of the crosses. Residues, features and areas directly associated with maize processing and utilization are ideally suited for the Pearsall/Piperno discriminant function analysis. Maize signatures from areas and features not directly associated with maize utilization, such as those examined during this study, may be diluted by environmental inputs from wild grasses not associated with subsistence. It should be emphasized that no diagnostic phytolith evidence for maize was observed; however, additional analyses are recommended. These would include phytolith *and* pollen sampling of areas most likely to be associated with maize processing and utilization. We have successfully developed pollen extraction techniques specifically for dryland terrestrial contexts that differ significantly from those developed for bogs and lake sediments that usually result failure when applied to archaeological sediments. At a minimum, it is highly recommended that sample 5 be subjected to pollen analysis.

The phytolith record from these samples may also contain some basic environmental information. The early occupation samples suggest that arboreal vegetation was more dense, grass populations were less dense, and soils had more moisture than that observed for the later occupation samples. The phytolith assemblage from sample 6, a late occupation feature from Lomo Segarra, was dominated by chloridoid grasses that thrive under hot, dry, and open conditions. Sample 4, a late occupation feature from Lomo Blasio contained a *Heliconia* sp. phytolith (Figure 4 F) that may be derived from subsistence (rhizome), wrapping food (leaf), or roofing material (leaves and branches). *Heliconia* is an archetypal early pioneer that quickly invades the edges of human clearings and large, natural forest gaps. Thus, its presence in the area may also be an environmental indicator. Differences in the abundance of phytolith-based food indicators between samples that represent early and late occupations of the site were not obvious. This is most likely due to the fact that the feature-types sampled varied dramatically in possible function, and may not have been directly associated with subsistence at all.

Finally, aggregates of melted rondels (Figure 2 G and H) indicate that thermal feature and/or cremation activities reached temperatures in excess of 1000° C, or temperatures at least 550° C for prolonged periods of time. Melted phytoliths were observed in samples 4, 5 and 6, but were greatest in sample 5.

With diagnostic phytolith evidence for plant-based subsistence, The El Dornajo site merits additional microfloral phytolith *and* pollen analysis. Although roots and tubers are dietary staples in many parts of the world, their detection through macrofloral analysis is extremely difficult. At a minimum, submission of some of the phytolith results to an academic journal would be merited, especially since the phytolith diagnostic of *Calathea allouia* tuber has only been reported in the scientific literature since 2006.

TABLE 1
PROVENIENCE DATA FOR SAMPLES FROM THE EL DORNAJO SITE, ECUADOR

Sample No.	Area	Unit No.	Strat.	Depth (bgs)	Feature No.	Provenience/ Description	Analysis
1	Loma Blasio	U 1	L	3 m	1	Fill from pit full of midden deposits, was dug into clay 3m below ground surface. Believed to be associated with initial phase of an artificial platform construction.	Phytolith
2	Loma Blasio	U 3	D-2	1 m	F 1	Fill from posthole in an upper level of platform modification about 1m below ground surface.	Phytolith
3	Loma Blasio	U 50	bottom of G	2.5 m	F B	Fill from bottom of hearth-like feature in the lowest level of the cemetery area, 2.5m below ground surface.	Phytolith
4	Loma Blasio	U 50	B-1	1 m	Floor 1	Fill from chalky ashy surface 1m below ground surface located near platform in cemetery area. Midden deposits found both above and below. Floor 1.	Phytolith
5	Loma Segarra	U 31	C	1.5 m	1	Fill from posthole 1.5m below surface in earlier floor of a household area far from platform and cemetery.	Phytolith
6	Loma Segarra	U 45	B	1 m	F 2	Fill from posthole 1m below surface in the later midden deposits of a household area far from platform and cemetery.	Phytolith

TABLE 2
MEASUREMENT AND DISCRIMINANT FUNCTION ANALYSIS OF CROSS SHAPED PHYTOLITHS FOR WILD GRASS VS. MAIZE PREDICTION

Sample No.	% Varient		$\bar{x}$ Size µm:Varient		n	df Classification[1]		df prediction
	1	6	1	6		Wild[2]	Maize[3]	
1	.27	.33	14.13	12.45	30	0.8182	0.1818	Wild
2	.28	.28	13.24	14.42	50	0.9835	0.0164	Wild
3	.65	.15	11.63	11.01	20	1.1306	-0.1306	Wild
4	.20	.44	13.34	13.62	41	0.9718	0.0281	Wild
5	.38	.26	15.84	14.46	50	0.5505	0.4494	Wild
6	.58	.16	13.62	15.24	50	0.8789	0.1210	Wild

[1] Identification of maize and wild grass cross-shaped phytoliths based on df developed by Piperno (2006)

[2] Wild grass df: 2.96669 - 0.1597589 ($\bar{x}$ width Var.1) - 0.0126672 ($\bar{x}$ width Var.6) - 8.20956^{-3} (% Var.1)

[3] Maize df: -1.96669 + 0.1597589 ($\bar{x}$ width Var.1) - 0.0126672 ($\bar{x}$ width Var.6) + 8.20956^{-3} (% Var.1)

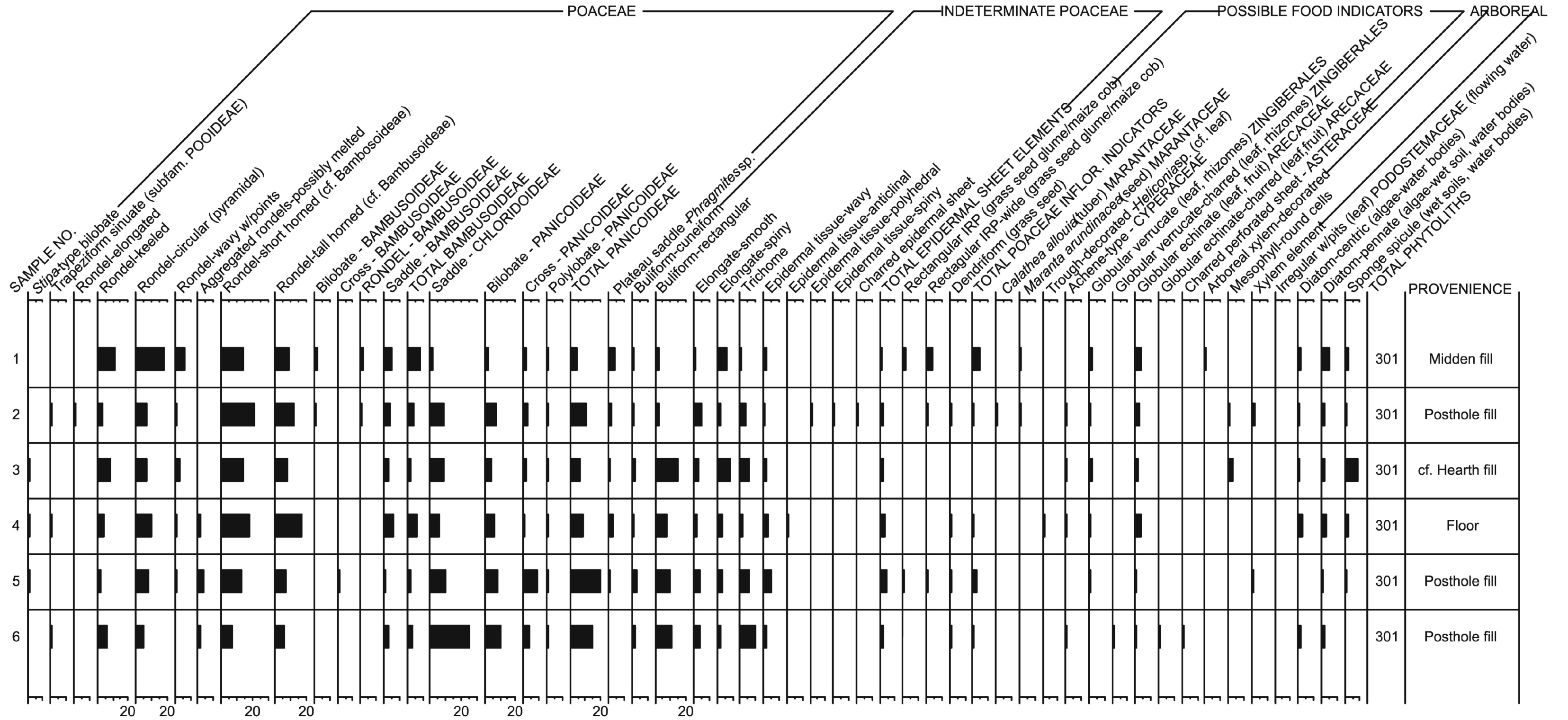

FIGURE 1. PHYTOLITH DIAGRAM FOR FEATURE FILL SAMPLES FROM THE EL DORNAJO SITE, ECUADOR.

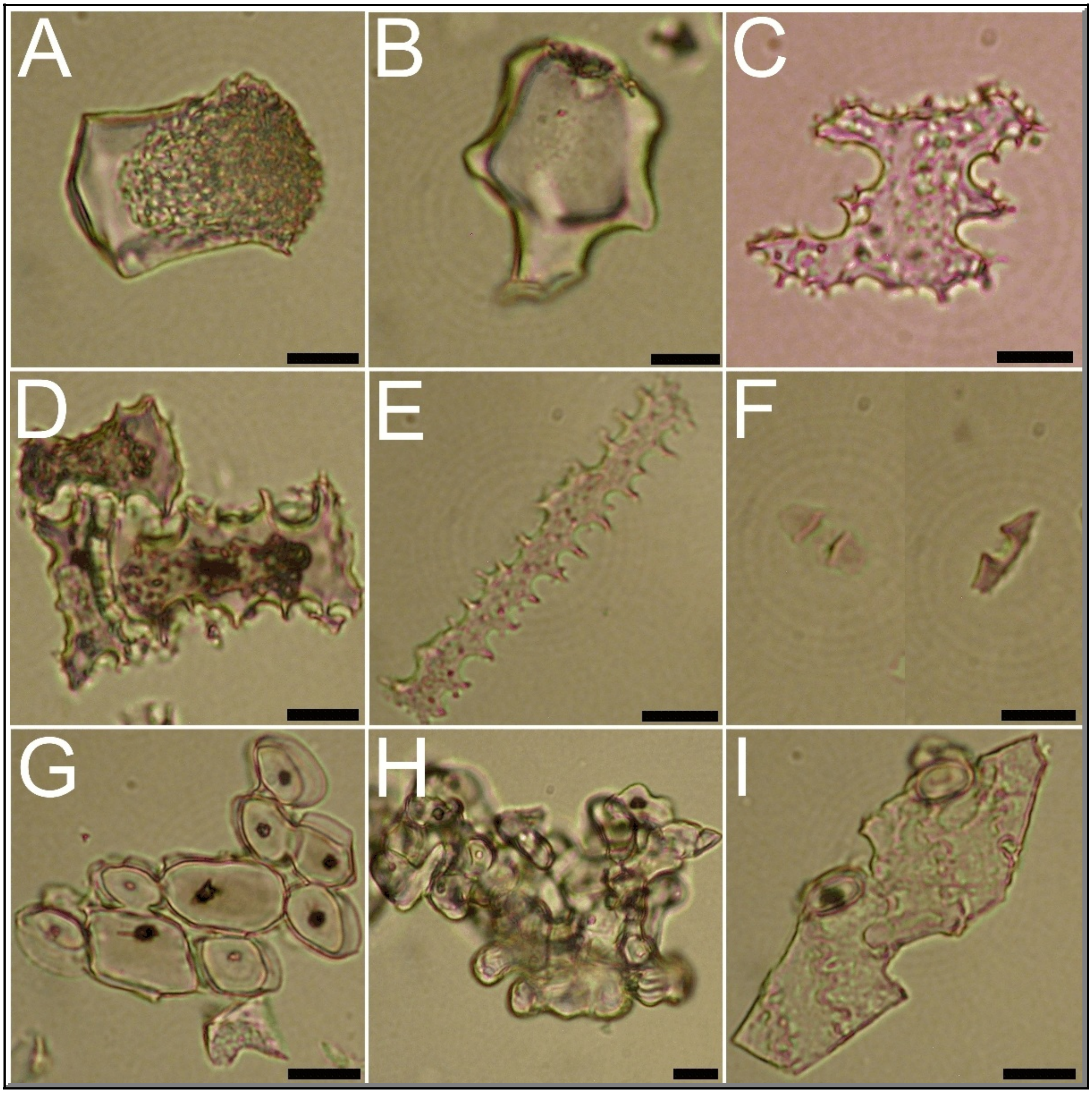

FIGURE 2. SELECTED PHYTOLITH MICROGRAPHS FROM FEATURE FILL SAMPLES, EL DORNAJO, ECUADOR. Scale bar = 10 µm. A) Tuber phytolith from *Calathea allouia*. B) Seed phytolith from *Maranta arundinacea*. C and D) IRP phytoliths common in maize cob, teosinte fruitcases, and some wild grass inflorescence structures. E) Dendriform phytolith common in non-*Zea* wild grass inflorescence structures. F) Decorated trough phytolith from *Heliconia* sp. leaf material. G) Poaceae rondels slightly melted together. H) Poaceae rondels severely melted together. I) Poaceae epidermal sheet element fragment with rondels, exhibiting possibly unnatural breaks across the long cells.

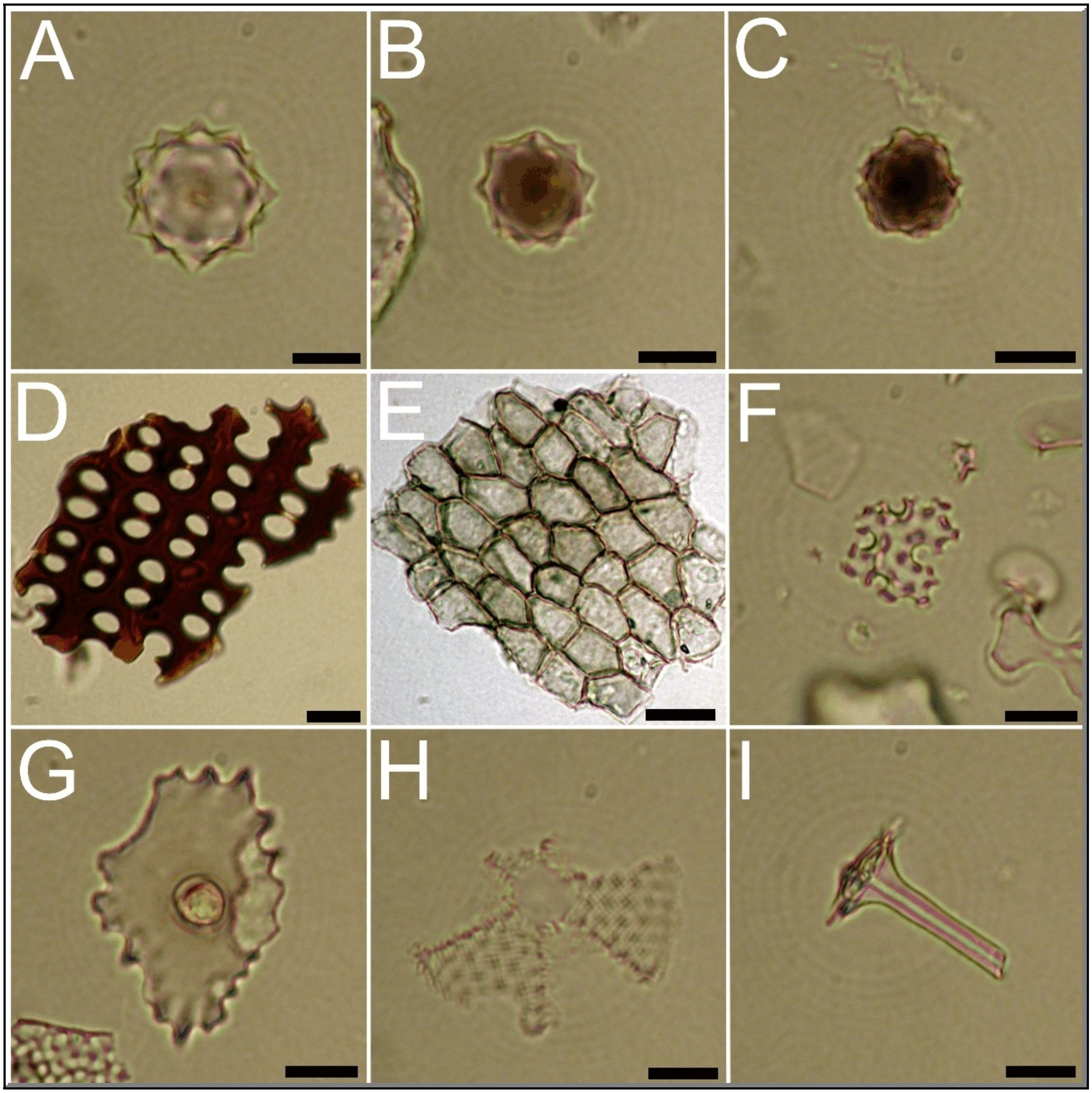

FIGURE 3. SELECTED PHYTOLITH AND MICROFOSSIL MICROGRAPHS FROM FEATURE FILL SAMPLES, EL DORNAJO, ECUADOR. Scale bar = 10 μm. A) Globular echinate from Arecaceae leaf and fruit structures. B) Charred globular echinate (Arecaceae). C) Charred globular verrucate diagnostic of the order Zingiberales (Marantaceae, Cannaceae, Costaceae, Zingiberaceae). D) Opaque perforated platelet from Asteraceae inflorescence. E) Silicified mesophyll cells (arboreal), possibly charred. F) Diagnostic phytolith of Podostemaceae leaf material. G) Achene phytolith from a member of the Cyperaceae (cf. *Scirpus*). H) Marine diatom from salt and brackish waters (*Actinoptychus* sp.). I) Gemmula microsclere fragment from a fresh water sponge species.

REFERENCES CITED

Bozarth, Steven

1993 Biosilicate Assemblages of Boreal Forests and Aspen Parklands. In *MASCA Research Papers in Science and Archaeology*, edited by D. M. Pearsall and D. R. Piperno, pp. 95-105. vol. 10. The University of Pennsylvania Museum of Archaeology and Anthropology, University of Pennsylvania, Philadelphia.

Brown, Dwight A.

1984 Prospects and Limits of Phytolith Key for Grasses in the Central United States. *Journal of Archeological Science* 11:345-368.

Chandler-Ezel, Karol, Deborah M. Pearsall and James Zeidler

2006 Root and tuber phytoliths and starch grains document manioc (*Manihot esculenta*), arrowroot (*Maranta arundinacea*), and lleren (*Calathea* sp.) at the Real Alto site, Ecuador. *Economic Botany* 60(2):103-120.

Duke, James Alan and Rodolfo Vasquez Martinez

1994 *Amazonian Ethnobotanical Dictionary*. CRC Press, Boca Raton, Florida.

Gould, F. N. and R. B. Shaw

1983 *Grass Systematics*. Texas A&M University Press, College Station.

Harvey, Emma L. and D.Q. Fuller

2005 Investigating crop processing using phytolith analysis: the example of rice and millets. *Journal of Archaeological Science* 32:739-752.

Jones, Robert L. and A. H. Beavers

1963 Sponge Spicules in Illinois Soils. *Soil Science Proceedings*:438-440.

Parr, J. F.

2006 Effect of Fire on Phytolith Coloration. *Geoarchaeology: An International Journal* 21(2):171-185.

Pearsall, Deborah M.

1989 *Paleoethnobotany, A Handbook of Procedures*. Academic Press, Inc., Harcourt Brace Jovanovich, San Diego, California.

Pearsall, Deborah M., Karol Chandler-Ezell and Alex Chandler-Ezell

2003 Identifying maize in neotropical sediments and soils using cob phytoliths. *Journal of Archaeological Science* 30:611-627.

Piperno, D. R. and P. Becker

1996 Vegitation History of a Site in the Central Amazon Basin Derived from Phytolith and Charcoal Records from Natural Soils. *Quaternary Research* 45(2):202-209.

Piperno, Dolores R.

1989 The occurrence of phytoliths in the reproductive structures of selected tropical angiosperms and their significance in tropical paleoecology, paleoethnobotany and systematics. *Review of Palaebotany and Palynology* 61:147-173.

2006 *Phytoliths: A Comprehensive Guide for Archaeologists and Paleoecologists*. Alta Mira Press, Lanham, MD.

Piperno, Dolores r. and Deborah M. Pearsall

1993 Phytoliths in the Reproductive Structures of Maize and Teosinte: Implications for the Study of Maize Evolution. *Journal of Archaeological Science* 20:337-362.

Ramsay, P.M. and E.R.B. Oxley

1996 Fire temperatures and postfire plant community dynamics in Ecuadorian grass paramo. *Vegetatio* 124:129-144.

Twiss, Page C.
1987 Grass-Opal Phytoliths as Climatic Indicators of the Great Plains Pleistocene. In *Quaternary Environments of Kansas*, edited by W. C. Johnson, pp. 179-188. 5 ed. Kansas Geological Survey Guidebook Series.