Phytolith and Starch Analysis of Archeological Soil Samples from the Market Street Chinatown, San Jose, California

Authored by
Chad Yost

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by

Chad L. Yost
Paleoscapes Archaeobotanical Services Team (PAST)
Tucson, Arizona
chadyost@hotmail.com

www.paleoscapesteam.com

PAST Technical Report 15011 prepared for:

Ryan Kennedy
Department of Anthropology
Indiana University
Bloomington, Indiana
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Preface to Technical Report 13

In this report, Chad Yost builds off of previous studies of macroscopic and microscopic plant remains from the Market Street Chinatown Archaeology Project that have yielded evidence for a wide variety of domestic and imported foodstuffs. Analysis of phytoliths, silica in-fillings of plant cells from various plant parts, and starch granules from seeds and roots provides another avenue to explore the variations of food consumption within the community.

The analysis shows that phytoliths were both well-preserved and highly concentrated in the 16 samples that were processed. A surprising result was the relatively high abundance of *Oryza* leaf phytoliths, which poses questions about the possibility of rice agriculture in the region and/or its processing methods. Additionally, the high abundance of *Phalaris* grasses is similar to that found in the previous study of phytoliths at the site (Puseman, et al. 2013) and raises questions about animal husbandry practices.

Ultimately, this report contributes to our ability to further integrate faunal and botanical data into a holistic understanding of food practices and land use at the Market Street Chinatown, such as that done in Chapter 8 of Technical Report 11.

The underlying data are available in athree Microsoft Excel files on the Market Street Chinatown Archaeology Project website (marketstreet.stanford.edu) as separate appendices.

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Barbara L. Voss
Principal Investigator, Market Street Chinatown Archaeology Project

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INTRODUCTION

Soil samples from archaeological features associated with the historic Market Street Chinatown located in downtown San Jose, California were analyzed for phytolith and starch plant remains (Table 1). The Market Street Chinatown was an immigrant Chinese community that existed between 1866 and 1887 and was comprised of commercial buildings, storefronts and residential areas. Previous studies of macroscopic and microscopic plant remains from this site have yielded evidence for a wide variety of domestic and imported foodstuffs presumably processed, sold and consumed by the immigrant population (Becks and Bestel 2013; Cummings, et al. 2014; Puseman, et al. 2013). The goal of this current study of 16 additional soil samples was to recover and identify microscopic plant remains in the form of phytoliths (silica in-fillings of plant cells from various plant parts) and starch granules from seeds and roots that can be used by archaeologists to better understand within-community variations in food consumption.

Table 1. Samples analyzed for phytoliths and starch granules

Locus	Sample No.	Feature No.	Layer/ Level	Additional info	Weight Sampled (g)	Volume Sampled
1	85-31/6-213	6	1S		24.153	20 cm^3
	85-31/6-215	6	3	Bottom S.	20.479	15 cm^3
	85-31/13-427	13	2		13.186	10 cm^3
	85-31/13-429	13	3	Fishbone feat.	10.948	10 cm^3
	85-31/13-432	13	4		11.806	10 cm^3
2	86-36/6-304	6	3		19.534	10 cm^3
3	86-36/5-1881	5		Strat. I	14.053	10 cm^3
	86-36/5-1882	5		Strat. IA	15.462	10 cm^3
	86-36/5-1883	5		Strat. 3	20.275	10 cm^3
	86-36/8-103	8	11		20.975	15 cm^3
4	86-36/13-329	13	1	Soil 2	16.387	15 cm^3
	86-36/13-333	13	2		10.808	10 cm^3
	86-36/13-335	13	3		14.709	15 cm^3
5	86-36/18-531	18	2		14.466	10 cm^3
	86-36/18-532	18	3		13.702	10 cm^3
	86-36/18-533	18	4		15.100	10 cm^3

MICROFOSSIL REVIEW

In addition to phytoliths and starch granules, other types of microfossils that may be of interpretive value were observed. A descriptive summary of all of these microremains follows.

Phytoliths

Phytoliths are biogenic silica ($SiO_2 \bullet nH_2O$) in-fillings and casts of cells that are formed in plant tissues such as leaves, stems, bark, fruit, and seeds. Phytoliths typically

range in size between 5 and 200 micrometers, and a single grass plant can produce 10^5 to 10^6 phytoliths (Yost and Blinnikov 2011). When plant matter decays, phytoliths are released and incorporated into soils and sediments. One gram of dry soil can contain 10^4 to 10^6 grass phytoliths (Yost, unpublished data) and one cm^3 of lake sediment can yield 10^4 to 10^5 grass phytoliths (Yost, et al. 2013). Because of their decay-in-place origins, phytoliths tend to represent a very localized vegetation record, whereas pollen records are influenced by both local and regional vegetation. However, depending on the geomorphology of the study area, a proportion of the phytolith record may have been deposited some distance from its initial place of formation due to wind or water transport.

In archaeological studies, phytoliths have proven extremely useful in identifying the utilitarian, medicinal and subsistence use of plants by Native Americans, as well as by European and Asian immigrants to North America. Phytoliths can survive exposure to natural and cooking fires, and are not subjected to the forces of organic decay that hamper the recovery of many perishable foodstuffs. Phytoliths diagnostic of corn, beans, squash, cereals, rice, roots, tubers and some fruits are routinely recovered and identified from feature fill, use surfaces, cooking residue and dental calculus (Cummings, et al. 2014; D. R. Piperno 2006).

Starch granules

Starch is a plant energy storage substance composed of crystalline and non-crystalline regions made up of amylose and amylopectin. Some of this starch forms globular, spherical, or polyhedral bodies referred to as either grains or granules. Starch granules are found in many plant parts, but are often concentrated in seeds, fruits, roots, and tubers. Starch granules range in size between 1 and 100 microns, and can persist in soil, artifact surfaces, cooking residue and dental calculus for tens of thousands of years. A single plant species often produces a variety of starch granule shapes, sizes and forms. Some of these morphotypes overlap with those produced by other plants; however, there are often morphotypes that are diagnostic of specific plants at various taxonomic levels. When viewed using polarized light microscopy, starch granules appear bright white against a black background, a phenomenon called birefringence. Chemical extraction, cooking, drying and environmental degradation can result in reduced or even the complete loss of birefringence (Gott, et al. 2006).

Diatoms

Diatoms are single-celled algae with a biogenic silica cell wall. They grow in a wide range of habitats, including the surfaces of wet plants and rocks, damp soils, marshes, wetlands, mudflats, and all types of standing and flowing aquatic habitats (Spaulding, et al. 2010). Their silica cells, or frustules, 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 of diatoms in soils and sediments can provide information about the nature of the local environment or the sources of water used for cooking and food processing.

Sponge spicules

Sponges are primitive members of the animal kingdom. They use biogenic silica to form skeletons comprised of spicules and other structures for support. Freshwater sponges inhabit a wide variety of wet habitats that include ponds, lakes, streams, and rivers; however, they do need a hard stratum for growth like submerged logs, aquatic plant stems and rocks. They typically thrive in water that is alkaline (above pH 7), and their abundance is negatively correlated with turbidity and sediment load (Barton and Addis 1997; Cohen 2003; Dröscher and Waringer 2007; Harrison 1988).

Chrysophyte cysts

Chrysophyte cysts are biogenic silica structures produced by chrysophyte algae during the resting stage of their life cycle and are often preserved in sediments. Chrysophytes are primarily unicellular or colonial organisms that are abundant in freshwater habitats throughout the world. Chrysophytes are related to diatoms, but are distinct organisms. Chrysophyte cysts are most common in fluctuating freshwater habitats of low to moderate pH and that experience some winter freezing. Many cyst types are found in specific habitats, such as montane lakes, wet meadows, ephemeral ponds, perched bogs, and the moist surfaces of rock and plant substrates. Chrysophyte cysts can also be found in sites that are only wet during certain seasons, such as snowmelt ponds and low swales (Adam and Mahood 1981). In cool-cold temperate lakes, chrysophytes are most common in the spring, when acidic snowmelt dominates the water chemistry. Chrysophytes are intolerant of eutrophic lake conditions (Cohen 2003).

Fungal spores

The Ascomycota are the largest division of the Fungi kingdom and contain organisms such as mold, smut, rust, yeast and mushrooms. These organisms produce microscopic sexual structures called ascospores (fungal spores), which can often be used to identify the fungus from which they arose. Fungal spores can persist for long periods of time in the environment and can be recovered using many pollen, starch and phytolith extraction methods. In paleoecological and archaeological investigations, fungal spores can be used to identify the presence of crop damaging molds like ergot and wheat smut, or the presence of dung fungus like *Sporormiella*, which further indicates the presence of browsing and grazing animals (Davis and Shafer 2006; van Geel, et al. 2003).

METHODOLOGY

Approximately 10 to 15 g of sediment from each sample was placed in a 500 mL beaker (Table 1). The starting mass varied depending on the perceived abundance of organic matter, course grained sediment, and metallic debris such as slag. Carbonates were removed by adding 20 mL of 37% hydrochloric acid (HCl). Once the reaction subsided, 100 mL of 70% nitric acid (HNO_3) was added to each beaker and placed on a hotplate at ~80 °C

for 1 hour to remove acid soluble organics. Samples were then rinsed 5 times with reverse osmosis deionized water (RODI) water. Next, 5 mL of a 10% solution of potassium hydroxide (KOH) was added to each sample to remove base soluble organics, and after 10 minutes, samples were rinsed with RODI water. Next, a 10% solution of sodium hexametaphosphate ($Na_6P_6O_{18}$) was mixed into each sample and the suspended particles were allowed to settle by gravity for one hour, after which, the remaining clay-sized particles still in suspension in the upper 10 cm of the beaker were decanted. This step was repeated until the supernatant was clear after two hours (typically 10 repetitions). The samples were transferred to 50 mL centrifuge tubes and dried under vacuum in a desiccator. The dried samples were mixed with 10 mL of sodium polytungstate (SPT, density 2.3 g/ml) and centrifuged for 10 min at 1,500 rpm to separate the phytolith fraction, which will float, from the heavier inorganic mineral and silica fraction. The resultant phytolith extracts were rinsed five times with RODI water and inspected for purity. Because a lot of platy minerals were obscuring the phytolith fraction, the samples were dried again and re-suspended in a 2.3 g/ml density heavy liquid solution of potassium cadmium iodide (KI_2/CdI_2), which greatly improved the phytolith recovery concentration.

Each phytolith extract was spiked with 15,000 microspheres for phytolith concentration calculations, rinsed once with RODI, followed by a final rise with 99% ethyl alcohol and then transferred to 1.5 mL storage vials. For microscopy, ~1 mg of the phytolith extract was mounted in optical immersion oil and the cover glass was sealed with fingernail polish. Phytolith counting was conducted with a transmitted light microscope using a magnification of 500x and a target count of 300 taxonomically significant phytoliths. A percentage diagram of phytolith relative abundance was constructed with starch granules, diatoms, microscopic charcoal and other non-phytolith particle percent abundance calculated outside of the phytolith sum. Phytolith concentrations were calculated from the microsphere counts and normalized to starting sediment weight.

RESULTS

Phytoliths were well preserved and highly concentrated (Figures 1, 2 and 3). Phytolith concentrations ranged from 9,925 to 423,343 per gram of soil. A total of seven starch granules were recovered. Other non-phytolith microfossils recovered included diatoms, sponge spicules and chrysophyte cysts. Microscopic charcoal ranging in size between 5 and 250 micrometers was also recovered in the phytolith extracts, and the charcoal concentrations ranged from 525 to 17,225 per gram of soil. An extremely high concentration of microscopic charcoal was observed in sample 85-31/6-213 from Locus 1.

Grasses

Phytoliths from cool season, C3 metabolism grasses dominated the overall phytolith record. Grasses in this category include native taxa and economically important taxa such as wheat, barley and rice. A particular phytolith type (keeled rondel; Figure 4*L-P*) diagnostic of maygrass (*Phalaris* sp.) was relatively abundant in many samples, especially

those from Locus 3, which had the highest abundance observed. Two species of *Phalaris* are native to moist habitats in California; however, several non-native species have been introduced and serve as important pasture grasses and fodder for livestock.

Phytoliths diagnostic of C4 grasses were rarely encountered, but present. Native C4 grasses are rare in California, but non-native taxa have been introduced to California since the 19th century. Important agricultural crops such as millet and corn are examples of C4 grasses and are likely the source of some of the C4 phytoliths recovered here.

Bamboo

Phytoliths highly distinctive of and most likely derived from the leaves of bamboo (Bambusoideae) were observed in samples from Loci 1, 4 and 5. The phytolith type is called an elongated saddle on the percent relative abundance phytolith diagram (Figure 1), and an example of one can be seen in Figure 4*I*. These phytoliths are typical of the genus *Arundinaria*, with three species native to the southeastern United States. No bamboos are native to California.

Indeterminate grass and sedge types

Phytoliths in the grass/sedge category on the phytolith diagram are another major group of phytoliths recovered here. They can be produced by either grasses (Poaceae) or sedges (Cyperaceae) and cannot be identified to any lower taxonomic level. Phytoliths that are diagnostic of sedges (Figure 5) were observed in all of the samples, but there is some variation in their relative abundance that may be of interpretive value. For example, sedges are a common weed of rice agriculture, and their presence here may simply be due to unintentional incorporation into harvested rice commodities.

Rice (*Oryza* spp.)

Phytoliths diagnostic of rice (*Oryza* spp.) were observed in all of the samples (Figure 6), but had particularly high levels of relative abundance in samples from Loci 1 and 4. *Oryza* phytoliths are not easily and reliably ascribed to specific species, but all of the *Oryza* phytoliths here are assumed to be derived from domesticated white or brown rice (*Oryza sativa*). Both disarticulated *Oryza* phytoliths and large silicified epidermis fragments with individual phytoliths still articulated between the long cells were observed and counted separately. Many grasses produce phytolith morphotypes that are unique to certain plant parts, and *Oryza* is no exception (Gu, et al. 2013; Harvey and Fuller 2005; Zhao, et al. 1998).

In the phytolith diagrams (Figures 1 and 2), *Oryza* phytoliths were further classified as either leaf-types or inflorescence (husk)-types, and also classified as being burned or unburned. Phytoliths, which are more or less translucent, can darken when exposed to fire. Certain types of grain processing like parching the husk prior to winnowing can result in darkened inflorescence phytoliths. However, if areas where rice was stored burned at some point, the darkened phytoliths may be unrelated to processing, but rather a sign of a catastrophic fire event. Because of the potential interpretive value, an *Oryza* specific

phytolith concentration diagram with plant part designations and burned/unburned classifications was produced (Figure 3). Samples from Locus 1 had the highest concentrations of *Oryza* phytoliths, three samples (85-31/13-427, 85-31/13-429, 85-31/13-4232) had exceptionally high concentrations of both leaf and inflorescence (husk) phytoliths. Samples from Locus 3 had very few *Oryza* phytoliths, and samples from Loci 4 and 5 had more inflorescence than leaf *Oryza* phytoliths.

Large fragments of silicified *Oryza* husk epidermis with articulated double peaked glume phytoliths were placed in their own category. These phytolith remains are a by-product of the milling stage of grain processing (Harvey and Fuller 2005) and their recovery and quantification may be useful in site interpretation. A ternary plot comparing disarticulated leaf phytoliths, disarticulated husk (glume) phytoliths and large fragments of husk epidermis was created to better visualize *Oryza* phytolith variation between the samples (Figure 7). Using this diagram, samples 86-36/18-531 and 86-36/18-533 had very few leaf phytoliths, no large husk epidermis fragments and only disarticulated husk (glume) phytoliths, suggesting that rice was either not processed here or the rice stored here was relatively devoid of husk material. By contrast, samples 85-31/6-213 and 85-31/13-429 had high proportions of leaf phytoliths and few disarticulated husk phytoliths and large husk epidermis fragments, suggesting the rice was at an early stage of processing or these were areas for discarded plant material. The majority of the samples plotted in the central region of the ternary diagram, indicating equal proportions of leaf and inflorescence phytoliths.

Cereal grains

Phytolith evidence for cereal grains such as wheat and barley is primarily represented by dendriform phytoliths (Figure 4*D*). Dendriforms originate in the bract material (lemmas, paleas, and glumes) that surrounds the seed (caryopsis) of some wild and domesticated grasses. They are very common in the bract material of Pooideae grasses, some of which are domesticated cereals. The presence of these disarticulated dendriforms indicates that cereal grains may have been utilized for subsistence. The highest abundance of dendriform phytoliths was observed in samples from Locus 3, which also had the highest abundance of *Phalaris* (maygrass) phytoliths. The recovery of diagnostic cereal grain starch confirms that wheat and/or barley was present in some of the samples; however, maygrass rather than wheat or barley may be a major contributor of dendriform phytoliths to these samples.

Corn (*Zea mays*)

Phytolith evidence for corn (*Zea mays*) in the form of diagnostic wavy-top rondels was observed in samples 85-31/13-427 and 85-31/13-429 (Figure 4*E* and *F*). Wavy-top rondels are produced in large numbers in the glumes of many varieties of corn. In addition to recovery from areas where corn cobs were discarded, a small amount of these phytoliths can accompany the processing, cooking, and consumption of corn. A few wavy-top rondels likely to be, but not unequivocally derived from, corn were observed in samples 85-31/13-

432, 86-36/5-1881, 86-36/5-1882, and 86-36/13-329. An example of one of these probable wavy-top rondels can be seen in Figure 4*G* and *H*.

Squash and gourds (Cucurbitaceae)

Phytolith evidence for utilization of a member of squash family (Cucurbitaceae) was observed in samples 86-36/13-329 and 86-36/13-335 from Locus 4 (Figure 4*A*-*C*). The cucurbit diagnostic phytoliths are hemispherical faceted phytoliths that tend to be lightly silicified and poorly preserved, thus typically underrepresented at historic archaeological sites. These phytoliths are found in the rind (exocarp) of some varieties of squashes, pumpkins and gourds (Dolores R. Piperno, et al. 2000). Many highly domesticated and modern varieties of cucurbits like summer squash and melons produce few to no hemispherical faceted phytoliths. The morphology of the cucurbit phytolith from sample 86-36/13-335 is suggestive of gourd (*Lagenaria siceraria*) and the cucurbit phytolith from sample 86-36/13-329 is more typical of winter squash (*Cucurbita* spp.).

Starch granules

Although the phytolith extraction methods used here are not optimized for starch granule recovery, several granules were observed in these samples (Figure 8). Grass seed starch that could not be identified to a more specific taxonomic level was observed in samples 85-31/6-215 and 86-36/5-1881. These starch granules could be derived from numerous grasses, including maygrass, rice, and corn. Lenticular starch granules diagnostic of cereals such as wheat and barley were observed in samples 85-31/13-429 and 86-36/5-1883. A sub-angular starch grain most likely derived from rice or corn was recovered from sample 86-36/13-333. Two starch granules of unknown origin were recovered from sample 86-36/5-1881 (Figure 8*F* and *G*). Because they both exhibited the unusual characteristic of birefringence without an extinction cross (right side of each image), these grains are likely from the same plant and may be identifiable with additional reference work.

Silica remains from water organisms

In general, silica frustules from siliceous algae (diatoms) were ubiquitous in these samples. Centric diatoms more typical of brackish to freshwater ponds and lakes were observed in samples from Loci 1, 4 and 5. Marine diatoms typical of ocean water and brackish coastal waters were observed in samples from all of the Loci, although they had their highest concentrations in samples 85-31/13-429 and 86-36/13-335. Diatoms can be introduced to feature fill in a number of ways. For example, diatoms can be derived from discarded fish remains (especially stomach contents), aquatic plant stems, and water used for cooking and drinking. Interestingly, chrysophyte cysts were observed in many of the samples. Chrysophytes are another type of siliceous algae, but they are restricted to clear, freshwater habitats with low to neutral acidity (pH). High elevation lakes and rivers with high elevation watersheds are habitats conducive to chrysophyte algae growth. Thus, the presence of chrysophyte algae suggests that water and/or aquatic resources were obtained from or sourced from higher elevations than downtown San Jose.

DISCUSSION

Given the importance of rice in the diet of the Market Street Chinatown residents (Becks and Bestel 2013; Cummings, et al. 2014), the relatively high abundance of *Oryza* phytoliths in these samples is not surprising. What is surprising is the high abundance of *Oryza* leaf phytoliths, which may be an indication that the rice was grown locally or regionally and probably not shipped from overseas. Rice suitable for long-distance transport would likely have been fully processed and dried, steps that would have eliminated most leaf fragments. Experimental and archaeological investigations of rice processing models indicate that phytoliths from rice leaves, sedges and other weedy plants are the by-products of early stages of rice processing (Harvey and Fuller 2005). The presence of significant quantities of these by-product phytoliths suggests that either some of the rice processing steps were conducted on-site, or that the finished rice foodstuff contained a lot of non-rice plant debris. Also interesting is the fact that many rice leaf and inflorescence phytoliths were darkened from exposure to fire. Although this burning could be related to catastrophic burning of Market Street Chinatown buildings, it is also possible that the harvested rice spikelets were intentionally parched. Parching would lower the moisture content of the grain, allowing for longer storage and would make the husk more brittle and easier to remove during the winnowing steps. Synthesizing the phytolith data with the macrobotanical data would be useful in determining if the rice processing model proposed by Harvey and Fuller (2005) can be used to better interpret rice origins, processing methodology, and quality of the rice consumed my Market Street Chinatown residents.

Phytoliths considered diagnostic of maygrass (*Phalaris* spp.) were ubiquitous in these samples; however, their concentrations were particularly high in all of the samples from Locus 3. In the previous Market Street Chinatown phytolith study (Puseman, et al. 2013), the presence of maygrass phytoliths may not have been adequately addressed, as maygrass was simply interpreted as being a possible weed of agricultural activities. Given the fact that *Phalaris* grasses are important pasture and fodder grasses for livestock, a possible relationship between maygrass and animal husbandry should also have been mentioned. In this previous Puseman et al. (2013) study, sample 86-36/7-1034 from a wood-lined pit had maygrass phytolith relative abundance at close to 30%, which is considered very high for a single phytolith morphotype. For the current study, three of the four samples from Locus 3 had maygrass phytoliths at or above 30% relative abundance. Interestingly, Locus 3 had the lowest occurrence of rice phytoliths, indicating a clear difference in the use of this area. Also, the high dendriform phytolith abundance in the Locus 3 samples indicates that the *Phalaris* phytolith assemblage is derived from entire *Phalaris* plants, meaning leaves and inflorescence structures were present. Given the fact that the two native species, *P. californica and P. lemmonii,* occur sporadically in forested habitats, valley grasslands and coastal sage scrublands (Munz 1973), it is unlikely that these phytoliths are inherited from older soils. In fact, the high *Phalaris* phytolith concentrations suggest that one of eight non-native species introduced to California are the source of these phytoliths. Across the United States, *Phalaris arundinacea* was often planted as a pioneering pasture grass after logging and other types of land clearance.

SUMMARY AND CONCLUSION

Analysis of 16 soil samples from archaeological features associated with the historic Market Street Chinatown yielded phytoliths and starch grains diagnostic of rice (*Oryza* spp.), cereal grains (wheat [*Triticum* sp.) and/or barley [*Elymus* sp.]), corn (*Zea mays*), squash and gourds (*Cucurbita* sp., *Lagenaria siceraria*). Rice phytoliths were ubiquitous, but most abundant in samples from Locus 1 and to a lesser degree in samples from Locus 4. The rice phytolith assemblage consisted of leaf-types, large fragments of husk epidermis, and disarticulated husk phytoliths, suggesting that the rice may have been grown locally or regionally and further processed (de-husked) on site. Phytoliths diagnostic of *Phalaris* species (maygrass, reed canarygrass) were ubiquitous, but most abundant in samples from Locus 3, which also had the lowest occurrence of rice phytoliths. The high abundance of *Phalaris* grasses in Locus 3 samples may possibly be derived from animal husbandry practices and this possibly should be considered further. Because of differences in taphonomy and preservation, this study should be synthesized with pollen and macrobotanical data to form the most comprehensive survey of plant-based resource utilization by residents of the Market Street Chinatown community.

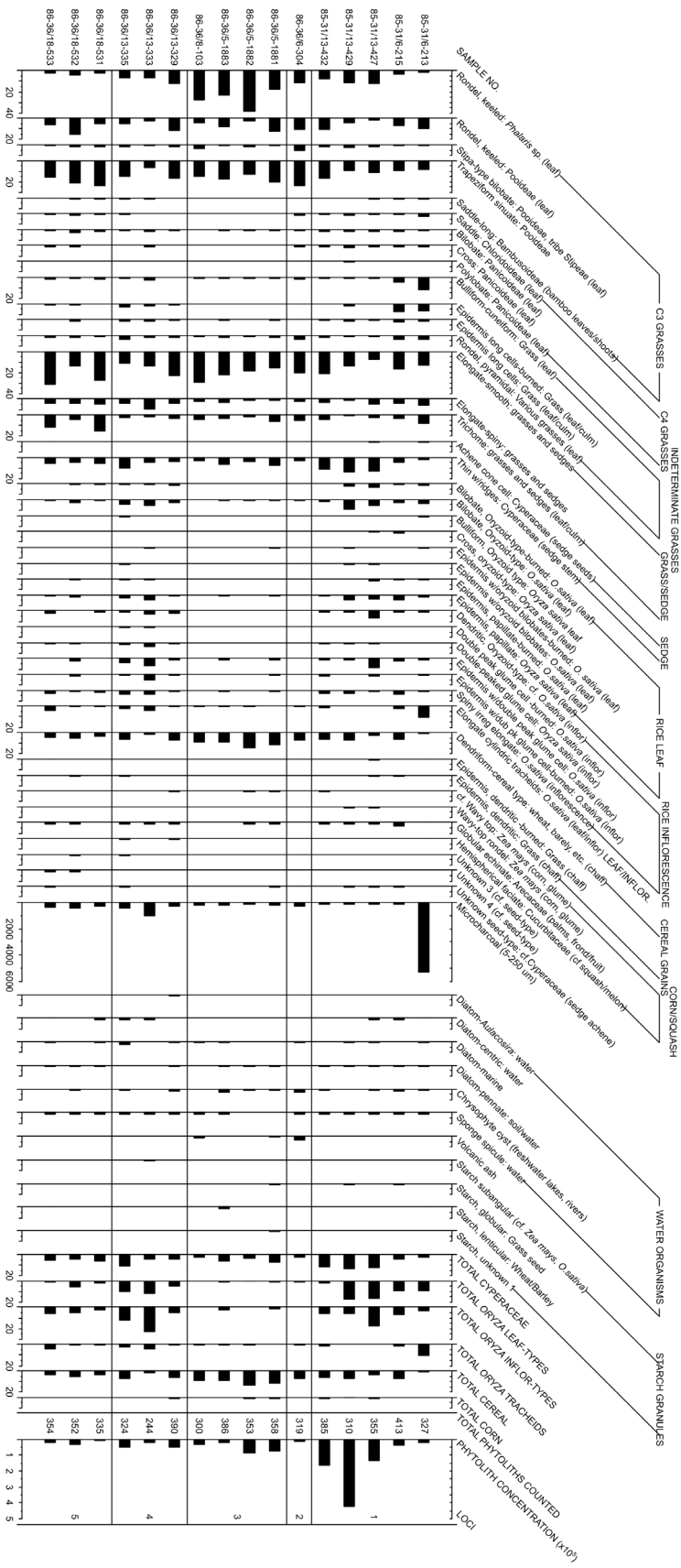

Figure 1. Phytolith percent relative abundance

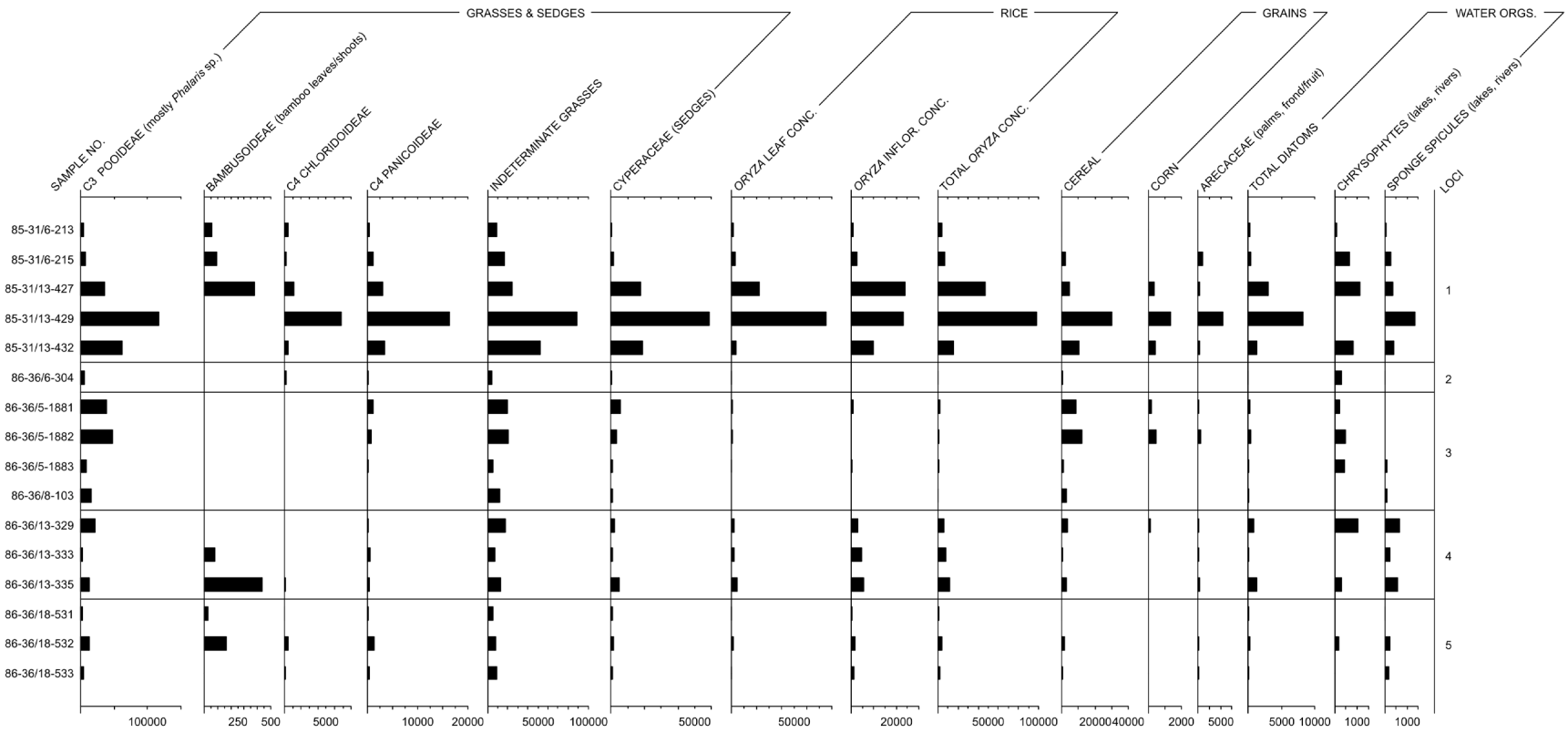

Figure 2. Phytolith concentration summary (#/g soil)

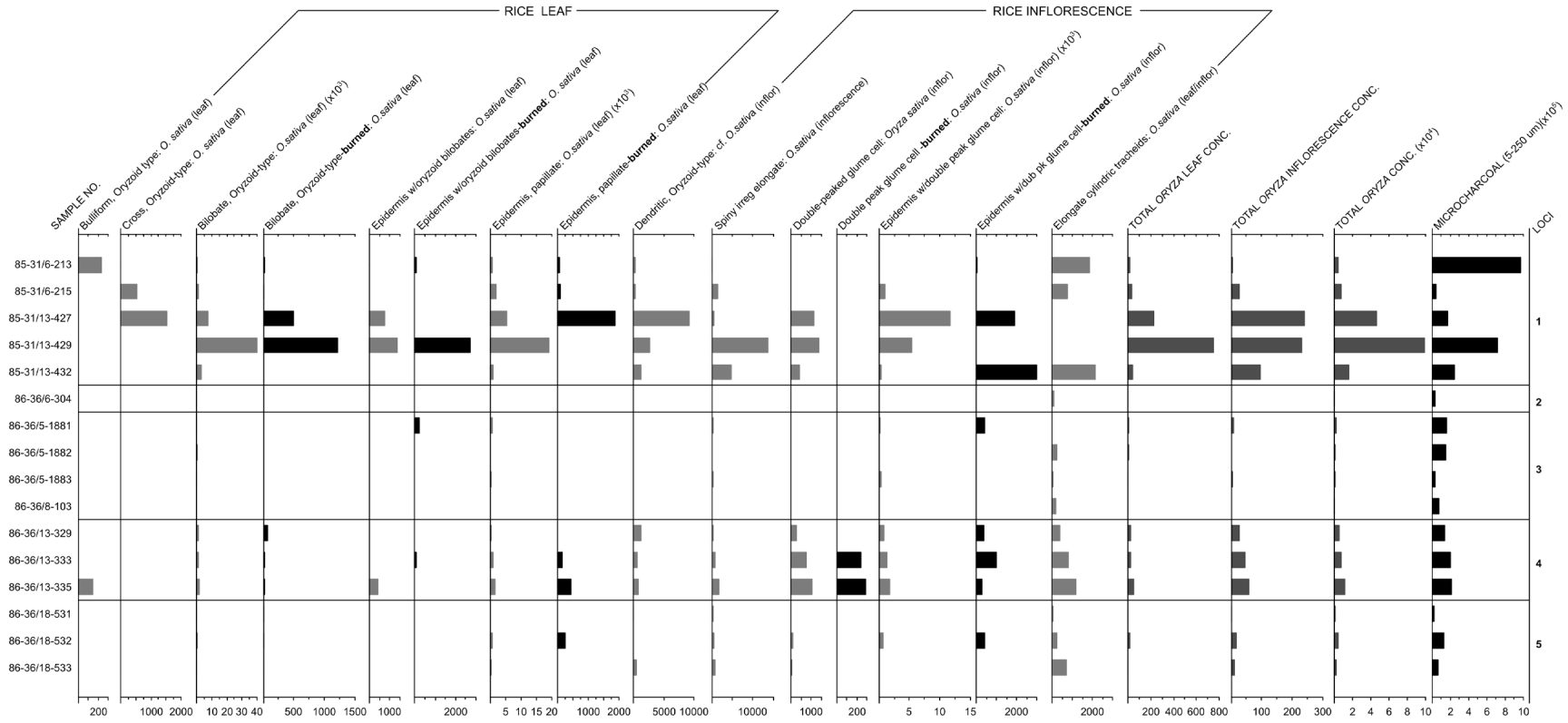

Figure 3. Rice (*Oryza*) phytolith concentration summary

Figure 4. Selected micrographs of economically significant phytoliths. White scale bars equal 10 micrometers. **A)** Hemispherical facetate phytolith diagnostic of the Cucurbitaceae family (squash, melon, gourd) in side view, and **B)** in top view, recovered from sample 86-36/13-335. **C)** Hemispherical facetate phytolith in top view diagnostic of Cucurbitaceae, recovered from sample 86-36/13-329. **D)** Disarticulated dendritic long cell diagnostic of grass chaff (inflorescence) structures. Domesticated cereals like wheat and barley are prolific producers of these phytoliths, which may also be derived from wild and cultivated grasses like Maygrass (*Phalaris* spp.). **E-F)** Wavy-top rondels diagnostic of corn (*Zea mays*) and derived from the glume that forms at the base of the kernel. These phytoliths were recovered from samples 85-31/13-429 and 85-31/13-427, respectively. **G)** Possible corn wavy-top rondel in top view, and **H)** in side view. The wave along the top of the rondel is not pronounced enough to be diagnostic of corn, but this phytolith recovered from sample 6-36/5-1881 is most likely derived from corn. Other possible corn phytoliths like this one are labeled as cf. Wavy-top on the Figure 1 phytolith diagram. **I)** Elongated saddle phytolith highly distinctive and possibly diagnostic of some genera of bamboo (Bambusoideae), in particular river cane (*Arundinaria* sp.). Bamboos are not native to California. **J)** Unknown phytoliths mostly likely derived from fruit or seed structures. **K)** Globular echinate phytolith diagnostic of palm genera (Arecaceae). **L-P)** Rondels with angular keel diagnostic of Maygrass (*Phalaris* sp.), of which, two species are native to California.

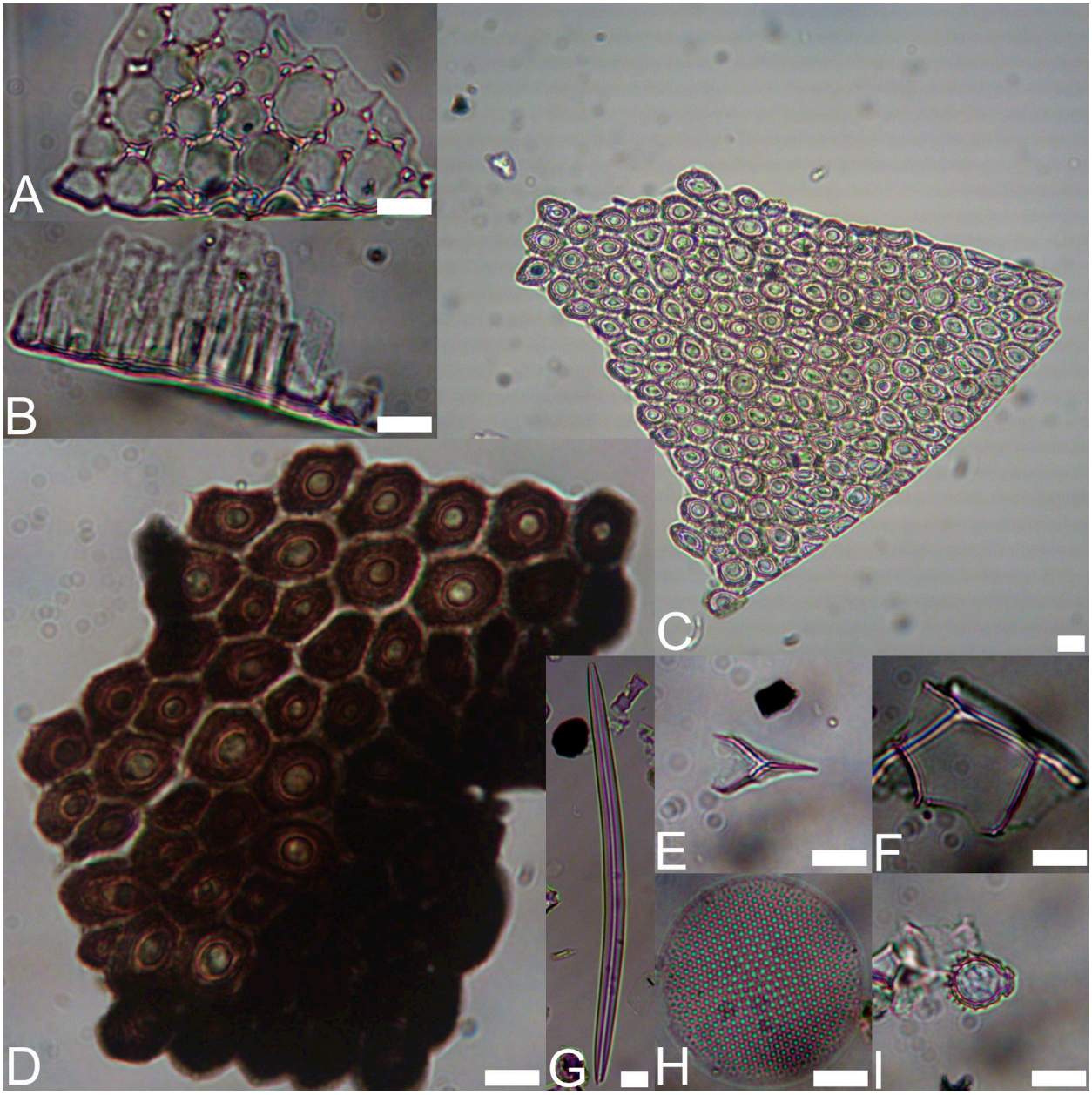

Figure 5. Selected micrographs of sedge (Cyperaceae) phytoliths and silica remains of aquatic organisms. White scale bars equal 10 micrometers. **A)** Unknown phytolith in top view, and **B)** in side view. This phytolith fragment has some similarity with sedge types, but may be derived from some other type of seed or fruit. **C)** Silicified sedge achene (seed) epidermis fragment with many individual cone cell phytoliths. **D)** Same type of sedge achene phytolith as in C, but the phytoliths are darkened from exposure to fire. **E-F)** Thin w/ridges phytoliths diagnostic of sedge stems. **G)** Freshwater or marine sponge spicule (part of the sponge skeleton comprised of silica). **H)** Marine diatom (siliceous algae) frustule. **I)** Chrysophyte cyst comprised of silica. Chrysophytes are restricted to clear, cool and neutral to acidic waters of lakes and streams.

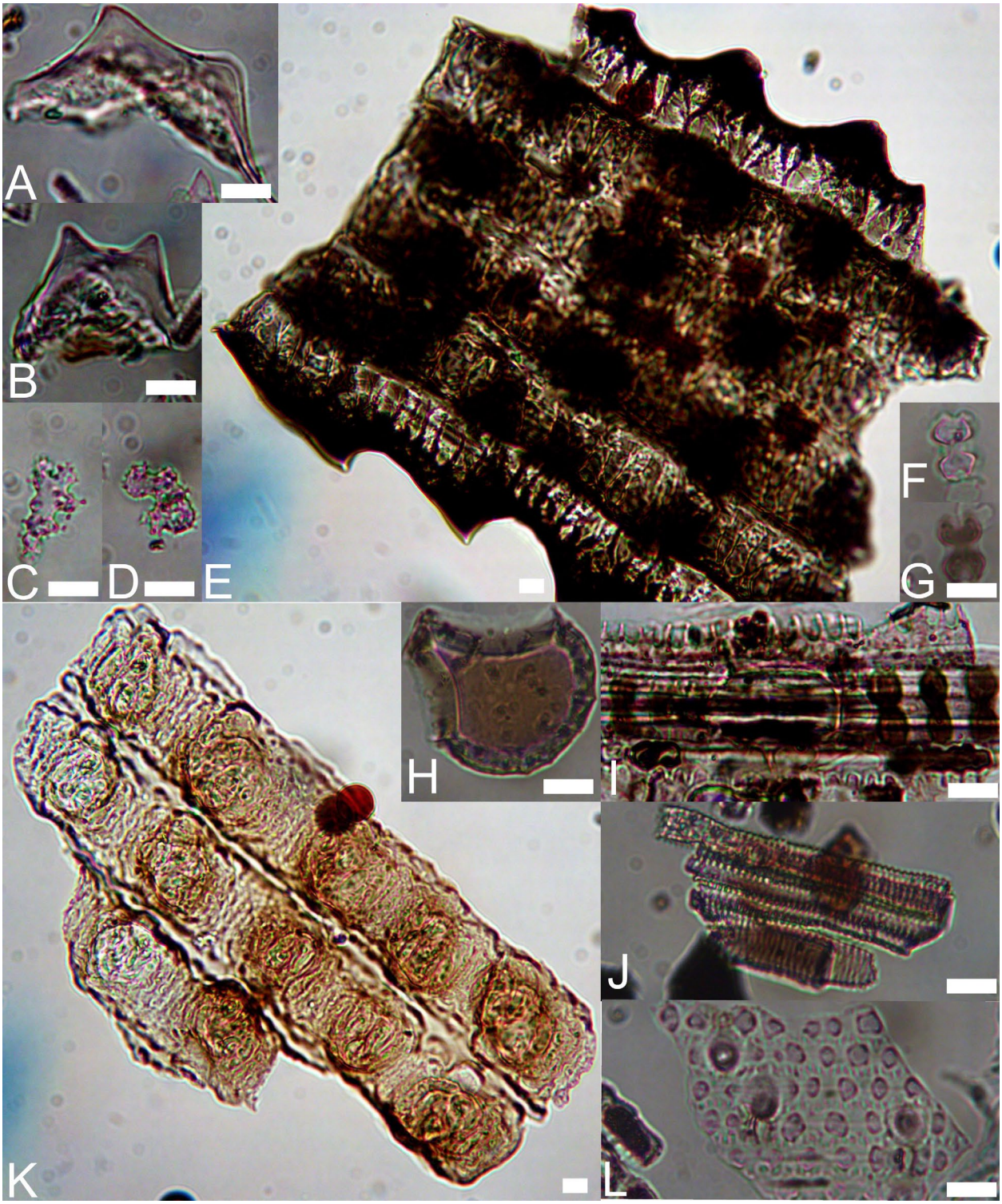

Figure 6. Selected micrographs of white rice (*Oryza* cf. *sativa*) phytoliths. White scale bars equal 10 micrometers. **A-B)** Disarticulated double peaked glume cells derived from white rice glume (husk) inflorescence material. **C-D)** Irregular spiny (short protrusion) morphotypes derived from *Oryza* inflorescences. **E** and **K)** Sections of burned *Oryza* inflorescence epidermis with double peaked glume cells. **F)** Unburned, and **G)** burned bilobate phytolith derived from *Oryza* leaf material. **H)** *Oryza*-type bulliform cell phytolith

from leaf material. **I)** Sequence of burned bilobate phytoliths from *Oryza* leaf epidermis. Silicified stomata and long cells are also visible in this epidermis fragment. **J)** Trachied phytoliths with helical thickenings from *Oryza* vascular tissue. These are reported in both leaf and inflorescence material by Gu et al. (2013), but are likely to be more common in leaves and stems. **L)** Papillate epidermis fragment diagnostic of the grass subfamily Ehrhartoideae and most likely derived here from *Oryza* leaf and stem epidermis.

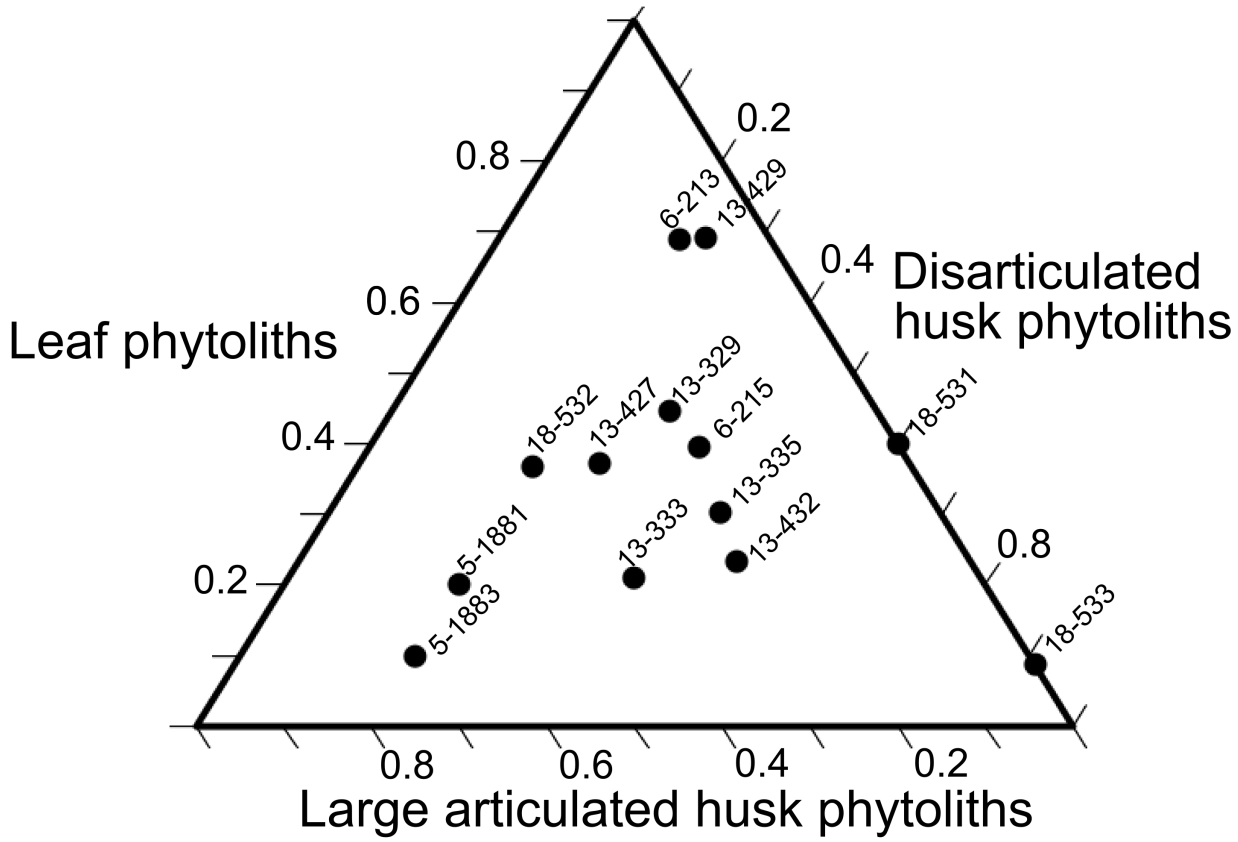

Figure 7. A ternary plot comparing the ratios of disarticulated leaf phytoliths, disarticulated husk (glume) phytoliths and large fragments of husk epidermis. Data from sample 86-36/6-304 and 86-36/5-1882 not plotted because of low *Oryza* phytolith recovery. No *Oryza* phytoliths were recovered from sample 86-36/8-103.

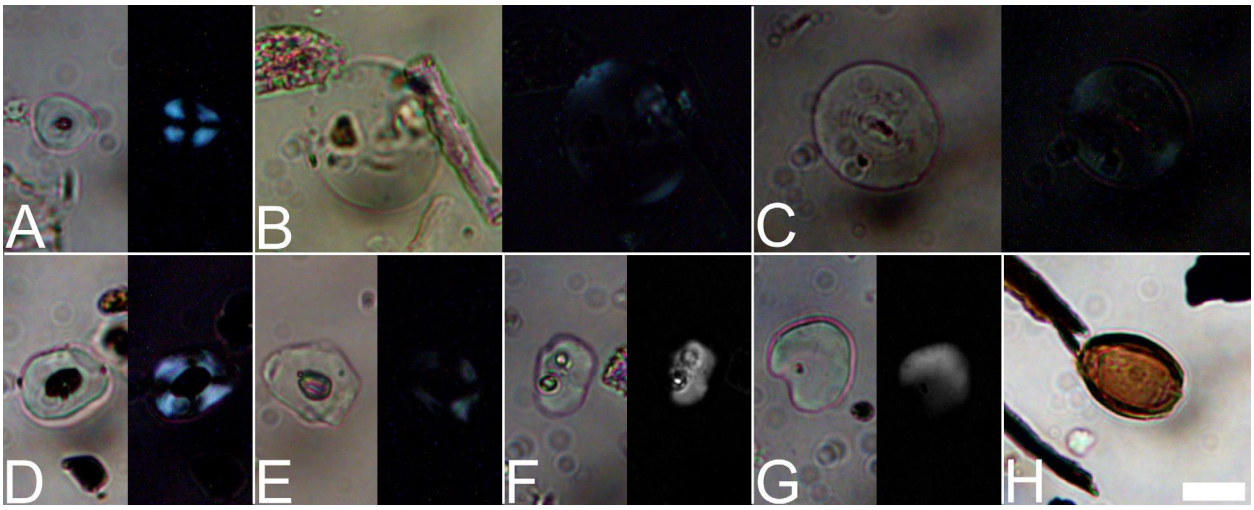

Figure 8. Selected micrographs of starch granules and a fungal spore. White scale bar equals 10 micrometers and applies to all images. The black (right) side of the image is the field of view under cross-polarized light. **A)** Grass seed starch granule lacking characteristics that could further its taxonomic resolution, recovered from sample 86-36/5-1881. **B-C)** Lenticular starch granules diagnostic of cereal grains such as wheat and barley, recovered from samples 86-36/5-1883 and 85-31/13-429, respectively. **D)** Subangular starch granule that could be derived from rice (*Oryza*), corn (*Zea mays*) or other grasses, recovered from sample 85-31/6-215. **E)** A more strongly angular (in outline) starch granule that is likely derived from either rice or corn, recovered from sample 86-36/13-333. **F-G)** Starch granules of unknown origin. Because they both exhibited the unusual characteristic of birefringence without an extinction cross (right side of each image), these grains are likely from the same plant and may be identifiable. Both grains recovered from sample 86-36/5-1881. **H)** Fungal spore that is most likely coprophilous (derived from herbivorous animal dung), recovered from sample 85-31/6-213.

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