

CHAPTER TWO
Residues of Maize in North American Pottery:
What Phytoliths can add to the Story of Maize
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Most of the chapters in this volume discuss the recovery of molecular residues from archaeological artifacts such as pottery. Chemical residue analysis has become an increasingly important and promising tool to archaeologists. We would like for archaeologists to not overlook an equally important source of information, the systematic recovery of physical residues from pottery. The encrustations on pottery, whether visible to the naked eye or not, are a veritable treasure trove of data and should be treated as an archaeological feature. Plants cooked in pottery often leave behind microscopic remains such as starch grains, pollen grains and phytoliths. Our work focuses on the recovery and identification of opal phytoliths from cooking residues that can be used to identify plant taxa. Opal phytoliths are formed in a number of plants. Most groundwater systems contain low concentrations of silicic acids that are absorbed through the root system of plants. As the plant loses water by transpiration, silica is exuded into or between the cells where it polymerizes into a silica imprint of the shape of these cells (Piperno 1988; 2006).¹ After the plant has died and decayed such imprints, known as opal phytoliths or silica phytoliths, can survive for thousands or even millions of years.

One problem with traditional microbotanical research is that it has relied almost exclusively on sediment samples (Pearsall 2000). While sediment samples have their place and can be very useful, there is the constant issue of tying the phytoliths to a secure cultural context. As a context for archaeological discovery, residues are superior to other contexts, such as soils. Food residues

incorporate phytoliths into their matrix, be it the encrustations found on the inside and outside of pottery, dental calculus that accumulates on teeth (of both human and non-human species), the working surfaces of stone tools, or the undigested waste in a coprolite (Thompson and Mulholland 1994; 2006). Residues are stable and do not facilitate movement or intrusions. As a context of discovery, one can reasonably expect to find that the plants present in the residues, for example inside a pot, were placed there purposely (Mulholland 1987; 1993). Residues are also amenable to accelerated mass spectrometry (AMS) radiocarbon dating, allowing us to obtain good dates on our cultural contexts. Once the soil contact layer is removed and the organic portion of the food residue matrix is dissolved away, the phytoliths remain as a secure cultural record of and important part of the paleodiet (Hart et al. 2003; Thompson et al. 2005; Thompson 2006).

Phytoliths have been studied for some time but have really come to hold their own in archaeology in the past few decades (Piperno 1988). Just like pollen types, there are different phytolith forms that have different taxonomic utility, ranging generally from family to genus. For example, many members of the Cucurbitaceae family produce phytoliths that can be identified at the level of genera (Piperno et al. 2002). One plant family, the Poaceae or grass family, has been shown to produce an abundance of phytoliths in the leaf, stem and inflorescence (Mulholland 1989; Piperno 1988; Piperno 2006). The Poaceae family is of particular interest to many archaeologists because it includes all of the staple annual grasses on which many agricultural systems were, and still are, based, such as wheat (*Triticum* spp.), rice (*Oryza* spp.) and maize (*Zea mays*). These grasses produce a very common phytolith in their inflorescence (the flowering or reproductive parts of the plant). These are commonly referred to as rondels because of their general round to oval appearance. In fact, Mulholland and Rapp (1992) characterize these shapes as indicative of grasses.

¹ Silicic acid is the name of a group of chemical compounds with the general formula $(\text{SiO}_x(\text{OH})_{4-2x})_n$. Very small amounts of simple silicic acids of geological origin, such as metasilicic acid (H_2SiO_3) and disilicic acid ($\text{H}_2\text{Si}_2\text{O}_5$), will dissolve in groundwater; ocean water contains small amounts of orthosilicic acid (H_4SiO_4). Common opal is amorphous $\text{SiO}_2 \cdot n\text{H}_2\text{O}$ (hydrated silicon dioxide) with a water content of 5-20% (Iler 1979).

Lusteck and Thompson: What Phytoliths can add to the Story of Maize

More recent research into these phytolith forms has shown that the particular characteristics of rondels are under genetic control (Piperno et al. 2001; Staller and Thompson 2002; Thompson 2006). Although this has not yet been fully explored in most grasses, it is somewhat understood in maize and its progenitor, teosinte (*Zea mays* ssp. *parviglumis*). A gene known as 'teosinte glume architecture' (*tga1*) was found to control the deposition of silica in the inflorescence of *Zea* species (Dorweiler et al. 1993; Dorweiler and Doebley 1997). As the name suggests, *tga1* directly controls the overall form of the inflorescence glumes, the small leaf structures that encapsulate the fertilized seeds in grasses. These are the pieces that are commonly stuck between teeth when eating corn on the cob. In the transition from teosinte to maize, the glumes have become greatly reduced in size so that they no longer cover the seed, but rather cradle it where it attaches to the cob.

The reorganization caused by the maize allele of this gene is one of the key changes in the transition from teosinte to maize (Doebley 2004). It was further recognized that *tga1* is a regulatory gene, meaning it interacts with other genes and the environment to create subtle variations in expression, unique to each lineage. As *tga1* interacts with other genes during cob growth, the amount of silica deposition as well as the morphology of the forms are impacted. While rondel forms are found in many grasses, examination of a 'population' of rondels from any maize lineage reveals a 'fingerprint' in the silica deposition. However, it has proven exceedingly difficult to determine how best to identify such fingerprints.

We are using a new term in phytolith analysis, the 'phenotypic profile' (Lusteck 2006). The phenotypic profile is defined as those phytoliths produced by a plant which, when statistically analyzed, are diagnostic at some level. This profile varies among plant types, but is consistent at some level, be it the species, variety etc. These profiles can be used to deal with the problem of phytolith redundancy. Although many plants produce the same types of phytoliths (redundancy), the suite of phytoliths that constitute each profile are unique. For the purposes of this research, although all grasses produce rondel phytoliths, the phenotypic profile for maize is significantly different from those of other grasses. Furthermore, as individual lineages pick up idiosyncrasies in their genetic code, the profile of a lineage of maize grown in one area will come to look different than the profiles of other maize populations.

Using the phenotypic profile, we can assign groups to genetically related lineages of maize. There are numerous problems with using actual genetics for such a study, most importantly the difficulty of obtaining viable DNA samples from charred maize remains (Janicke-Deprés et al. 2003; Janicke-Deprés and Smith 2006).

The phenotypic profile produced by phytoliths in maize cobs is directly controlled by genetics and can serve as an adequate proxy. The profile cannot detect all genetic change, clearly, only those that in turn affect the deposition of silica. However, this seems to be a sufficiently sensitive characteristic to pick up major changes. And the level of the lineage is still much more informative than a typology based on row-number.

Like many cereals, maize has lost the ability to easily disarticulate the seeds and will not continue to grow in an abandoned area as many other domesticates will. Without the direct intervention of humans to harvest and disperse the seeds, maize will disappear (Hart 1999). Therefore, if maize remains are found, one can reasonably assume that humans were directly involved. Unlike many other domesticates, maize is very distinct from its progenitor. At a microscopic scale the differences may be subtle, size ranges and characteristics of microremains from maize and teosinte may overlap (Russ and Rovner 1989), but the macroscopic phenotype is always very distinct.

Perhaps most importantly, however, is the social significance that is commonly associated with maize. Many archaeologists have failed to critically examine maize use and the context of maize adoption into a culture. This has biased the archaeological history of maize in many regions; archaeologists have looked for proof of preconceived notions of maize use, instead of letting the data dictate their interpretations (Thompson et al. 2005). For example, if maize was primarily adopted as a staple in New York, it should appear ubiquitously. This does not occur before around 900 CE, yet maize phytoliths dating to 2270 BP have been recovered, suggesting a much different history of use (Hart et al. 2003). Maize may have been introduced as a source of alcohol or, as has recently been suggested in Mexico, a source of sugar from stalk quids (Smalley and Blake 2003). It is necessary to keep an open mind regarding the possible uses of maize. Maize often has special significance within cultures well before becoming a staple. The social context of maize is different than other crops in both modern and prehistoric cultures. In Peru, maize chicha (beer) was used to maintain reciprocal ties and political alliances during the Inca expansion (Hastorf and Johannessen 1994). In the Caribbean, Newsom and Deagan (1994) propose that maize may have been limited to elite or ritual contexts. In fact, in many cultures, maize is intimately tied with ceremonial and religious contexts (Cowan 1985; Swanton 1946).

Materials and Methods