STARCH GRAIN ANALYSIS OF BEDROCK MILLING FEATURES: IN HONOR OF HELEN MCCARTHY

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Bedrock mortars are ubiquitous throughout California and their function has been a long-standing question for archaeologists. Many have assumed a function associated with acorn intensification, but McCarthy took the time to conduct an in-depth ethnographic study on their function. It was this work that helped inspire my own research into bedrock mortar function, and gave me a start in questioning the assumptions about other often-dismissed cultural remains such as fire-cracked rock. This paper will present the bedrock mortar research conducted for my thesis that was partly inspired by McCarthy’s work, and the future avenues of this research.

Bedrock milling features are ubiquitous throughout the Sierra Nevada region, and consist primarily of mortars along with occasional milling slicks. These features will be referred to as BRMs throughout this article. BRMs are found in a variety of bedrock materials throughout California (Francisco 1976). In the Sierra Nevada, most BRMs are found in granite outcrops or boulders (Figures 1 and 2), but are also present in outcrops of other stone materials when granite is unavailable (e.g. sandstone). Figure 1 is an example of a BRM feature in a large, somewhat flat outcrop of decomposing granite with multiple mortars. This particular outcrop is located above 8,000 feet in elevation. Figure 2 is an example of a boulder BRM feature with two mortars within a granitic boulder and at least one pestle, located at around 3,120 feet in elevation, in the Mokelumne River watershed.

RESEARCH DESIGN

The function of BRM features, in addition to their life-history, and potential for yielding information on past lifeways, have been long-standing research themes in California archaeology (Elsasser 1960; Gifford 1936; Heizer and Elsasser 1953; Basgall 1987; McCarthy 1993). The goal of my research was to develop an effective method and research design to address these broad questions (Wisely 2016). One such method of inquiry is starch grain analysis, which has been an under-utilized analytical method in California. To date the most extensive starch grain analysis conducted in California is by Scholze (2011) in northeastern California. This article presents the emerging results of using starch grain analysis to issues related to BRM features and the functional categories modeled on the ethnographic research conducted by Helen McCarthy (1993). The functional categories used in my research are modeled after McCarthy (1993) (Figure 3). McCarthy (1993) warns readers about using her categories outside the territory of the Western Mono; however, they provide clearly testable hypotheses that mortar depth can be used to establish function. The emerging results have demonstrated that mortars of different depths can serve different functions. In this article, first a brief summary of starch grain analysis is presented, followed by a discussion of the collection and processing methods.

STARCH GRAIN ANALYSIS

First a brief summary of starch grain analysis. Starch grains are semi-crystalline structures that are formed within the plant from two organic polymers, amylose and amylopectin. They are microscopic grains designed for long-term storage of energy that can be found in various parts of a plant, but primarily in the storage components such as roots, seeds, or nuts (Gott et al. 2006:36; Pearsall 2010:178). For example, cattail (Typha spp.) has identifiable starch grains within the rhizome, but can also yield starch grains from the stem. Many of these grains can be diagnostic to family, genus, or species. For a full discussion of previous starch grain research, see Wisely (2016).
Figure 1. BRM Feature with Multiple Mortars in a Large Outcrop of Decomposing Granite.

Figure 2. Boulder BRM Feature with Two Mortars in a Granitic Boulder. Note at least one pestle present.
Diagnostic Features

Diagnostic features of starch grains include those seen in cross-polarized light as well as transmitted light. Identifications were made based on morphological features (Figure 4), and further refined based on measurements (Figure 5).

Cross-polarized Light

Under cross-polarized light, the extinction cross of the starch grain is the most diagnostic, and is due to how light passes through the semi-crystalline structure of the grain. Identifying traits can be the arms of the cross, angle of the arms, as well as the level of birefringence. The shape and location of the extinction cross can help orient the three-dimensional view of the grain. Damage from crushing or heat can be ascertained from visible changes to the extinction cross, as gelatinization of some starches begins to occur at temperatures as low as 122° Fahrenheit (Barton and Matthews 2006:79-83). Crushing damage can be identified by similar alterations to the extinction cross, and supported by visible fractures under transmitted light.

Transmitted Light (Normal Light)

Under transmitted light, features such the hilum, fissuring, surface morphology, and the overall shape can be diagnostic. The level of compounding and faceting can also be diagnostic, such as the facets that can be seen on the holly-leaf cherry pit starch. Damage to the starch grain’s structure identified under cross-polarized light can be further described and identified under transmitted light.

Measurements

Starch grains can be further identified from archaeological contexts based on their size. Starches from a single plant can vary greatly in size, so the identification key is based on multiple measurements, with identifications made within one standard deviation of the mean. Figure 5 utilizes a portion of the original comparative collection (Wisely 2016) to demonstrate the different sizes for starch grains. Starch grains of grass seeds, such as rice grass or brome grass, are typically on the smaller side. Starches of nuts such as acorns from black oak are larger. Geophytes starch grains, for example *Typha* or *Perideridia*, are larger yet.
Figure 4. Example of Starch Grain Morphological Features Under Cross-Polarized Light and Normal Light.

Figure 5. Example of Selected Starch Grain Measurements.

Challenges of Starch Grain Analysis

There are several challenges in starch grain analysis. The first has to do with contamination. Contamination is always a major concern, both natural contamination (duff, debris, rodent activity, etc.) and modern contamination (modern food starch, industrial starches, etc.). For natural contamination, research has shown that the artifact can provide a microenvironment that protects the anthropogenic residue adhering within the surface from taphonomic pressures (enzymes, organisms, etc.), while natural contaminants within soils are not protected by this microenvironment (Hart 2011; Haslam 2004). To address modern contamination several controls have been built into the methodology. These include wearing new powder-free gloves for each artifact sampled, and identifying modern starch contaminants.
In modern manufacturing, corn starch is used in the production of various plastics, as well as powder-free gloves (Crowther et al. 2014). As the potential for this modern contaminant cannot be fully controlled for, corn starch has been included in the comparative collection in order to better identify and account for contaminants.

The second challenge is about the age of the mortars being sampled for starch grain. Starch grain analysis cannot date the mortar itself; however, there is enough material to be dated if a recovered starch grain can be isolated for AMS dating (personal communication with Janet Niesnner October 8, 2016). It is important to note that the dated starch grain would likely not represent the BRM’s original date of manufacture, but rather the most recent usage of the BRM. Preservation is a very important question, and part of what protects the artifact from contamination also provides for preservation, i.e. the microenvironment provided by the artifact itself (Haslam 2004). Forest fires are a major concern, but so far starch grains have been recoverable from BRMs in areas that have undergone repeated fires. I suspect that the dirt typically accumulated within the mortar helps insulate the milling surface from the heat, but this hypothesis has not yet been tested.

**Starch Grain Analysis and Bedrock Mortar Sampling in California**

There are three stages of sampling bedrock mortars starch grain. First is the field sampling, followed by lab processing, and analysis. The identifications are based on a modern, ethnographically-informed comparative collection of native California plants (Aginsky 1943; Barrett 1908; Barrett and Gifford 1933; D'Azevedo 1986; Elsasser 1960; Gifford 1936; Heizer and Elsasser 1953; Kroeber 1908; Kroeber 1970; Levy 1978; Lowey 1940; McCarthy 1993; Merriam 1907). In other words, the comparative collection is based on plants described in the ethnographic literature as being important food resources and those likely to have been processed in BRMs. The methods are briefly summarized below, but refer to Wisely (2016) for details.

**Field Sampling**

A portable starch grain sample collection kit is needed for field sampling that is light enough to carry on long surveys or to remote sites. The tool kit consists of the necessary tools for starch extraction, such as sonic toothbrushes, distilled water, and centrifuge tubes (Figure 6). Typically, the extraction process consists of collecting three samples are collected at each feature. The first control sample comprises manual collection of any duff or debris contained within the mortar, using a gloved hand and small paint brush to move the materials into a resealable bag. The secondary control sample is taken by lightly brushing the milling surface with a toothbrush and distilled water, pipetting the resulting aqueous sediment into a centrifuge tube marked with provenience. The third sample, which is the cultural sample, is taken using distilled water and a sonic toothbrush. The resulting aqueous sediment is pipetted into a centrifuge tube marked with provenience.

**Lab Processing**

The lab processing entails distillation and heavy liquid flotation of the collected samples. Distillation is achieved through centrifuging the sample to force all the material to the bottom of the tube, and pipetting off the excess water. Once the sample is distilled down, heavy liquid is added and the sample is centrifuged again forcing the starch grains to float on the denser heavy liquid. This is pipetted onto slides, mounted, and ready for analysis.

**Analysis**

The analysis consists of transecting the slide under cross-polarized light at 100x magnification. Starch grains are located based on their distinctive extinction cross caused by birefringence, which is light differentially passing through the semi-crystalline structure of the grain. Once a grain is observed,
magnification is increased to 400x, and the grain is photographed under cross-polarized light and transmitted light to document the diagnostic features. Lightly tapping the slide cover can induce movement within the slide material, allowing for a three-dimensional view of the starch grain.

**Emerging Results**

BRMs were sampled from archaeological sites in Alpine, Amador, Calaveras, and Yuba counties (Wisely 2015; Wisely 2016; Wohlgemuth et al. 2017). The elevations of the sites range from the lower foothills in Yuba County, to high elevation sites in Alpine County. A total of 34 BRMs (mortars and slicks) of varying depths were sampled. The results of this research provide insight into the function of BRMs, as well as associated artifacts such as handstones, pestles, millingslabs, and even fire-cracked rock. The various starch grains recovered both confirmed aspects of McCarthy’s work and clearly demonstrate that Native American diets were more polyphagous than monophagous (Mayer 1976).

**Identified Resources**

For the purposes of this article, I combined resources such as geophytes and wild-cherry pits in the “other” group to better organize the results to McCarthy categories (1993). Figure 7 demonstrates that the results support McCarthy’s categories. For example, acorn starch grains were found in both starter and

*Figure 6. Necessary Tools for Field Sampling of Starch Grain Residues.*
Figure 7. Occurrence of Identified Resources within BRMs. Please note that some mortars yielded multiple resources.

Figure 8. Resources Identified by Mortar Depth.
finishing mortars, but not in the deeper mortars which are attributed to small seed processing. However, grass seed starch grains were identified in all mortar categories, as were other foods such as geophytes. Figure 8 demonstrates the presence of different resource categories (nut, grass seed, or others) identified in bedrock mortars. There is some overlap in the resources, as some mortars yielded starch grains from multiple resource types.

It is important to document the extent of resource processing overlap within these mortars. Of the mortars sampled, 47.81% of the mortars had a single resource type being processed, 43.5% had two resource types being processed, and 8.7% had 3 or more resource types being processed. Looking at the identified resources by elevation, some differences in resource processing are noted. Nut processing occurred more at the lower to middle elevations where oaks are abundant, than in higher elevations. Grass seed starch grains were identified at nearly all elevations. Fairly equal processing of resource types at around 6,000 feet elevation.

**DISCUSSION AND CONCLUSIONS**

The seminal ethnographic research conducted by McCarthy (1993) provided a testable hypothesis that was incorporated into the research presented in this article. The emerging results support several tenets of her conclusions, specifically that BRM function can be associated with depth and that care should be taken when borrowing her results for other tribal landscapes. This research also demonstrates the successful interaction between modern ethnographic research and starch grain analysis.

Using McCarthy’s categories as a case study, bedrock mortar function can be associated with the depth of the mortar in regard to nuts versus small seeds. However, further samples are necessary to determine: 1) if this is true throughout California; and 2) if mortar depth plays a role in processing other resources such as geophytes. This research demonstrates the potential of starch grain analysis. There are several future avenues of research for starch grain analysis in California archaeology. Testing McCarthy’s depth categories is only one example. With extensive sampling of additional categories of BRMs there is potential to provide insights into aspects of food processing, particularly in areas where fine-grained ethnographic research is lacking. Finally, there is also the potential to sample portable artifacts, in particular those found within sites that also have BRMs, and comparisons can be made about differential processing of foods by portable milling artifacts versus non-portable milling features.

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