

## POTENTIAL ROLE OF STARCH-GRAIN ANALYSIS IN DETERMINING GEOPHYTE USE WITHIN NORTHEASTERN CALIFORNIA

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*Within the Late Archaic diet of northeastern California, ethnographic, biogeographic, and archaeological data suggest that root crops were an important economic resource. Definitive evidence for the prehistoric existence of this pattern remains somewhat equivocal, however, requiring new approaches to the problem. One of the more promising methods for this is starch-grain analysis, which has the potential to profoundly improve our understanding of geophyte use and its significance with respect to broader issues of resource intensification and environmental change.*

Ethnographic, biogeographic, and archaeological data suggest that root crops were an economically important part of the Late Archaic diet in northeastern California. The development and intensification of root exploitation has been pivotal to many cultural historical and evolutionary debates over much of western North America, but archaeological identification of this activity is often problematic. One of the reasons for this is the lack of root preservation and/or identification in most archaeological contexts. Some root crops (e.g., *Brodiaea*, *Dichlostemma*, and *Calochortus*) required limited processing and left few tools or other direct evidence for their use. Furthermore, when tools were required, many were either made of perishable material (e.g., basketry, digging sticks), or their function was so generalized that they cannot be directly linked to the use of roots, as with milling implements.

Still, other root crops (e.g. *Camassia*, *Allium*, and *Lomatium*) required construction of roasting ovens and storage facilities to exploit efficiently, but even these remains may be difficult to locate or identify archaeologically. Given these constraints, most root use has been identified or inferred through a combination of indirect indicators, including a heavy reliance on biogeographic and ethnobotanical data, ethnographic documentation, the presence of presumed storage and/or roasting features, and purportedly distinctive flaked and ground stone artifacts.

### GEOPHYTE BIOGEOGRAPHY

The biogeography of root-producing genera has been used to assess their potential significance among the ethnographic groups who exploited them. Starchy underground organs characterize members of geophyte-producing plant families (e.g., *Lilaceae* and *Apiaceae*) that generally flower between May and June, but as late as August especially at higher elevations. The distributions of various species within these families are extremely widespread; they grow in a variety of soil types, elevations, and climatic settings (Hickman 1993; Munz and Keck 1959).

### ETHNOGRAPHIC IMPORTANCE OF ROOTS

Ethnographic data indicate that geophytes were intensively exploited in ethnohistoric times throughout much of western North America (Garth 1953, 1978; Kniffen 1928; Merriam 1926; Olmsted and Stewart 1978; Powers 1877; Ray 1963; Spier 1930; Voegelin 1942). This includes the interior Columbia Plateau, Pacific Northwest, and northern Great Basin, where other highly abundant, storable resources (e.g., acorns or pine nuts) were limited. The abundance, predictability, and resilience of wild root crops have all been proposed as reasons for increased settlement and intensification of root use within these areas (Prouty 1995:9). In northern California, 85 percent of 73 ethnographic sources make

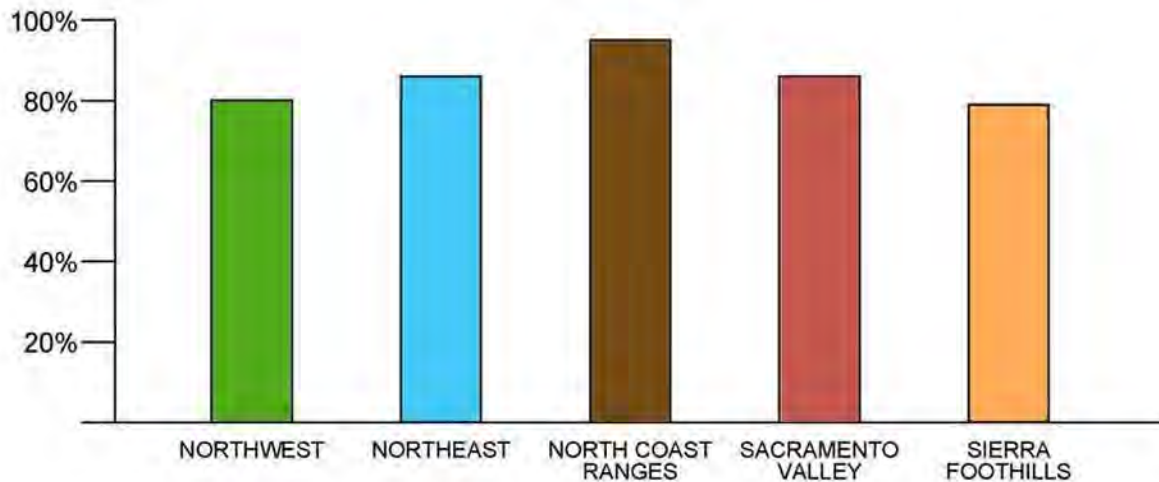


Figure 1. Percentage of general root use within northern California ethnographic sources.

reference to root exploitation, allowing for some type of root use among northern California groups (Figure 1; Scholze 2007). This suggests that root use may have been more important than previously thought.

The use of geophytes in the northwestern Great Basin and northeastern California was of generally greater importance than in surrounding areas, given the lack of acorns, pine nuts, and other food staples. Evidence for this can be seen in the ethnographic importance of three root crops that were exploited by anywhere from half to three-quarters of the local groups: *Camassia* spp. – 71 percent, *Perideridia* spp. – 57 percent, and *Brodiaea* spp. – 42 percent (Figure 2; Scholze 2007). This implies that roots were the single most important staple that could be gathered and stored in sufficient quantities for winter use.

### ARCHAEOLOGICAL IMPORTANCE OF ROOTS

Direct archaeological evidence for the importance and use of roots is more difficult to recover, but site location and assemblage content can provide important clues. Ethnographically, root gathering and processing employed similar technologies regardless of the species involved (Holt 1946; Kelly 1932; Kniffen 1928; Ray 1963; Spier 1930; etc.). These included scrapers/peelers for the skinning of roots, milling equipment for grinding (e.g., hopper mortars, milling stones, hand stones, etc.) or macerating fibrous tissues, and roasting/storage features for root preparation and preservation. Many of these artifacts have been recovered from presumably geophyte-related sites throughout western North America, and may provide at least indirect means for identifying root exploitation (Alexander and Matson 1987; Delacorte 1997a, 1997b; Foster-Curley 2006; Gleason 2001; McGuire 2000; Prouty 1994, 1995; Thoms 1989; Waechter and Andolina 2005).

### GEOPHYTE ARCHAEOLOGICAL SIGNATURE

Establishing a more consistent archaeological signature of geophyte use would substantially improve efforts to assess the economic significance of roots at various times and places in the past. Certain artifact use-wear and other patterns may, for example, indicate the processing of specific plant resources (Adams 1996; Kolvet and Eisele 2000; Odell and Odell-Vereecken 1980; Vaughn 1985).

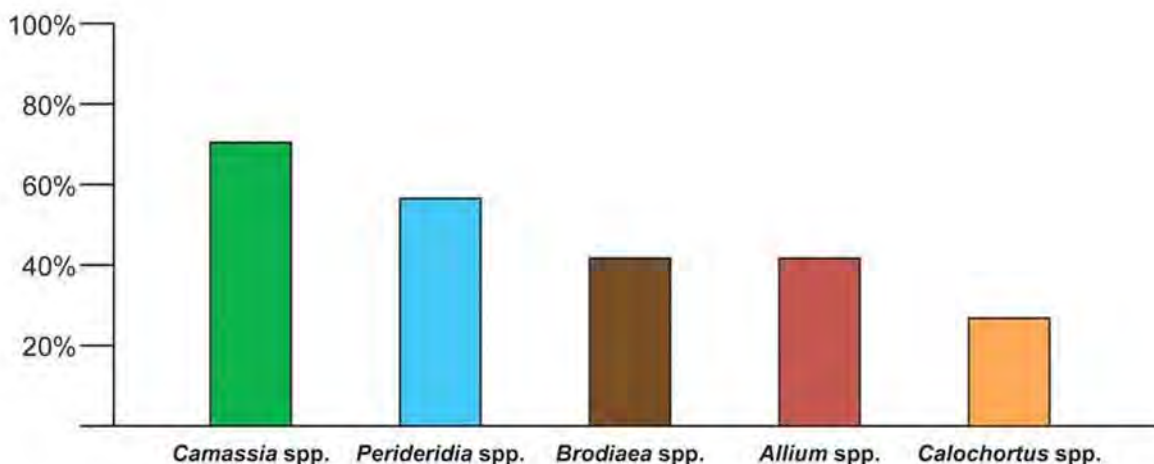


Figure 2. Percentage of specific root use within northeastern California ethnographic sources.

Delacorte (2002) presented four lines of evidence for upland root exploitation: 1) scarcity of economically important seeds in conjunction with abundant ground stone, 2) flaked stone tools with steep, extensively step-fractured edges used as scrapers, 3) large collections of milling equipment that lack “intentionally shaped, pecked/refurbished, or extensively curated implements,” and 4) expedient milling assemblages with numerous scavenged and reused tools. Each of these markers may be individually important, but they assume greater significance in combination.

Much the same is true for geophyte-related features, which can include storage structures such as rock rings, talus pits or underground caches, and roasting facilities or earth ovens (Aikens and Jenkins 1994; Delacorte 1997a, 1997b, 2000, 2008; Elston 1979; Leach 1988; Prouty 1995; Thoms 1989; Waechter and Andolina 2005). The number, size, and proximity of storage and processing features, in the absence of readily storable foods other than geophytes, provide at least indirect evidence for root exploitation. By the same token, the presence of rock-lined storage features and cache pits in proximity to residential settlements signals likely heightened use of roots as resource staples during periods of limited food availability (Prouty 1995).

When combined, these lines of evidence provide a persuasive, but still less than definitive, case for root exploitation. As such, other evidence must be sought to identify the use and importance of root procurement in the past. One of the more promising methods to accomplish this is the application of starch-grain residue analysis. This type of analysis has the potential to profoundly improve our understanding of geophyte use, allowing for the more definitive identification of root exploitation on the basis of less contestable starch-grain evidence.

### STARCH-GRAIN RESEARCH

In the past, starch-grain research of recently excavated artifacts has been used to evaluate plant domestication, prehistoric diet, mobility patterns, artifact function, and more (Loy et al. 1992; Piperno and Holst 1998; Piperno et al. 2000; Van Peer et al. 2003; Williamson 2004). This includes artifacts from both open-air and protected rock shelter sites that date from ancient to modern times (Matthews and Torrence 2006:19). When combined with other forms of analysis, including lithic, phytolith, ground stone, and pollen studies, these techniques have been instrumental in addressing a variety of topics

*Table 1. Starch grain measurement criteria.*

Style of Cross	3 nominal categories	Torrence et al. 2004
Shape	12 nominal categories	Torrence et al. 2004
Lamellae	Presence/Absence	Torrence et al. 2004
Margins, Thick	Presence/Absence	Torrence et al. 2004
Vacuole	Presence/Absence	Torrence et al. 2004
Particle @ Hilum	Presence/Absence	Torrence et al. 2004
Raphides	Presence/Absence	Torrence et al. 2004
Granule Area	Numeric	Wilson et al. 2009
Granule Length	Numeric	Wilson et al. 2009
Granule Width	Numeric	Wilson et al. 2009
Aspect Ratio	Numeric	Wilson et al. 2009
Min. Box Area to Granule Area Ratio	Numeric	Wilson et al. 2009
Squared Boundary Length to Area Ratio	Numeric	Wilson et al. 2009
Variance in Distance from Boundary to Granule Centroid	Numeric	Wilson et al. 2009
Elliptical Variance	Numeric	Wilson et al. 2009
Circularity	Numeric	Wilson et al. 2009
Total Concavity	Numeric	Wilson et al. 2009
Maximum Concavity	Numeric	Wilson et al. 2009
Area of Polarization Cross to Granule Area Ratio	Numeric	Wilson et al. 2009
Distance from Hilum to Centroid	Numeric	Wilson et al. 2009
Minimum Angle between Cross Arms	Numeric	Wilson et al. 2009
Hilum Eccentricity	Numeric	Wilson et al. 2009

surrounding plant/human interactions and evolutionary trajectories in numerous cultural contexts outside of North America.

## **UTILIZATION OF CURATED COLLECTIONS**

An as-yet-unexplored avenue for examining starch grain residues to address various research issues is the analysis of older curated collections. Many of these collections have been boxed and forgotten, with little, if any, analysis conducted after the initial report. With many previously unimagined questions being asked, and costly and consumptive fieldwork studies increasingly difficult, the importance of legacy or existing collections continues to grow. This includes the use of starch-grain analysis on long-unearthed materials of potentially unique character.

One of the greatest uncertainties is the condition and preservation of starch grains on artifacts from both archaeological and subsequently curated collections. Previous studies have shown that stone tools and other artifacts can operate as “starch traps,” protecting starch grains from decay by microorganisms for long-periods (Fullagar 2006:177). Starch granules have also been recovered from the surface of stone and wooden artifacts in Australian museum collections (Barton 2007), showing that they can survive and be retrieved from curated artifacts.

## **METHODOLOGY**

With this Australian success in mind, a low-cost starch-grain analysis methodology was developed and tested on locally available collections. A modified extraction technique employing both a manual and sonification wash was conducted, followed by a heavy liquid separation technique using sodium polytungstate to isolate the starch from heavier materials. Microscope slides of the extraction solution were prepared for starch image acquisition using a cross-polarizing compound microscope and digital camera. Starch-grain images were measured using the digital image-processing program Image J, developed by the National Institutes of Health (2004). The measurement criteria employed for this and

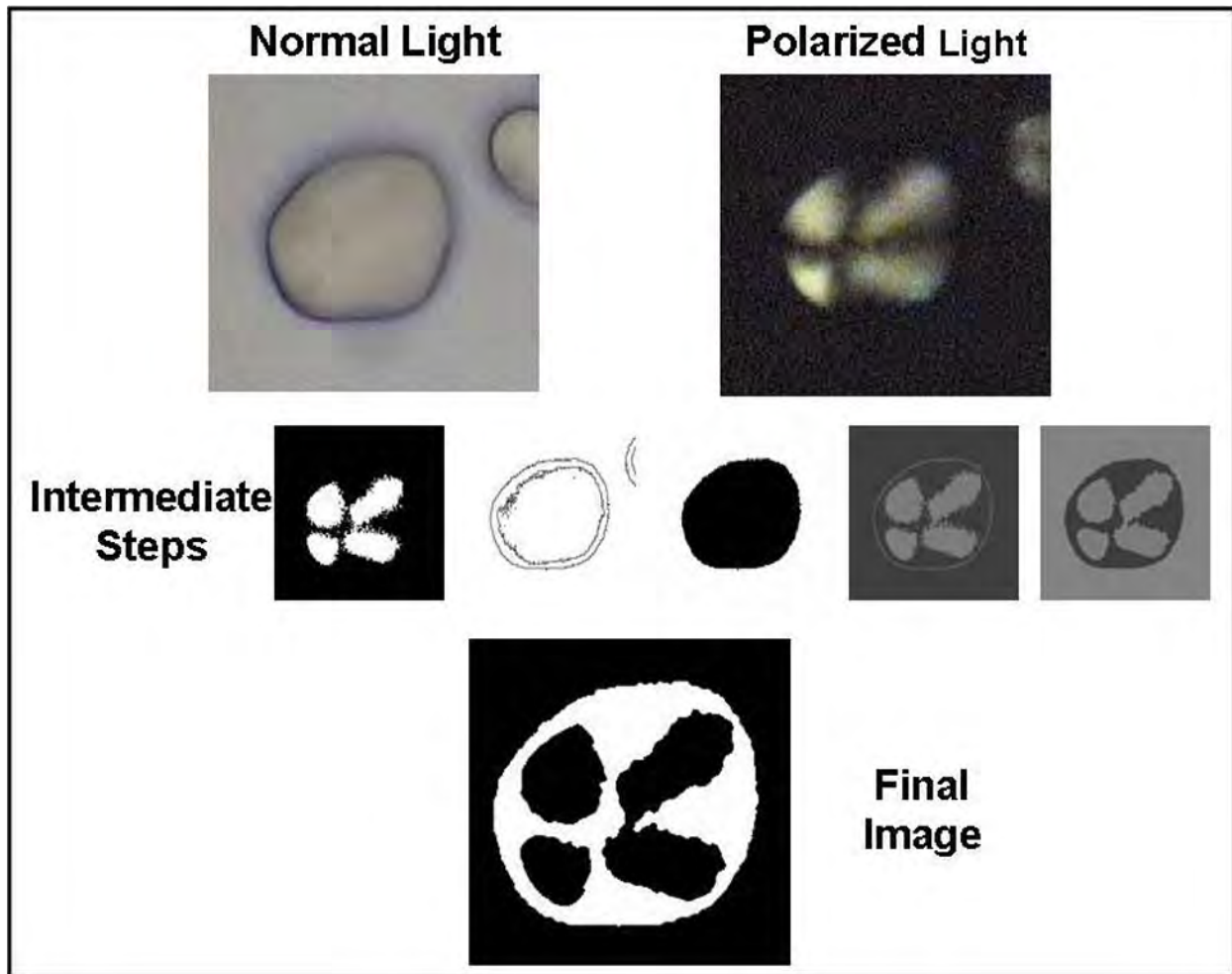


Figure 3. Normal and polarized light images and steps taken to generate measurable image.

future research are based on a combination of morphologically descriptive and morpho-metrically calibrated variables (Table 1) derived from both Torrence et al. (2004) and Wilson et al. (2009).

Prior to the detailed analysis of extracted specimens, a comparative starch collection must be created to provide comparable images and a quantitative database. This is done by capturing two images of a particular starch – a normal incident light image and a fully cross-polarized image. These images are then transformed and layered into an impartial image (Figure 3), allowing computer measurement that reduces variation between analysts. Existing measurement criteria are extrapolated from each image on 100 to 200 grains for each species to generate an average and range of granule size for every ethnographically available plant resource.

With the comparative data in hand, evaluation of starch-grain preservation on curated artifacts could proceed. For the purpose of this pilot study, curated artifacts were selected from two museum collections: an older 1964 excavated sample and a more recent 2008 collection. Although starch preservation between these collections might be compared, they derive from markedly different environments that may affect such matters, and they should be independently evaluated. Two artifacts from the older (CA-BUT-84) collection were analyzed -- a bowl mortar (#8581) and a shaped hand stone (#10167) (Figure 4) -- and two artifacts were evaluated from the more recent (INY-1384) collection -- a formed flake tool (#4463) and a milling slab fragment (#4462) (Figure 5). Inasmuch as the present goal



Figure 4. Artifacts analyzed from the CA-BUT-84 collection: shaped hand stone (#10167) and bowl mortar (#8581).

was merely to assess starch preservation and/or condition, a minimal amount of extraction solution or artifact wash was analyzed.

## RESULTS

Artifacts from the older BUT-84 collection produced generally damaged and desiccated starch grains (Figure 6). The Maltese cross or diagnostic attribute on starch from these artifacts was not very evident, and all of the grains were ruptured and/or fractured. The more recently excavated INY-1384 artifacts also yielded starch, but it was less degraded (Figure 7). These grains, though ruptured and/or cracked, revealed a more discernable Maltese cross under polarized light. This permits better measurements and more secure identification of the starch or starches represented on the tools. This suggests that the duration of curation may influence starch preservation, but additional work will be necessary to exclude other potential factors affecting starch preservation and recovery.



Figure 5. Artifacts analyzed from the CA-INY-1384 collection: formed flake tool (#2263) and milling slab fragment (#4462).

### SUMMARY AND CONCLUSIONS

The present research highlights the growing data potential of existing museum or legacy artifact collections. Starch grains were found on both older and recently excavated specimens that had been similarly washed and treated. The grains found on ground stone artifacts from BUT-84 were highly damaged and desiccated and are probably unidentifiable, but some of the starch characteristics do survive and may permit at least tentative classification. The grains recovered from the more recently excavated INY-1384 artifacts show some damage but are more intact, increasing the likelihood that they can be identified to genus or species. The potential for identifiable starch may also increase, given other factors such as the artifact's archaeological context, material type, and condition. Overall, starch granules were found on all of the curated artifacts. This demonstrates the potential of starch-grain analysis for providing previously unimagined information from curated artifacts and the significance of museum collections in the wake of state and federal legislation designed to safeguard such irreplaceable data.

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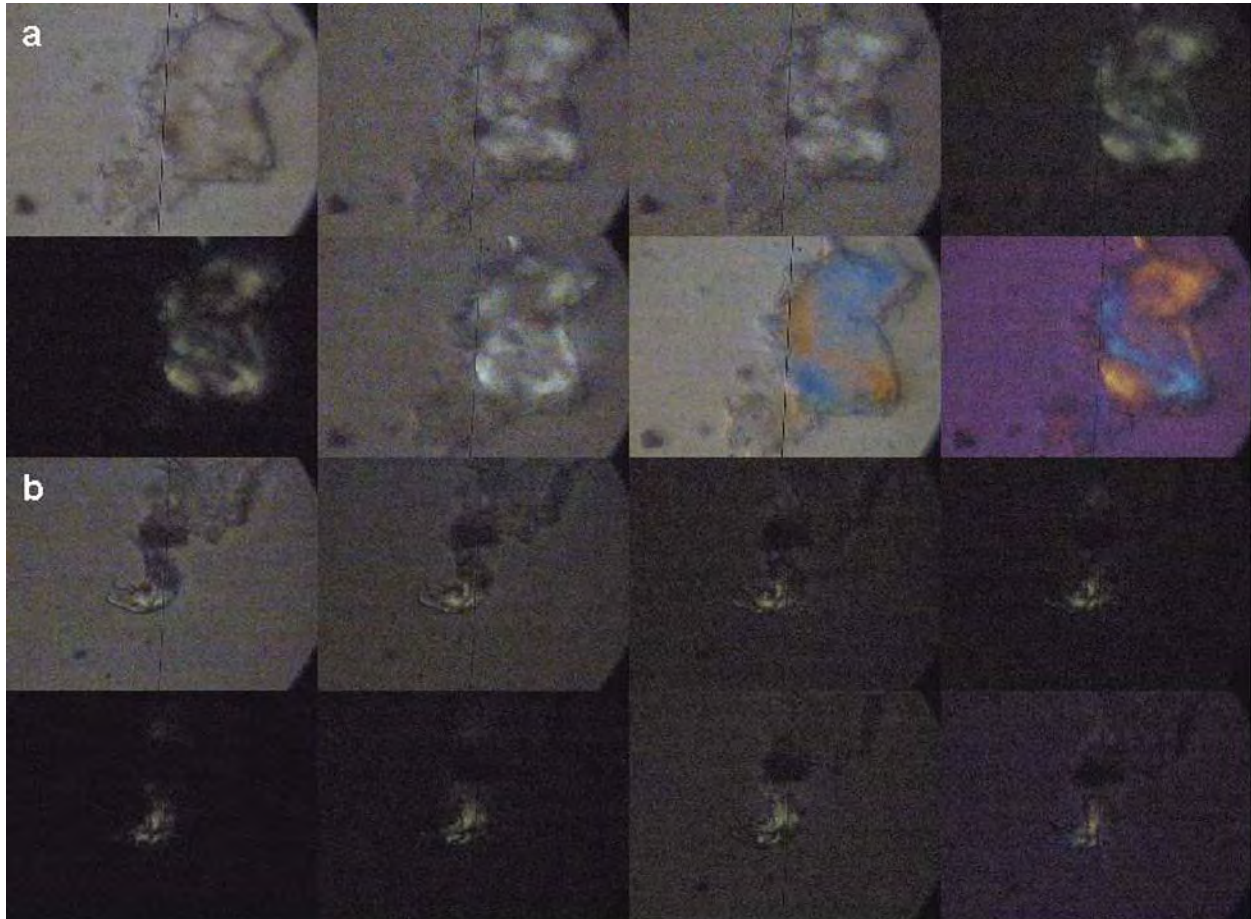
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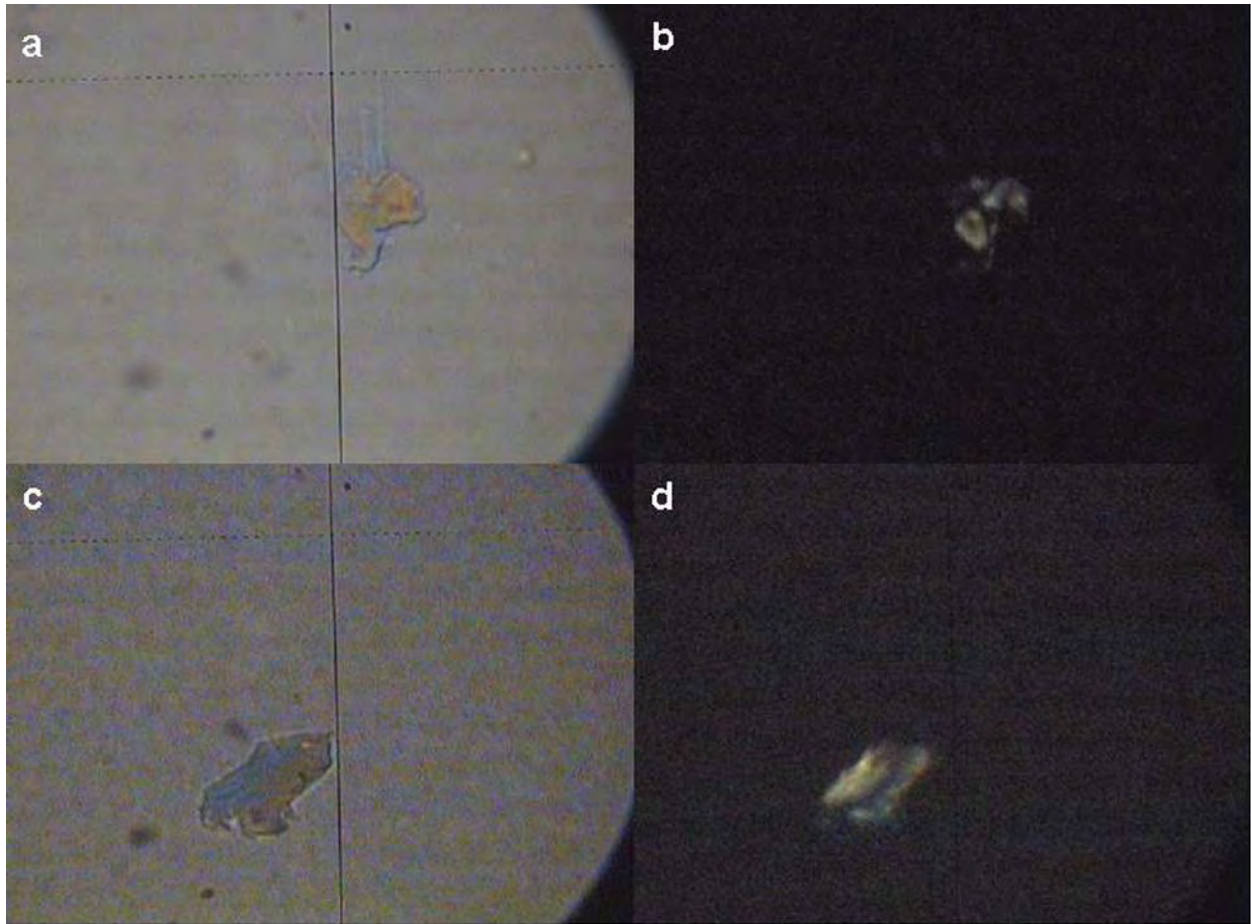
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*Figure 6. Starches extracted from CA-BUT 84 collection: two image montages (a) and (b) of two different starches extracted from a bowl mortar (#8581).*



*Figure 7. Starches extracted from CA-INY-1384 collection: two different starches in normal incident light image (a) and (c), with their corresponding fully polarized light images (b) and (d).*