# Envisioning Ancient Human Plant Use at the Río Tanamá Site #2 (Arecibo-039) Through Starch Analysis of Lithic and Clay Griddle Implements

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## 1. Introduction

This report discusses the results derived from the analysis of seven starch residue samples obtained from five stone tools and one clay griddle (two samples from three fragments of a simple burén) recovered from Río Tanamá Site #2 (AR-039), located in the Arecibo municipality of northwestern Puerto Rico. This study provides new data that contributes to a better understanding of the nature of plant use and consumption during one of the most intriguing periods of socio-economical and cultural change in the ancient history of Puerto Rico.

The time frame pertinent to this study can be bracketed between *ca.* AD 640 and AD 770, covering Periods II-b (late Cuevas) and III-a (Ostiones) of the regional chronology devised by Rouse (1992). Period II-b (ca. AD 400-800) is a time when the Saladoid people, interacting with other peoples in a multi-cultural island scenario, probably began to emphasize their social and economical activities to a new regional political context based on settlement hierarchies. According to various regional analyses produced for the eastern part of Puerto Rico (Curet 1987 and 1992; Pagán Jiménez 2007; Rodríguez López 1990 and 1992), during this phase of changes, the Saladoid-Cuevas people –different to the settlement pattern developed by the early Hacienda Grande ones– began to occupy some inland portions of Puerto Rico. At the same time, their settlement configurations on a regional basis began to show some kind of clusters made up of individual villages, probably related with broader geo-political and/or demographic changes that emerged during this phase. Period III-a (ca. Rouse's AD 900-1200/1300) is a time when marked inequality and social complexity seem to have emerged in tandem with 'monumental' architecture in the form of sites with multiple plazas and ball court precincts (Curet and Oliver 1998; Curet 2005: 22-26, 90-91; Siegel 1999). However, questions about the emergence of elites (caciques) and the nature of their botanical and economical cultures are difficult to address given that the remains of crops from pre-Columbian archaeological contexts are few and far between

despite all the recent advances in tropical archaeobotany (Newsom and Wing 2004; and de France and Newsom 2005).
The significance of most of the identified plants (and animal) species are still largely discussed at a coarse level of resolution (subseries and series) with the consequence that understanding what is going on at the levels of the household, the community, and discrete social groups remains vague. It is in this context that this starch residue analysis will serve as an initial effort toward gaining new insights on the ancient agrarian economies of the Caribbean, especially for the late Cuevas (Saladoid) and early Ostiones (Ostionoid) times.

The data gathered from this study, in spite of being limited, suggests that during the late Cuevas and early Ostiones times there were interesting social and ethnobotanical dynamics never described before in a clear way for this peoples. The complexity of such dynamics is difficult to stress here in detail due to the scarcity of the archaeobotanical samples studied. However, with this data we have a more realistic picture of the Cuevas-Ostiones botanical cultures for the Arecibo-39 community, which might serve to develop comprehensive statements about the so called transition between the Saladoid and Ostionoid peoples and cultures.

## 2. Site and Tool Contexts

### 2a. Arecibo-39 (Site #2)

The Phase III Archaeological Mitigation at Río Tanamá Site #2 (or Arecibo-39) produced a relatively high quantity of artifacts associated, in one way or another, to plant food processing and/or cooking. The entire site has been defined as a Late Cuevas/Early Ostiones activity area because both ceramic styles are mixed together. In terms of traditional lithic and pottery morphological classifications, many of those implements can be linked to various village activities where people were interacting internally and externally at different social and cultural levels. It should be noted that it is during such intra and inter-communal activities, like those related to food plant production and the processing-cooking of the resulting meals, when special human interactions (e.g., negotiations-contestations) between community members takes place (Pagán Jiménez 2007).

**Table 1. Summary of Artifacts Selected for Analysis by Provenience, Type, and Location/number of Point Samples; Río Tanamá Archaeological Project (Phase III), Arecibo, Puerto Rico.**

| **Artifact Number (Cat. #)** | **Provenience** | **Artifact type and raw material** | **Use wear sections and number of samples points in parenthesis** | **Lab. Number** and ***sample weight in grams*** |
|---|---|---|---|---|
| **Artifact 1 (FS-274)** | E.U. 15 Feature 3; Single Stratum, Level 2 (21 cmbd) | 3 griddle fragments: clay | Used section (1), and opposite side (1): two samples | 06-04 and 06-05 *(0.079 and 0.127)* |
| **Artifact 2 (FS-255)** | E.U. 12 Feature 3; Single Stratum, Level 3 (27-30 cmbd) | Conical pestle: limestone | Battered or pecked surfaces (1) | 06-03 *(0.155)* |
| **Artifact 3 (FS-242)** | E.U. 12 Feature 3; Single Stratum, Level 3 (29 cmbd) | Edge battered cobble: basalt | Faceted and pecked sections (1) | 06-01 *(0.080)* |
| **Artifact 4 (FS-244)** | E.U. 12 Feature 3; Single Stratum, Level 4 (30-33 cmbd) | Edge ground-cobble: basalt | Faceted and pecked sections (1) | 06-02 *(0.037)* |
| **Artifact 5 (FS-289)** | E.U. 16 Feature 3; Single Stratum, Level 4 (27-37 cmbd) | "Nutting" stone: diorite | Two concavities and pecked surfaces (1) | 06-06 *(0.044)* |
| **Artifact 6 (FS-278)** | E.U. 16 Feature 3; Single Stratum, Level 2 (17-27 cmbd) | Edge battered cobble: Diorite | Battered or pecked section (1) | 06-21 *(0.099)* |

Three of the six implements analyzed for starch content came from Excavation Unit (EU) 12, and the other three came from EU 15 and 16 (**Table 1**; personal communication, Betsy Carlson [2006] and *End of Field Work Report* 2005). All of these artifacts were obtained from Feature 3, which is a large deposition area (between 11-14 meters) made up of several depressions or pits filled with midden materials (e.g., faunal, ceramic, and lithic remains). This cultural deposit was all one single stratum subdivided in arbitrary excavation levels. There is one date so far from EU 17 (adjacent to EU 16), specifically from level 3 (29-39 cmbd) with a 2 sigma date of Cal. AD 640-770. In order to understand the socio-cultural nature of Feature 3, one of the aims of the mitigation project is to compare its different areas based on the distribution and associations of their respective material culture, which includes the utilitarian artifacts (for plant processing) and their "embedded" vegetal signatures. Preliminary interpretations suggest the possibility that the southern area (EU 12) of Feature 3 can be slightly later in time that the northern area (EU 16). One of the evidences used in such an interpretation is the lower percentage of Cuevas sherds with respect to the Ostiones ones in the southern area.

Other differences between the areas are not that clear and simple, but the fact is that they are not identical assemblages. In the one hand, the northern depression (presumably the earlier section of Feature 3) has cooking bone remains like fish, bird, and hutia as well as fire-cracked rocks, and many clay griddle fragments. On the other hand, the southern depression (the later section of

Feature 3) has more lithics/cobbles, very little bone (only hutia), and human remains. As a point of interest for this archaeo-microbotanical analysis, a great part of the microlithics studied in this volume (see Rodríguez Ramos's Chapter in this volume) came from the northern area of Feature 3 in spite the southern area were sampled with 1/16" producing no microlithics. As many of us know, some bipolary flaked microlithics with a particular type of use wear in their edges, have been associated with the so called cassava graters. Based on the synopsis presented above, some basic questions about plant-people interactions in Arecibo-39 emerges: Can the implements selected for this study be truly related to plant processing?; what kind of plants-vegetal organs (exogenous or endogenous) were processed at Arecibo-39?; and finally, can we see changes in plant use and/or processing through time in spite of the limited samples and contexts analyzed?

## 3. Materials and Methodology of Starch Residue Analysis

Table 1 describes the possible functional attributes of the five lithic implements and the clay griddle fragments selected for analysis. All the selected implements were bagged in the field, subsequently were transported to the project's laboratory in Florida and finally returned to Reniel Rodríguez Ramos Lithic Laboratory in Puerto Rico. Artifacts 1, 2 and 3 were not washed at any point in time. However, artifacts 4, 5 and 6 were washed during lab procedures. At a later date, the sediment samples were extracted from various pin-point locations for each tool by Pagán Jiménez in Puerto Rico (**Table 1**). The reason for multiple point sampling was to insure that microbotanical signatures were recovered from different facets or aspects of the same tool that had evident use-wear patterns apparently related to plant-processing functions. All the seven samples analyzed (≥0.006g each see **Table 1**) were processed for the separation of starch grains with cesium chloride (CsCl), as discussed in the section below.

The work surface of the implement was thoroughly cleaned with a new, moist rag. A sterile paper was placed on the working surface and, over the paper, the portion of the artifact to be sampled. Next, sediment residues (dry method) were extracted using a sterilized dental pick (see also Pearsall et al. 2004; Perry 2004). Finally, the extracted sediment was placed on sterile micro-centrifuge tube of 1.5 ml, which was then placed inside sterile plastic zip-lock bag with the appropriate label.

For all the samples, the following protocol was applied, modified from Atchison and Fullagar (1998), Barton et al. (1998) and Pearsall et al. (2004). As it was noted earlier, each sample was placed in a sterile plastic centrifuge tube of 1.5 ml, and then a solution of CsCl with a specific gravity of 1.79g/cm$^{-3}$ was added. The objective was to separate the starch grains through flotation and to isolate them from other particles, as the starches are known to have an average specific gravity of 1.5g/cm$^{-3}$ (Banks and Greenwood 1975). The separation was conducted by a centrifuge running at 2500 rpm and lasting for 12 minutes during the first phase. The supernatant, where the starch grains would be contained, was then decanted and poured into a new sterile centrifuge plastic tube. The next step was to add distilled water to the sample and agitate the mix for ten seconds. This process reduced the specific gravity of the mixture through the dilution of salt crystals with the objective of eliminating, with repeated washes, their presence. This last step was repeated two more times, but adding less water in each successive step, and running each sample through the centrifuge at 3200 rpm for 15 minutes. A droplet taken from remaining residue was then placed on a sterile slide. Half a drop of liquid glycerol was added and stirred with a stick or needle in order to increase the viscosity of the medium and enhance the birefringence of the starch grains.

## 4. The Taxonomic Ascription of the Recovered Starch Grains

The study of starch grains in archaeology provides a useful means to address questions about plant utilization. It is not meant to be a substitute for other macro- and micro-botanical (phytolith, pollen) analytical techniques, but rather to complement them. As other studies have shown, starch residues can preserve for a long time in the imperfect, irregular (i.e., pores, fissures, cracks) surfaces of lithic and ceramic tools related to the processing of plant organs (e.g., Haslam 2004; Loy *et al.* 1992; Pagán Jiménez 2002, 2005, 2007; Pearsall *et al.* 2004; Piperno and Holst 1998; Rodríguez Suárez and Pagán Jiménez 2007). If starch grains can be extracted from a tool and correlated to the starch of a known plant then a direct link can be established between the implement and the starch-rich plant or plants that it processed.

At present Pagán Jiménez (2007) have assembled a comparative reference collection of starch grains obtained from modern economic plants (see also **Table 2**). It includes 40 specimens that have been formally described, along with 20 others informally described, together representing 30 genera and 51 species that encompass wild, domesticated, and cultivated species from the

Antilles, continental tropical America, and parts of the Old World (Pagán Jiménez 2004; 2007 [Appendix B]). The detailed bi-dimensional description of the morphological traits of the modern starch, through comparison, allows to identify the taxa of the archaeological starch –as long as these grains exhibit sufficient diagnostic traits. The latter are previously established from the descriptive analysis of the modern samples in the reference collection. If these conditions are not met by the archaeological starch gains, then the taxonomic identification is deemed less secure. In such cases we use the categories "cf." (in reference to the closest tentative classification) and "unidentified". A reliable or secure identification will not be established if archaeological starch grains exhibit traits that are *not* documented in our reference collection or in the published literature (Pearsall *et al.* 2004; Piperno and Holst 1998; Piperno *et al.* 2000; Perry 2002a, 2002b, 2004; Ugent *et al.* 1986).

The identification of archaeological starch grains was conducted with an Olympus BH-2 (with polarizing capacity) employing a 10X eyepiece with reticule and a 40X objective. The principal diagnostic element used to discern starch gains from other residues is the presence of the extinction or Maltese cross observable under polarized light. The slides with the archaeological samples were comprehensively examined and their X/Y coordinates were annotated to facilitate their location in later inspections. After the analysis, the slides were stored in standard horizontal cardboard slide-holders.

**Table 2. Dimensions of the starch grains from some plants of the reference collection**

| ***Taxa*** | **Measuring range in µm (minimum and maximum dimensions from groups of starch grains)** | **[Mean] and media in µm. (Standard deviation of the media in parenthesis)** | **Number of measurements considered** |
|---|---|---|---|
| **Domesticates** | | | |
| Maíz (*Zea mays*) | | | |
| Pollo | 2-28 | [13.7414] and 13 (±3.9) | 116 |
| Caribe temprano | 3-20 | [12.86] and 13 (±3.6) | 101 |
| Frijol (bean) *Phaseolus vulgaris* L. | 10-40 | [21.59] and 20 (±6.1) | 111 |
| **Cultivars** | | | |
| Batata (Sweet potato) *Ipomoea batatas* | 5-40 | [20.32] and 20 (±7.4) | 100 |
| **Wild** | | | |
| Haba (Jack bean) *Canavalia rosea* (Sw.) D.C. | 10-53 | [28.24] and 28 (±8) | 109 |
| Palmita de jardín *Zamia portoricensis* Urb. | 5-50 | [22.56] and 20 (±9.9) | 108 |
| Marunguey *Zamia amblyphyllidia* D.W. Stev. | 1-83 | [21.75] and 18 (±13.5) | 103 |
| Guáyiga *Zamia pumila* L. | 6-95 | [32.55] and 30 (±16) | 110 |

## 5. Results and discussion

The analysis of the seven soil samples obtained from the six selected implements reveals the presence of starches from different plants, many of them known as food items. Artifact 1 (the clay griddle or burén fragments), from which two soil samples were extracted from the used surface and from the opposite side, shows the highest species richness of food plant items (see **Table 3**, **Figure 1**). As has been discussed elsewhere (e.g., see the case of Eastern Cuba in Rodríguez Suárez and Pagán Jiménez 2007) this kind of cooking implement has shown the presence, not only of plant remains, but also of faunal derivates (fatty acids) that do not corresponds with the typical uses commonly attributed to them (i.e., the cooking of cassava bread). The burén fragments studied here reflects basically the same general use pattern observed in the Cuban burenes, the presence of plants such as *Zamia amblyphyllidia* (marunguey), possibly *Zea mays* (maíz), *Fabaceae* (probably a wild bean or frijol), *Ipomoea batatas* (batata) and two starches that match nicely with those produced by wild grasses (**Plate 1**). The total absence of *Manihot esculenta* Cranz (manioc, cassava or yuca) is intriguing as well. The occurrence of starches from those important plant organs (tuberous stems, seeds and tuberous roots respectively) suggests a clear picture of previous and intentional grinding or pounding of their main vegetal organs to produce flour or for making them (e.g., the poisonous marunguey) suitable for food consumption. Looking at the different plant starches found it can be inferred the confection of different types of dough or combined ones. Thus, previous interpretations of the presence of different sources of starch grains in burén implements is confirmed here, opening an interesting inter-island scenario (between Cuba and Puerto Rico) that breaks down the current prevalent notion of some Caribbean scholars regarding the simple use of the burén as a cassava bread implement.

**Table 3. Total distribution of the identified taxa from lithic and clay griddle implements at Tanamá Site#2 (Arecibo-039).**

| ***Artifact #*** / ***Taxa*** | ***Artifact 1 Used surface*** | ***Artifact 1 Non-used surface*** | ***Artifact 2*** | ***Artifact 3*** | ***Artifact 4*** | ***Artifact 5*** | ***Artifact 6*** | ***Total grains*** | ***Ubiquity[1] (%)*** |
|---|---|---|---|---|---|---|---|---|---|
| *Zamia amblyphyllidia* | 1 | | 2 | | | | | 3 | 28.57 |
| *Phaseolus vulgaris* | | | | 1 | | | 2 | 3 | 28.57 |
| *Zea mays* | | | | | | | 3 | 3 | 14.29 |
| cf. *Zea mays* | 3 | | | | | | | 3 | 14.29 |
| *Poaceae* (wild) | | 2 | | | | | | 2 | 14.29 |
| *Fabaceae* | 1 | | | | | | | 1 | 14.29 |
| *Ipomoea batatas* | 1 | | | | | | | 1 | 14.29 |
| Not identified | | | 1 | | | | | 1 | ---------- |
| Total grains | 6 | 2 | 3 | 1 | 0 | 0 | 5 | 17 | ---------- |
| Species richness[2] | 3 | 1 | 1 | 1 | 0 | 0 | 2 | _____ | |

[1] The ubiquity in Table 3 refers to the occurrence of a reliably identified taxa between the analyzed samples (there may more than one simple per analyzed tool); tentative identifications are excluded from consideration.
[2] To determine species richness per sample only the secure identifications are considered; tentative or insecure samples are excluded.

Artifact 2 (or the conical pestle) showed particularly atypical results (**Table 3**). Although this kind of artifact is usually related with the pounding of seeds, we only found two starches of the tuberous stem of marunguey (**Figure 2**, **Plate 2**). Another starch grain found could not be identified. It should be noted that the general dimension of this implement is sufficiently small to infer that it was not used to produce great quantities of flour for food for the entire community. This characteristic of dimension plus the intentional confection of the morphology of the artifact can be better related with the preparation of religious-magical or medicinal dust. One point of interest is the presence of a consolidated reddish crust (maybe ochre) attached to one of the used sides of the pestle. As we must know, the use of colorants derived from minerals is typically related to ritual or special activities (initiation, funerary rituals, and feasting). In this context the finding of marunguey starches within an artifact more related with ritual activities can be an interesting association between Caribbean plants and island culture peoples that probably were developing or consolidating mythological histories of self belonging to the territory. The marunguey starches found in other Caribbean archaeological sites have been linked to various social and economical activities, from the Archaic to the late ceramic age previous to the contact period (see also Sturtevant 1969; Veloz 1992). This plant and its derivate products (foods, ritual dusts), have suggested earlier the possibility of its different meanings in relation to the dissimilarities of the artifact histories in which they have been found (see Pagán Jiménez *et al.* 2005; Pagán Jiménez and Oliver 2007; Pagán Jiménez 2005 and 2007; Rodríguez Suárez and Pagán Jiménez 2007). It is plausible to think that the marunguey, as an endogenous plant with the most ancient history of economical and social significance in the Caribbean paleoethnobotany, have been integrated in the cosmology of the different indigenous peoples of the islands as an important or vital entity. This implies that we need to see the plants and their different meanings in a broader context of human interactions, where its derivates (dough, flour, etc.) could be understood not only as food items, but also as constituents of histories, myths, and deities related to the superstructural-cosmological level (as medicinal, magical or food for feasting).

Artifact 3 (or one of the edge battered cobbles studied here; **Figure 3**) revealed only one starch grain. This residue fits well with the domesticated *Phaseolus vulgaris* or frijol that have been found also in many other types of lithic artifacts (stone milling bases and pestles) and burenes from other Caribbean sites (Pagán Jiménez 2007; Pagán Jiménez *et al.* 2005; Rodríguez Suárez and Pagán Jiménez 2007). The isolated presence of this starch grain (associated with a minimal use of this artifact in processing plants) highly suggest the use of this edge battered cobble in other pounding or flaking activities that probably produced the pecked or battered surfaces observed.

Interestingly, artifacts 4 and 5 (the edge ground-cobble and the "nutting" stone respectively; **Figures 4** and **5**) produced no starch grains probably due to the previous washing of its surfaces during previous lab procedures. The selection of those artifacts was made on the basis that: a) they had sufficient soil attached to the cracks and pores of the used facets and b) other similar and washed lithic artifacts from other Puerto Rican sites, at least in the case of the edge ground-cobbles, demonstrates the occurrence of starches attached to their cracks, fissures and pores. Other edge-ground cobbles studied before (washed or unwashed, see Pagán Jiménez 2007) were generally made from basalt and produced small quantities of starches, thus indicating that the faceted and heavily polished surfaces produced in those kinds of artifacts are not so deep or irregular to facilitate the incrustation of starches. The "nutting" stone analyzed here has not been studied before in any Puerto Rican archaeological site. However there are some marks near the concavities sampled that suggest another types of use more related to the bipolar reduction of stones (Rodríguez Ramos 2007, personal communication) than to the processing of hard coat seeds like the corozo palm fruits (*Acrocomia media*). There are more possible explanations to make a plausible account for the total absence of starch grains in those artifacts (e.g., pedological/taphonomical processes), but unfortunately we do not have more direct data (chemical-physical soil processes) to elucidate this preservation/displacement phenomena for artifacts 4 and 5.

Finally, artifact 6 (or the other edge battered cobble) was selected after the starch analysis of artifacts 1 to 5 was ended (**Figure 6**). Our intention here, with the help of the lithic specialist Reniel Rodríguez Ramos, was to test the criteria used in the selection of the artifacts and to verify the different steps employed during the previous protocols of analysis. The lithic specialist and Pagán Jiménez decided to select amongst the non-processed materials the artifact most heavily associated to plant processing based on its wear traces. With the expertise of the lithic specialist and the experience of Pagán Jiménez doing starch analysis in many types of lithic artifacts, both decided to select artifact 6 based on the pronounced battered surface along its longest axis. Other criteria used to select this artifact were the presence of great quantities of cracks in the used facet and the porous characteristics of the raw material employed.

The resulting starches recovered from this artifact show that it was used, apparently, for pounding hard coat seeds like maíz and frijol (**Plate 3**). It should be noted that the other edge battered cobble studied here (artifact 3, see **Table 3**) produced one starch grain of frijol. Other implements from different Puerto Rican sites that have similar use wear patterns usually produce starches of maize and frijol too (domesticated and wild), but also from corms, tuberous roots and tuberous stems of plants like *Xanthosoma* sp. (yautía), batata, and marunguey. Previous suggestions about the type of uses of the edge ground-cobbles and similar artifacts indicate their apparently mixed function for grinding seeds as well as for pounding tubers (see Pagán Jiménez *et al.* 2005; Rodríguez Ramos 2005).

### 5a. Community plant access and use through time

As has been discussed earlier, only four of the six archaeological implements selected here produced archaeobotanical information. Vertically speaking, artifacts 4 and 5 are the deepest ones, although they did not produce starches. Thus, artifacts 2 and 3 are the oldest studied artifacts of the Feature 3 if one considers the basic assumption that in a trash pit area the deepest artifacts were deposited earlier than the above ones. So, considering this matter we can see that the marunguey tuberous stems and the frijol seeds (both residues recovered in artifacts 2 and 3 respectively) were pounded and ground for various purposes, not only for quotidian activities but also and probably for ritual ceremonies. Arecibo-39 is located in an alluvial bank surrounded by limestone hills rich in useful plant species. *Zamia amblyphyllidia* (or marunguey), as well as other important economic plants (*Dioscorea-Rajania* or yams; many types of vines for basketry and medicinal rhizomes from the *Smilax dominguensis*) currently grows in surrounding hills without human intervention. Re-taking the data interpreted in previous sections for artifact 2, it is feasible to believe that some plants like the marunguey could have been tended by humans during its development, maturation and vegetative reproduction if they were integrated in the value system of the people of Arecibo-39. Those kind of plants, in spite of the facts that they are wild, can be maintained and reproduced artificially in their same original habitat, thus expanding its range of distribution and increasing their vegetative production. If plants like marunguey were heavily integrated in the cosmology of the inhabitants of Arecibo-39, it is not difficult to think that the same limestone hills where the marunguey grows naturally began to be an important component of the ritual or mythological landscape of those people.

The access to the frijoles is quite different because it is a domesticated plant that requires direct human intervention to reproduce them. In this case, the seeds of frijol need to be maintained and protected *a priori* to guarantee its consistent production through time. Based on those characteristics, it is more plausible to believe that two agro-technological systems could be employed in the production of frijol. One of them is the well known domestic (or house) garden (similar to the tropical South American *chacras* or *chagras*, see Oliver 2001), where domesticates can be maintained in joints with useful cultivated and wild plants. The other system, and better suitable for plants like the frijol, is the open and cleared plot where domesticates can be managed more efficiently when eliminating those plants (generally wild) that are negative for the development and maturation of the protected ones. As we shall see below, other plants like maíz needs to be maintained in open and cleared plots, too.

Artifacts 1 and 6 were probably the latest ones to be deposited in Feature 3. So, the plant residues extracted from them can be ascribed here to the latest manifestation of human-plants inter-relations in Arecibo-39. Interestingly, those two artifacts produced the highest quantity and variety of plant processed and cooked at the site. As we discussed earlier, artifact 6 revealed the presence of starches from two different sources: frijol and maíz. In the case of artifact 1 (the burén), starches from five different sources were found: marunguey, probably maíz, a wild grass, some type of wild frijol and batata. Seeing the data in a unified way, during this late time for Arecibo-39 a combined agro-technological system can be suggested: the development of house gardens (for the production of batata and wild grasses), open plots (for the production of maíz, frijol and probably wild frijoles) and forest management (for the procurement/production of marunguey).

This combined plant producing scenario has been suggested for earlier human groups from Puerto Rico, since the Archaic age through the late ceramic period (Pagán Jiménez *et al.* 2005; Pagán Jiménez 2007; Pagán Jiménez and Oliver 2007). Marunguey and frijol were constantly represented in the arbitrary time frame exposed here while plants like maíz, batata, and wild legumes and grasses could be integrated later in time to the vegetal food recipes of the people of Arecibo-39.

## 6. Concluding remarks

When comparing the starch content of the artifacts studied here with respect to other Puerto Rican and Cuban sites it can be noted that we found few of them in Arecibo-39. We think that they are many reasons that should explain this situation. We mentioned before that artifact 6 was selected and studied after we finished the starch grain analysis for the other artifacts. Our intention here, with the help of the lithic specialist Reniel Rodríguez Ramos, was to test the confidence of the previous aspects involved during the selection of the artifacts and to verify the different steps employed during the previous protocols applied. The results obtained from the processing and analysis of the soil sample of artifact 6 showed no problem with the analytical protocol (that was exactly the same used for the previous samples) and that the quantity and presence of starch grains in the different artifacts studied here are more related with specific plant processing activities and with the nature of the soil taphonomic/pedological processes.

On the one hand, we believe that the absence of starch grains in artifacts 4 (edge ground-cobble) and 5 (nutting stone) is a product of mixed processes that involve: 1) the previous wash of the artifacts, 2) the probable little relation of the artifacts to plant processing activities and 3) the particular pedological/taphonomical processes of the artifacts in Arecibo-39 with respect specifically to starch preservation. On the other hand, artifact 2 (conical pestle) showed dimensions and intentional confection of the morphology that can be better related with the preparation of religious-magical or medicinal dust. We mentioned earlier the presence of a consolidated reddish crust (maybe ochre) attached to one of the used sides of the pestle, which could be suggesting another kind of uses for this artifact different from those for producing food derivates. With respect to unwashed artifact 3 (edge battered cobble), the isolated presence of a frijol starch grain can be associated with the minimal use of this artifact in processing plants. This suggests the use of this edge battered cobble in other pounding or flaking activities that probably produced the pecked or battered surfaces observed.

Finally, the burén fragments proportioned the highest quantity of starches confirming the preservation of this type of residue in ceramic griddles submitted to heat during the process of cooking. Similarly to other Cuban burenes studied for starch content (see Rodríguez Suárez and Pagán Jiménez 2007) there are several explanations that deserve to be reproduced here. It is possible that the group of elements involved in the preparation of the determined foodstuffs (e.g. vegetable oil, animal, resins, minerals) when mixed with the starch in a medium missing intentional exposure to an open flame, could have provoked an isolating, consolidating environment that would permit the starches to "survive" to inclement "in situ" exposures, i.e. on the surface on which the previously mentioned product was processed.

Clay is a bad heat conductor and even when it heats up this occurs gradually. The burenes are fairly thick, and even if some are relatively thin or have fine temper, the following possibilities must be considered. If the starches are exposed to heat in a dry environment (e.g. in the already prepared dough and in a soft state over a hot surface), the water component present in the molecular structure would respond slowly to the temperature gradient in the burenes; that is, the grain would dehydrate little by little and the loss of water could have helped it to preserve its structure and morphology, perhaps behaving like a body buried in the desert that mummifies by dehydration. This same principle could even apply if the burén had reached high temperatures because the dough that was placed on the cooking surface would have been cold or at room temperature. It could be expected that the dough warms up slowly. Dehydration of the starches that were not in direct contact with the artifact's cooking surface would have occurred in the same way. Under these circumstances, the starches would not be in a liquid environment that would allow them to gelatinize and since they are not strictly organic material they could not carbonize by contact with hot surfaces. This would explain why hydrating the starch grains during the process of sample flotation or by analyzing the sample directly would return them to their original state, unless they were broken by some other cause.

Another possibility is that the inhabitants of the Arecibo-39 community perhaps did not wash their hands during the handling of the starch-rich foods when processing them in the burén and could have been carrying grains on themeselves; we do not consider that they ever washed the burén between one preparation and the other. Starches have been found on both sides of the burén fragments and as we know the artifact does not heat up uniformly, in which instance the grains could have been well preserved in the less heated areas.

Other possibility could be that the clay was sufficiently porous to trap some unaffected grains. If we consider what we have previously said concerning temperature gradients, all of the starches may not have been exposed to the same level of heat and thus some may have been preserved better than others. One last possibility for the preservation of starches on the burén fragments is that the artifacts were used in their last stage (i.e., after their use as a cooking utensil) or before their disuse and abandonment (i.e., after their usefulness as cooking tools) to process fresh material (e.g., pounded material or "flour" derived from starchy plants) on work surfaces (the burén like a table work surface).

In spite of the artifacts selected for this study were few, they evidenced for the first time in a Cuevas-Ostiones period a range of tuberous and seed plants that are indicative of a broad spectrum of potentially high yield food plants. Manioc or yuca, still regarded to be the staple 'super-crop' that underpinned the development of complex societies (cacicazgos) in the Caribbean was not identified in this study. As we mentioned before for the case of the burén fragments studied for starch content, our findings supports those obtained from Cuban late agro-ceramic sites where the manioc was never identified. That does *not* mean that manioc was insignificant or marginal, particularly since other important implements that were most likely involved in processing, such as the triangular micro-flakes inserted on wood boards (i.e., güayos), are absent from the tool sample analyzed.

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**Figure 1** Clay griddle fragments (artifact 1). The fragments above show the used facets. Below, the same griddle fragments. All of the three fragments are from the same artifact.

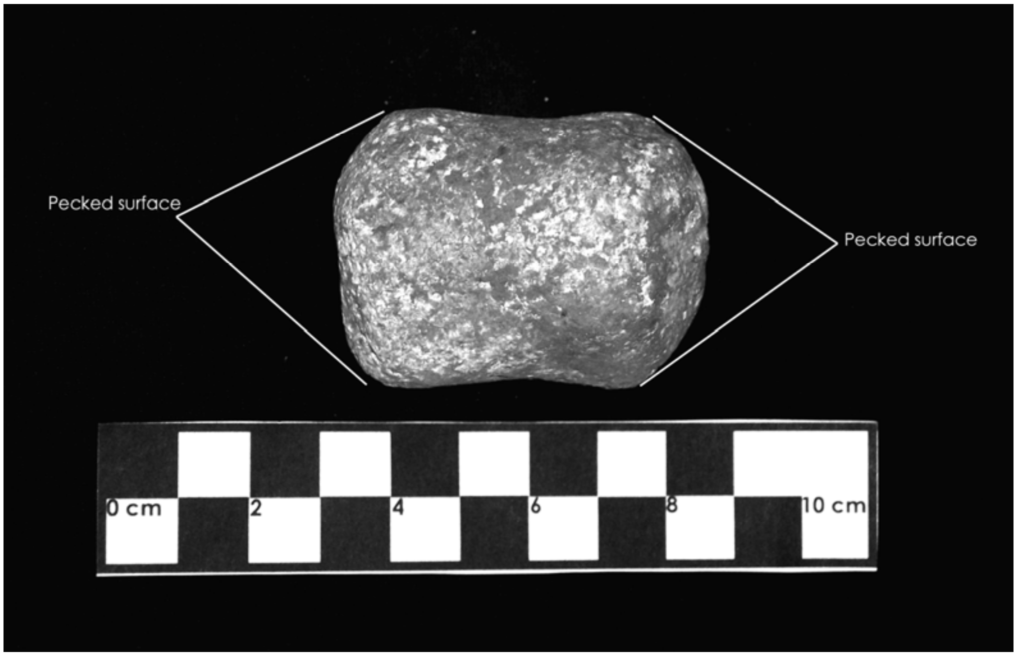



**Figure 2** Stone pestle (artifact 2) made from limestone. See the opposite extremes (sections used) and the general rhomboidal shape of the implement.

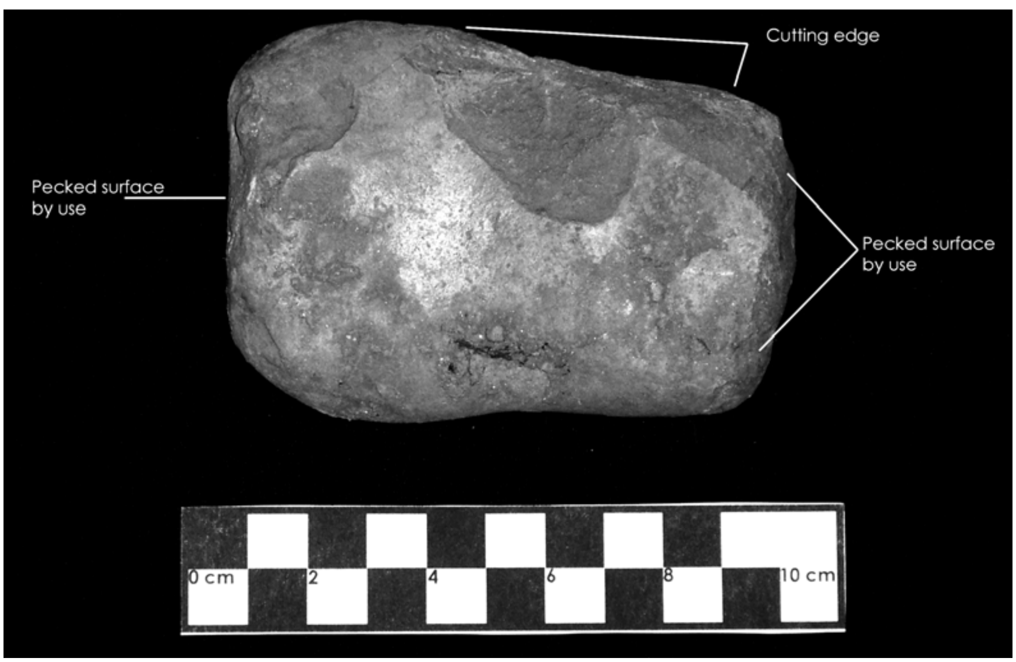



**Figure 3** Edge battered cobble (artifact 3) made from basalt. Note the pecked surfaces produced by use in opposite sides of the artifact, and the cutting edge with use evidence in the longest axis.

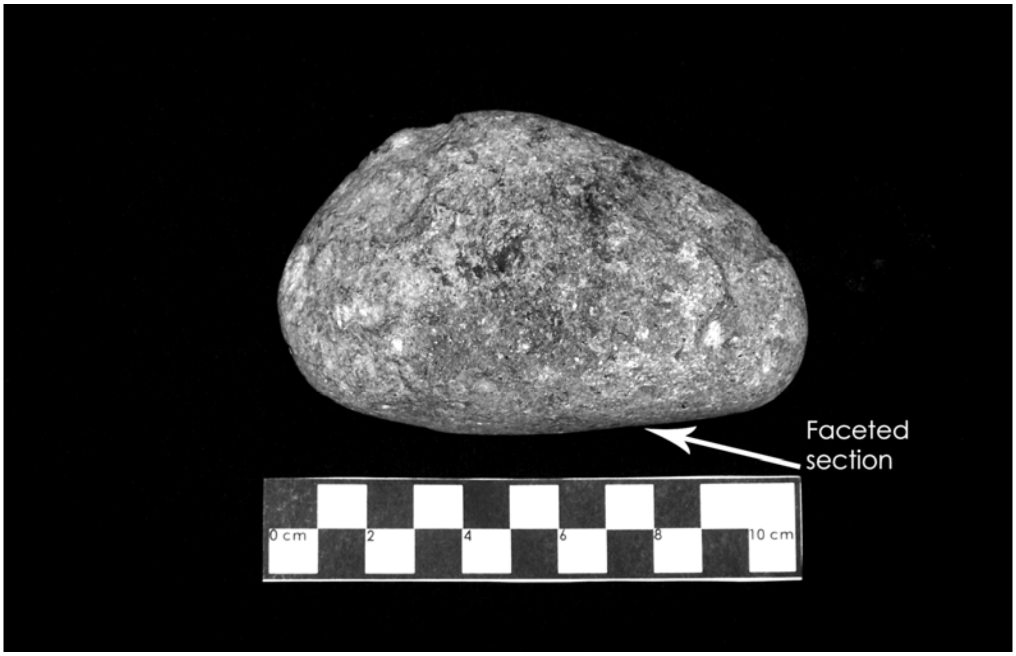



**Figure 4** Edge ground-cobble (artifact 4) made from basalt. The faceted section have been polished by use despite the raw material is now (probably meteorized) porous.

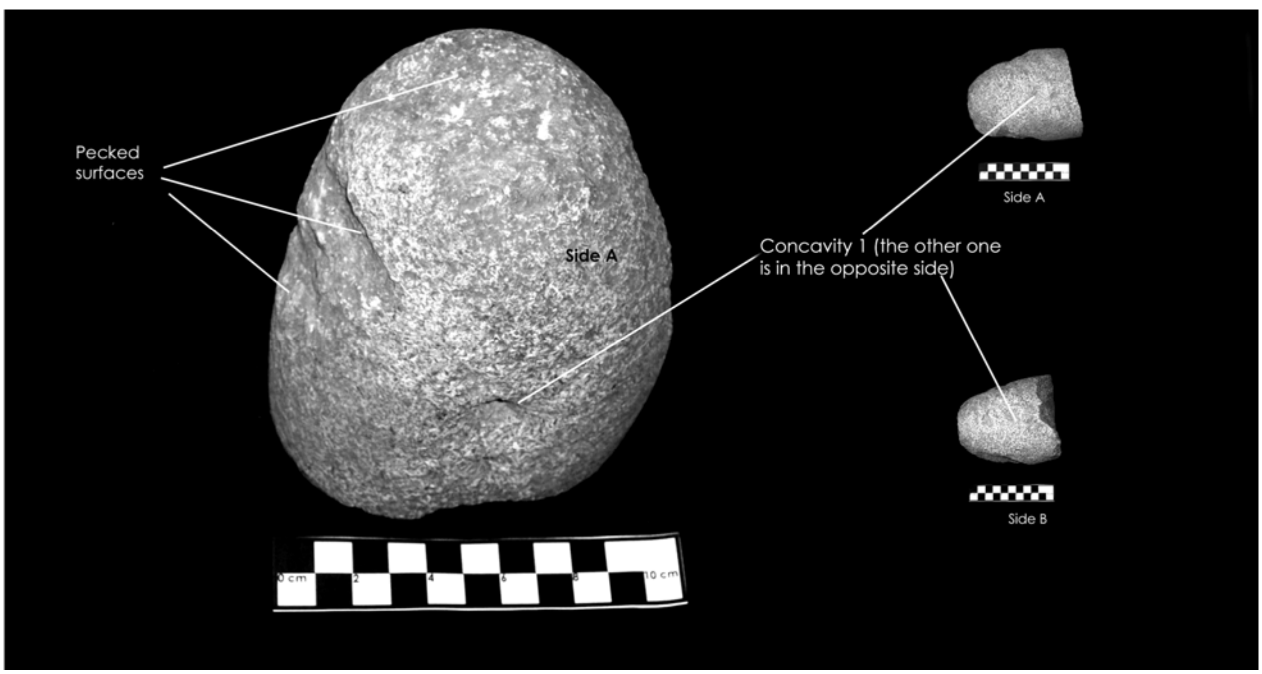



**Figure 5** "Nutting" stone (artifact 5) made from diorite. There are two concavities as opposites in each side of the artifact.

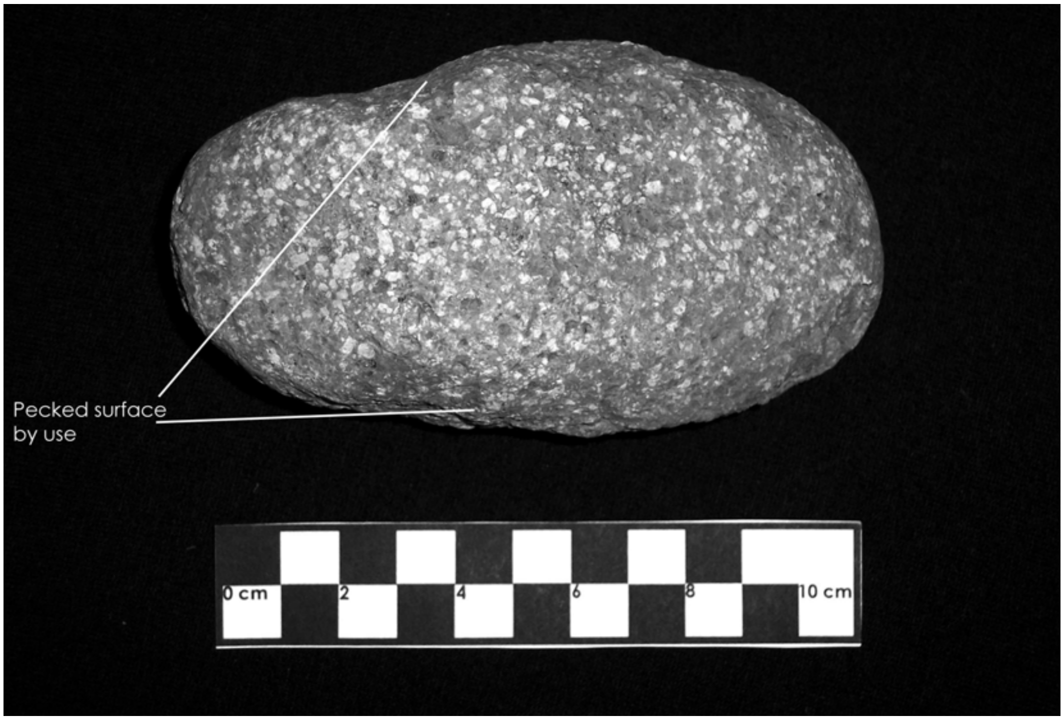
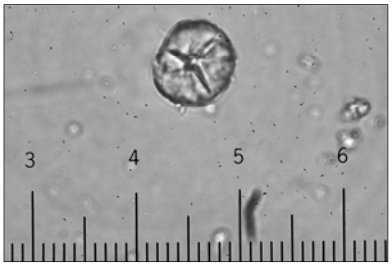



**Figure 6** Edge battered cobble (artifact 6) made from diorite rock. There are no polished facets in the artifact that suggest its unique use (e.g., pounding) with soft plant material. The pecked facets are more related to the constant breaking of hard materials (hard seeds) like those recovered (frijol and maíz) from this artifact.



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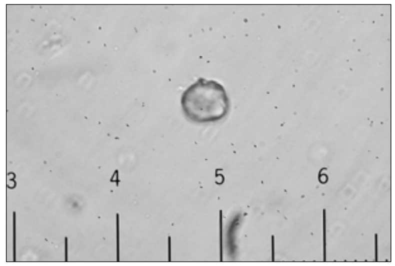

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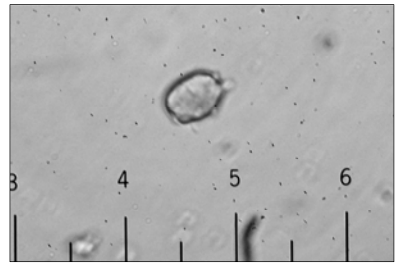

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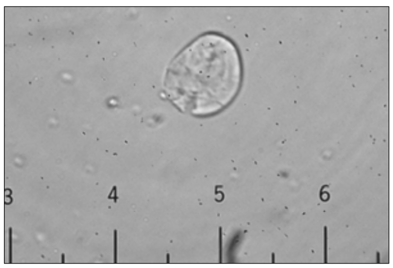

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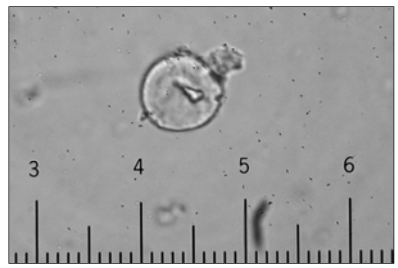

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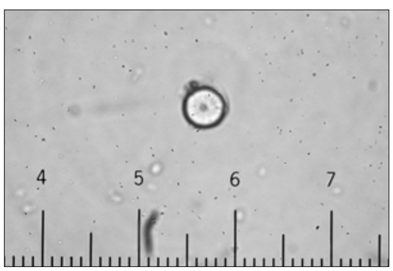

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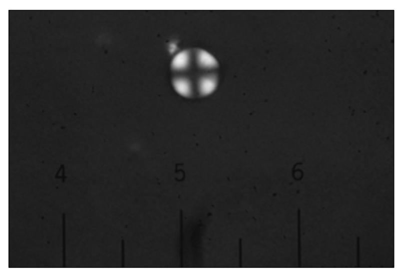
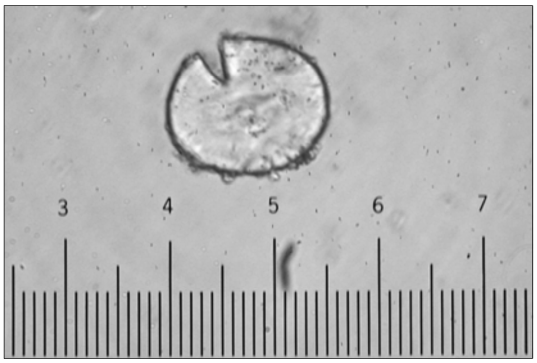
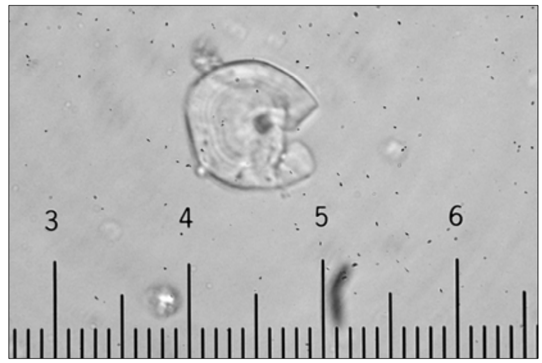


g)

**Plate 1** Archaeological starch grains from Artifact 1 (burén fragments) ***a)*** *Ipomoea batatas* showing a typical "T" shape fissure; ***b)*** and ***c)*** *Zea mays*; ***d)*** broken star granule from *Fabaceae*; ***e)*** *Zamia amblyphyllidia* and ***f)*** a wild grass starch with prominent radiating fissures and ***g)*** the same starch granule with cross polarized light showing the characteristic extinction cross of some grasses, including maíz. Graphic scales for all the photomicrographs (taken with an Olympus BH-2) are 37.5μm between each major unit.




a)




b)

**Plate 2** Archaeological starch grains from artifact 2 (conical pestle). Both starches (***a*** and ***b***) are from *Zamia amblyphyllidia* or marunguey. ***a)*** Note the great dimension of this broken starch (60 x 40μm) that is consistent with the majority of starches from modern marunguey; ***b)*** this starch is broken too and the lamellae or growing rings of amylose and amylopectin are clearly visible. Graphic scales for all the photomicrographs (taken with an Olympus BH-2) are 37.5μm between each major unit.

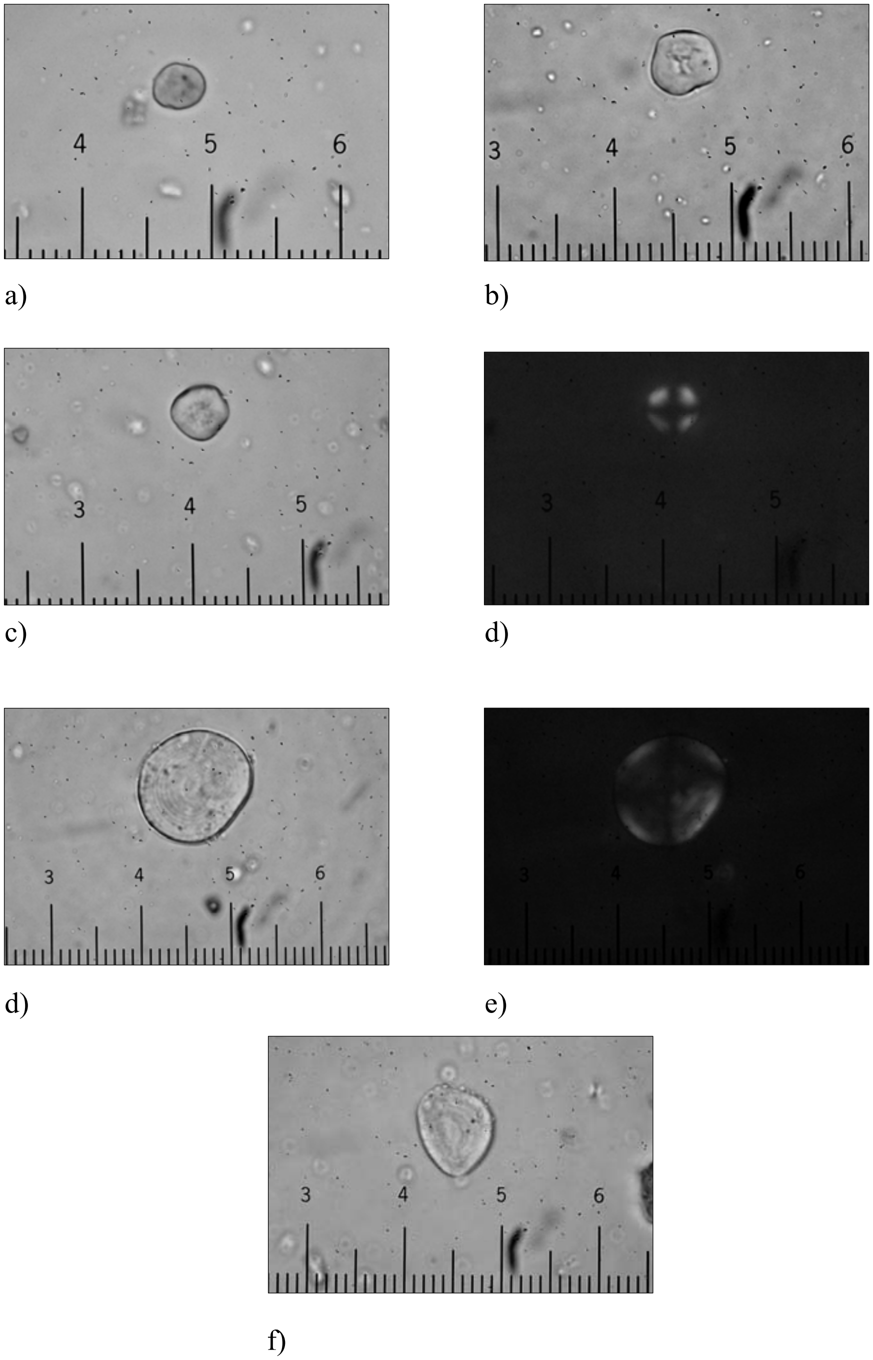



**Plate 3** Archaeological starch grains from Artifact 6. ***a)*** and ***b)*** are from maíz; ***c)*** and ***d)*** are the same maíz starch grain (***c*** is under white normal light and ***d*** is with cross polarized light); ***e)*** and ***f)*** are the same marunguey starch grain showing their typical lamellae with white (***d***) and cross polarized light (***e***); ***f)*** is another marunguey starch grain . Graphic scales for all the photomicrographs (taken with an Olympus BH-2) are 37.5µm between each major unit.