CROSSING THE BORDERS

New Methods and Techniques in the Study of Archaeological Materials from the Caribbean

Edited by

Corinne L. Hofman, Menno L. P. Hoogland, Annelou L. van Gijn

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Starch Residues on Lithic Artifacts from Two Contrasting Contexts in Northwestern Puerto Rico

Los Muertos Cave and Vega de Nelo Vargas Farmstead

Jaime R. Pagán Jiménez and José R. Oliver

Introduction

This chapter discusses the preliminary results derived from the analysis of 15 starch residue samples obtained from seven ground stone tools recovered from Los Muertos Cave (SR-1) and Vega de Nelo Vargas (Utu-27) sites, both located in the karst mountain region of northwestern Puerto Rico (Figure 11.1). This study provides new data that contribute to a better understanding of the nature of the agrarian economy of ancient Puerto Rico, one of the main objectives set forth in the Utuado-Caguana Archaeological Project, codirected by Oliver and Rivera Fontán (see Oliver 1998, 2005; Oliver et al. 1999).

The time frame pertinent to this study is bracketed between A.D. 680 and A.D. 1450, covering Periods IIIa–b (early to late Ostiones) and IVa (Capá), if one follows the regional chronology devised by Rouse (1992). Period IIIb (ca. A.D. 900–1200/1300) is a momentous time, as it was when inequality and social complexity seem to have emerged in tandem with "monumental" architecture in the form of sites with multiple plaza and ball court precincts (Curet 2005:22–26, 90–91; Curet and Oliver 1998; Siegel 1999). By Period IVa (ca. A.D. 1250/1300–1500) complex polities, with varying degrees of centralization and hierarchical (and perhaps also heterarchical) organization, dominated the political scenario of ancient Puerto Rico, although not all polities in the island were necessarily subject to a paramount chief, and may have maintained a certain degree of decentralization and political autonomy (see Oliver 2003).

Earle and Johnson (2000:257–258) and Earle (1991:1–15), among others, have argued that the political economy of chiefdoms and states were financed by exercising political control over staple crops (staple finance) and/or over material wealth

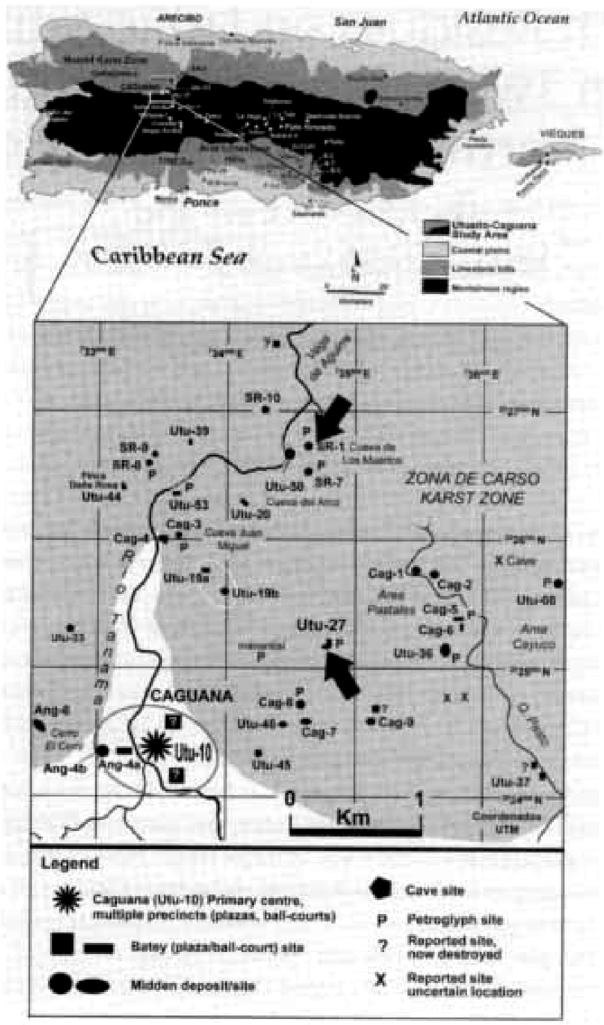

Figure 11.1. Map of Puerto Rico showing the location of archaeological sites; the Utuado-Caguana study area, showing the distribution of various types of archaeological sites. Arrows indicate the location of Cueva de Los Muertos (SR-1) and Vega de Nelo Vargas (Utu-27).

of various kinds (wealth finance). Earle (1997:70–75) remarked that staple crops seem to play a larger role than wealth in financing chiefdoms than in states. For the historic Taíno, Moscoso (1986:414–432) compiled data from the early Spanish colonial documents that suggest that paramount caciques (chiefs) exhibited direct control over vast *conucos*, or plantations, cultivated principally with *yuca*, or manioc (*Manihot esculenta*), and *ajes*, or sweet potatoes (*Ipomoea batatas*), with other crops playing less important roles.

Questions about the emergence of elites (caciques) and the nature of their political economy, however, 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 (De France and Newsom 2005; Newsom and Wing 2004).

The significance of most of the identified plant (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 household and local community and discrete social groups remains vague. It is in this context that the foregoing starch residue analysis is an initial effort toward gaining new insights on the ancient agrarian economies of the Caribbean.

The preliminary data emerging from this study suggest that the phyto-cultural dynamics of northwestern Puerto Rico do not neatly conform to the widely accepted, conventional views on the nature of the pre-Columbian agricultural economies of the Caribbean. The evidence points to different agricultural production scenarios that coexisted in the intra- and interisland contexts.

Site and Tool Contexts

Los Muertos Cave (SR-1)

The karst zone in the Utuado-Caguana region exhibits an abundance of caves, some of which were selected for human utilization. One such cave is Los Muertos Cave (SR-1), located some 2.8 km due north of the Vega de Nelo Vargas site and 1.5 km north of the civic-ceremonial site of Caguana (Figure 11.1). The cave consists of a relatively large and well lit main chamber (A), with its mouth opening to the northeast, and a dark, long gallery into the back of the cave extending some 25 m before it reaches a dead end. The main chamber contains a dozen or so petroglyphs and a single human burial. The long back gallery yielded a human skeleton laid to rest on its surface, while two secondary burial bundles were found in a niche sealed with a limestone slab along this gallery.

This cave has an unusually high frequency of exogenous igneous rocks (metavolcanic); many were subjected to postmanufacture firing. The closest source of igneous rocks is Pasto Creek located to the southeast (Figure 11.1). The metavolcanic materials included a variety of modified tools, nuclei, *débitage*, and unmodified rocks, suggesting that their manufacture was in situ. Given the high number of plant-processing stone implements, the question arises as to what kinds of plants were being processed and why these were processed in what appears to be, at first glance, a ritual-religious burial site. Seemingly, there is something about the location and the use into which the resulting tools would be put that made it necessary to manufacture them in this cave and not back at home or at a workshop nearer the Pasto Creek.

The three tools analyzed for starch came from a 2 x 1 m test excavation adjacent to a human burial pit (see Figure 11.2). Artifact 2 (FS-905) came from Stratum II, characterized by loose dark soil and ashes mixed with abundant land snails and a few animal bones. The few ceramics recovered are all Ostiones style. Artifact 3 (FS-916), came from Stratum IIIa, whereas Artifact 1 (FS-998) came from Stratum IIIb. Stratum III is a dense and compact midden, with abundant ashes, charcoal, land snails, and *buruquena* crab claws (*Epilobocera sinuatifrons*), and registered the highest frequency of ceramics (also Ostiones style) and metavolcanic implements. The three implements are from granodiorite rocks (Utuado Pluton). Stratum IV is similar to Stratum IIIb but for two key differences. First, the still abundant *buruquena* claws are mostly from juvenile or immature specimens; second, pottery is absent.

A preliminary assessment of the lithic assemblage by Reniel Rodríguez Ramos suggests that the reduction protocol and formal end products for metavolcanic rocks from Stratum IV do not show major or obvious differences with that of the upper strata. Nevertheless, at this stage it cannot be determined with certainty whether Stratum IV represents an Archaic or a Ceramic Age component. Two dates were obtained: sample GrN-30060, from Stratum IIIa, dates to cal A.D. 1020–1190 (2σ), and GrN-30059 from Stratum IIIb dates to cal A.D. 680–950 (both at 2σ using OxCal v. 3.10). These dates agree with those from nearby habitation site Utu-44 and Juan Miguel burial cave site (Oliver and Narganes Storde 2005; Rivera Fontán and Oliver 2005).

Vega de Nelo Vargas (Utu-27)

The Vega de Nelo Vargas site is located less than 2 km due northeast of the major civil-ceremonial center of Caguana (Figure 11.1). The site is typical of other dispersed settlements (farmsteads) in the karst area of Utuado-Caguana (Rivera Fontán and Oliver 2005:235; Oliver et al. 1999). Located on a "saddle" between the karst hills (hereafter *mogotes*) it overlooks a small circular valley. The site has a *batey*, or plaza, demarcated with limestone slabs decorated with petroglyphs and a single midden deposit spilling down slope from the edge of the saddle (Oliver and Rivera Fontán 2004). Several test pits and long trenches were conducted on the midden area and the plaza in 2001. The midden was rich in both artifacts and subsistence remains, reaching a maximum depth of 90 cm below surface. The plaza area was scraped with a backhoe (machine scraped) in 2002, over which two long trenches

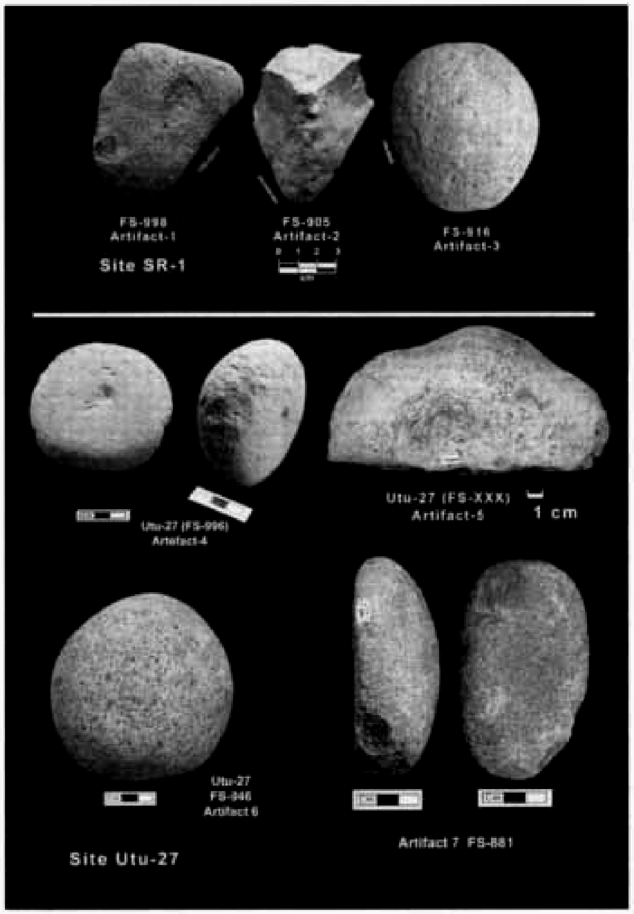

Figure 11.2. Lithic tools from Los Muertos Cave and Vega de Nelo Vargas; top left: artifact 1, FS-998, granodiorite mortar/edge grinder; top middle: artifact 2, FS-905, fragmented granodiorite mortar implement; top right: artifact 3, FS-916, a spherical granodiorite mano or pounding/grinding stone; middle left (two views): artifact 4, FS-996, dorsal and lateral views of a mortar-mano edge grinding implement made of granodiorite rock; middle right: artifact 5, FS-XXX, limestone mortar with a central concavity; bottom left: artifact 6, FS-946, a spherical granodiorite mano; bottom right (two views): artifact 7, FS-881, a coarse mano with edge battering made of a brittle species of granodiorite, showing the lateral and anverse facets.

(N-S, E-W) were excavated. The plaza area had a significantly lower frequency of cultural materials. Two assays from Stratum II calibrated to A.D. 1300–1430 (GrN-26413) and to A.D. 1290–1400 (GrN-26412; both 2a). Stratum III assays calibrated to A.D. 1290–1400 (GrN-30051) and A.D. 1280–1400 (GrN-30050; both 2σ).

Artifacts 4 (FS-996), 5 (FS-XX), and 6 (FS-946) (see Figure 11.2), came from the machine-scraped exposed surface of the *batey* area, corresponding to Stratum I of the North-South Trench profile (Table 11.1). Artifact 7 (FS-881), came from Test Unit 3, Stratum III (Table 11.1). Artifacts 4 and 5 are made of a compact granodiorite stone, whereas Artifact 7 is made of a meteorized granodiorite with large hornblende crystals (Oliver and Rivera Fontán 2004:10). Artifact 5 is the only limestone implement to be analyzed in this study.

To summarize, Artifacts 1, 2, and 3 at Los Muertos Cave came from a midden deposit associated with Ostiones-style ceramics (ca. A.D. 850 and 1250/1300). These implements are made of imported igneous materials probably brought from Pasto Creek into a cave site that seemingly had a religious function, but which does not exclude other kinds of (secular?) activities.

Artifacts 4 to 7 came from a late Capá period (cal A.D. 1280–1430) habitation site, Vega de Nelo Vargas, where farmstead-level domestic activities combined with the civic-ceremonial activities carried out in the plaza. The site probably was occupied by a single household whose members may have been of some standing (elite?), as several prestige/wealth items were found (Rivera Fontán and Oliver 2005). However, the site is nowhere near Caguana's (Utu-10) "monumentality" and its impressive iconographic display (Oliver 1998, 2005).

Materials and Methodology of Starch Residue Analysis

Table 11.1 describes the possible functional attributes of the seven lithic implements selected for analysis. All the selected lithic implements were bagged in the field and subsequently transported to the project's laboratory in San Juan. None of these lithics were washed at any point in time. At a later date, Pagán Jiménez extracted the sediment samples from each artifact.

The sediment samples were extracted from one or more pinpoint locations for each tool (Table 11.1). The reason for multiple point sampling was to insure that these were recovered from different facets or aspects of the same tool that had evident use-wear patterns and which could have had different plant-processing functions. In other instances, samples were extracted from the periphery of the (evident) use-wear areas, thus allowing a comparison of the results obtained from different sections or facets of the same tool, with or without evident use-wear signs. Of the 15 samples analyzed, 11 (= or >0.006 g each) were processed for the separation of starch grains with cesium chloride (CsCl), as discussed in the section below. The remaining six samples were mounted directly on the slides with a

Table 11.1. Summary of Artifacts Selected for Analysis by Provenance, Type, and Location/Number of Point Samples.

Artifact Number (Cat. #)	Site and Provenance	Artifact type and raw material	Use-wear sections and number samples points in parenthesis
Artifact 1 (FS-998)	Cueva de Los Muertos (SR-1) Strat. IIIb-Lev. 4. 128–165 cm BD	Mortar and possible edge-ground tool: granodiorite	Concavity (1), faceted section (1), lateral facet (1) and use-wear periphery (1)
Artifact 2 (FS-905)	Cueva de Los Muertos (SR-1) Strat. II-Lev. 2	Mortar fragment: granodiorite	Concavity (1) and use-wear periphery (1)
Artifact 3 (FS-916)	Cueva de Los Muertos (SR-1) Strat. IIIa-Lev. 3 125- cmBD	Spherical mano (pestle): granodiorite	Pecked surface (1) and use-wear periphery (1)
Artifact 4 (FS-996)	Vega de Nelo Vargas (Utu-27) Block E (mss)*	Mortar and possible edge ground tool: granodiorite	Concavity one (1), concavity two (1), faceted surface (1) and use-wear periphery (1)
Artifact 5 (FS-XXX)	Vega de Nelo Vargas (Utu-27) Block E (mss)*	Mortar: limestone	Concavity (1)
Artifact 6 (FS-946)	Vega de Nelo Vargas (Utu-27) Block C: N940.72-W852.15 (mss)*	coarse spheroidal mano, granodiorite	Faceted surface(1)
Artifact 7 (FS-881)	Vega de Nelo Vargas (Utu-27) Test Unit N951-W857.5 Stratum 3	Mortar: meteorized grandiorite (large hornblende crystals)	Faceted surface (1)

*(mss) = machine-scraped surface; that is, on top of Stratum I as recorded in the North-South Trench

solution of water and liquid glycerol, since the volume and weight (< 0.006 g) of the sample was insufficient to process with CsCl.

The work surface of the implement was thoroughly cleaned with a new, moist rag. To handle the artifacts, talc-free latex gloves were used at all times. 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). Before each new point sample was taken, the workspace was cleaned again, and materials were replaced. Finally, the extracted sediment was placed on sterile white paper, which was then placed inside a sterile plastic zip-lock bag with the appropriate label.

For 11 of the samples, the following protocol was applied, modified from Atchison and Fullagar (1998), Barton et al. (1998) and Pearsall et al. (2004). Each sample was placed in a sterile plastic centrifuge tube, and then a solution of CsCl with a specific gravity of 1.79 g/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 1.5 g/cm-3 (Banks and Greenwood 1975). A centrifuge running at 2,500 rpm and lasting for 12 minutes during the first phase effected the separation. The supernatant, where the starch grains would be contained, was 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 3,200 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.

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 microbotanical (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 tools related to the processing of plant organs (e.g., Haslam 2004; Loy et al. 1992; Pagán Jiménez 2002a, 2002b, 2005a, 2005b; Pearsall et al. 2004; Piperno and Holst 1998). 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 we have assembled a comparative reference collection of starch grains obtained from modern economic plants. 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 some from the Old World (Pagán Jiménez 2004, 2005b [Appendix B]). The detailed bidimensional description of the morphological traits of the modern starch, through comparison, allows us to identify the taxon of the archaeological starch—so long as these grains exhibit the necessary and 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; Perry 2002a, 2002b, 2004; Piperno and Holst 1998; Piperno et al. 2000; Ugent et al. 1986).

The identification of archaeological starch grains was effected through an IROSCOPE PT-3LIT (with polarizer) employing a 10x eyepiece and a 40x objective. The principal diagnostic (but not exclusive) element 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 coordinate positions noted to facilitate location and perspective in later inspections. After the analysis, the slides were sealed with varnish and stored in standard cardboard slide holders.

Results

The results of the identification of the plants and organs through starch signatures obtained from the archaeological tools (Tables 11.2–3) show the existence of a dynamic "phyto-cultural" scenario in the Utuado-Caguana region. This is the first time that several of these plants have been identified for late pre-Columbian contexts in Puerto Rico.

Los Muertos Cave (SR-1) is a nonresidential site, whose most overt functions relate to religious activities having to do with burial and postburial rituals and/or ceremonies related to the numinous petroglyphs (Oliver 2005; Oliver and Narganes Storde 2005). The preliminary archaeobotanical data (Table 11.2, Figure 11.3) indicate that the three sampled tools were utilized to process *Zamia; guáyiga,* or *marunguey* (*Zamia amblyphyllidia*); maize, or *maíz* (*Zea mays*); sweet potatoes, or *batata; boniato* (*Ipomoea batatas*); yams, or *ñame* (*Dioscorea* sp., possibly domesticated); *lerén* (*Calathea allouia*); *yautía* (*Xanthosoma* sp., possibly two spe-

Table 11.2. Total Distribution of the Identified Taxa from Lithic Implements at Cueva de Los Muertos (SR-1).

Taxa/ Artifact	Artifact 1 Concavity	Artifact 1 Faceted section	Artifact 1 Lateral facet	Artifact 2 Concavity	Artifact 3 pecked surface	Peripheral sediment Artifact 1	Peripheral sediment Artifact 2	Peripheral sediment Artifact 3	Total grains	Ubiquity[1] (%)
Zamia amblyphyllidia	19	1				4	1	1	26	62.5%
cf. *Zamia* sp.		1					1		2	25%
Zamia sp.	1					2			3	25%
Calathea allouia	4			1	2				7	37.5%
cf. *Calathea allouia*		1			1				2	25%
Zea mays				2	2	2	5	1	12	62.5%
cf. *Zea mays*	1		1	1		2	1		6	62.5%
cf. *Xanthosoma undipes*	1	8			2	ca. 480 cluster in cellulosic tissue			ca. 491	50%
Xanthosoma sagittifolium	1				2				3	25%
Ipomoea batatas						2		2	4	25%
cf. *Ipomoea batatas*			1			1			2	25%
cf. *Ipomoea* sp.						1			1	12.5%
Manihot esculenta				1	3				4	25%
cf. *Manihot esculenta*		4						1	5	25%
Dioscorea sp. (poss. domestic)			1						1	12.5%
cf. *Acrocomia media*		1			1				2	25%
cf. *Bixa orellana*					1				1	12.5%

Fabaceae					2	6	1	1	10	50%
Phaseolus vulgaris						1			1	12.5%
Maranta arundinacea							1	2	3	25%
Not identified	1	5	0	0	1	1	0	0	8	—
Total grains	28	21	3	5	17	ca. 502	10	8	ca. 594	
Species richness[2]	4	1	1	3	5	5	2	5	—	—

[1] The ubiquity in Table 11.2 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 simples are excluded.

Table 11.3. Total Distribution of the Identified Taxa from Lithic Implements at Vega de Nelo Vargas (Utu-27).

Taxa /Artifact	Artifact 4 Concavity 1	Artifact 4 Concavity 2	Artifact 4 Faceted surface	Artifact 5 Concavity	Artifact 6 Faceted surface	Artifact 7 Faceted surface	Peripheral sediment Artifact 4	Total grains	Ubiquity[1] (%)
Zea mays			4		1		2	7	42.86%
cf. *Zea mays*					1	1		2	28.57%
Fabaceae			1		1	4		6	42.86%
Zamia amblyphyl.	1		1					2	28.57%
Zamia sp.				11				11	14.29%
cf. *Zamia* sp.						3		3	14.29%
cf. *Xanthosoma undipes*				ca. 331				ca. 331	14.29%
Xanthosoma sagittif.	2			2				4	28.57%
cf. *Manihot esculenta*			1					1	14.29%
cf. *Ipomoea batatas*				1				1	14.29%
Dioscorea sp. (wild)			1					1	14.29%
cf. *Canavalia* sp.							1	1	14.29%
Canna cf. *indica*					Fragments (MN = 4 starches)			4	14.29%
Not identified	1	—	0	0	0	0	1	2	—
Total grains	4	0	8	ca. 345	7	8	4	ca. 376	—
Species richness[2]	2	0	4	2	3	1	1	—	—

[1] The ubiquity in Table 11.3 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.

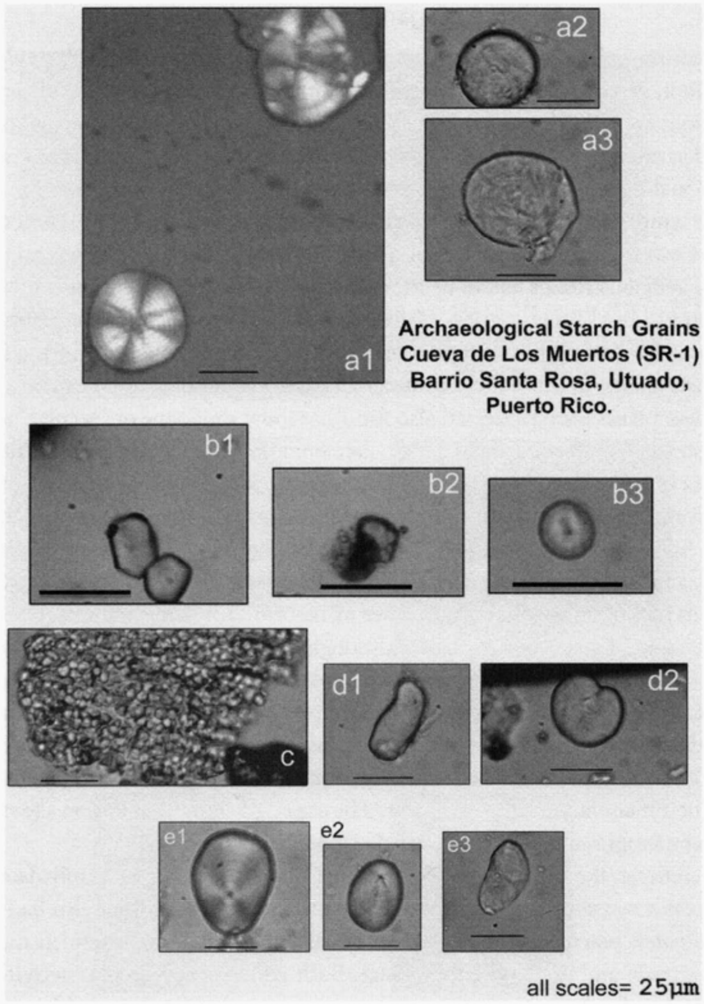

Figure 11.3. Archaeological starch grains from Cueva de Los Muertos site. a: *Zamia amblyphyllidia*. Starch grains show symmetric lamellae and extinction crosses. Image a1 is taken in a bright field and cross-polarized light. Images a2 and a3 were taken with a white nonpolarized light. b: *Zea mays*. Starch grains of maize with a central hilum visible in images b1 and b2, and possibly evincing two different maize sources (soft and hard endosperms). All images were taken with a white nonpolarized light. c: cf. *Xanthosoma undipes*. Starch grains show as a cluster in a cellulosic tissue. Image was taken with a white nonpolarized light. d: *Disocorea* sp. Starch grains from a possibly domesticated yam shown in image d1, and *Phaseolus vulgaris* in image d2. Both show concentric lamellae. Both images were taken with a white nonpolarized light. e: *Maranta arundinacea*. Starch gains show concentric lamellae and eccentric open hilum (images e1, e2). All images were taken with a white nonpolarized light.

cies); corozo palm seeds (*Acrocomia media*); beans, or *frijol* (*Phaseolus vulgaris*); arrowroot, or *yuquilla* (*Maranta arundinacea*); manioc; and the seeds of *annatto*, or *achiote*, *bija* (*Bixa orellana*) for red pigment. This suite of economic plants (and their derivates) would seem to have two possible areas of significance: one as a nutritional/dietary resource and the other as a ritual/religious resource.

The temptation is to assume that at Los Muertos Cave the principal objective of visitors was to conduct activities of a religious nature. Certainly, at several points in time religious rituals had to be the main focus of activity, when the individuals were laid to rest (funerary rites). It is reasonable to hypothesize that plants were processed for consumption (foods) or other uses (*achiote* colorant) during funerary feasts and/or in subsequent commemorative celebrations. But it can be argued that these plants were processed also for other more mundane or "secular" activities instead of, or in addition to, religious ceremonies. One should consider that the starches in these implements do not provide any clues as to how they might have been prepared into different kinds of meals or point to the ways in which they might have been displayed, served, distributed, or employed. Whether religious or not, and unlike other burial cave sites (Oliver and Narganes Storde 2005), Los Muertos has an unusually high number of metavolcanic tools manufactured and used in situ to process edible plants. Although only three tools have been analyzed for starch content, there are many more implements of similar morphologies and use-wear characteristics that point to plant processing (and tool manufacture) as a significant activity, and also point to the cost of transporting (heavy) stones uphill from the Pasto Creek. The frequency of metavolcanic implements and detritus from their manufacturing process would be expected from a habitation site such as at the contemporaneous site of Finca de Doña Rosa (Utu-44).

By contrast, the Vega de Nelo Vargas site (Table 11.3, Fig. 11.4), firmly dated between cal A.D. 1280–1430, is primarily a farmstead settlement that also had a domestic *batey*, where periodic religious rituals, civic ceremonies, and feasts (including trade and exchange) took place. Both religious and secular activities, in the context of a domestic (residential) environment, have to be considered in regarding the use of the suite of economic plants identified (Table 11.3, Figure 11.4): *Zamia*, maize, beans, *yautía*, sweet potatoes, wild yams, and the *gruya* or *achira* (*Canna indica*, a root crop), the latter showing up only in Artifact 7 recovered from the midden. The plants processed by the four implements reflect everyday food preparation activities as much as the confection of particular meals for religious ceremonies or civic (public) events conducted in the farmstead.

The tool and starch sample, of course, is too small to execute a balanced comparison between the two sites (Tables 11.2 and 11.3) or to make any solid inferences between the sites. Nevertheless, on the basis of the analysis of the ubiquity of the taxa of the studied tools, it is possible to sketch two distinct scenarios. Since the local landscape, implements, and native population can be invested with meanings

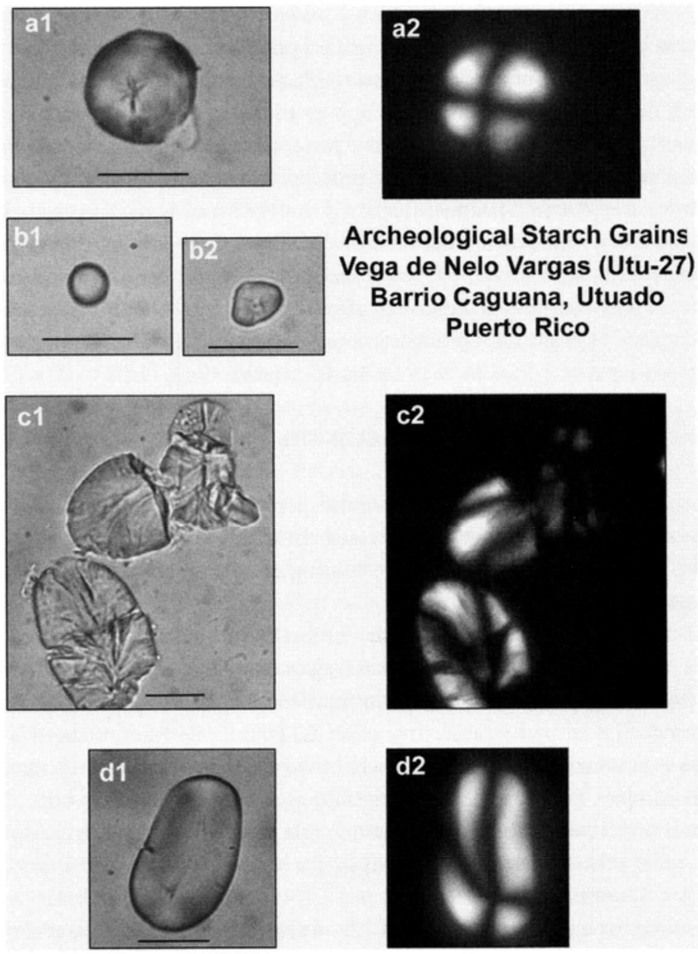

Figure 11.4. Archaeological starch grains from Vega de Nelo Vargas site. a: *Zamia amblyphyllidia.* Starch grains show asymmetric lamellae and diagnostic central stellate fissure. Image a1 is taken with a white nonpolarized light. Image a2 is the same as a1, but taken in a dark field and cross-polarized light. b: *Zea mays.* Starch grain from possibly two different maize sources (soft and hard endosperm); the grain in image b2 has a central open hilum. Both images (b1, b2) were taken with a bright nonpolarized light. c: *Canna* cf. *indica.* Damaged and fragmented gruya starch grains. Both images are the same, but c1 is taken with a white nonpolarized light while c2 is taken in a dark field with cross-polarized light. d: *Dioscorea* sp. (wild). The starch grain shows eccentric linear fissures. Both images are the same, but d1 is taken with a white nonpolarized light while d2 is rotated and taken in a dark field with cross-polarized light (cf. Pagán Jiménez et al. 2005:Figure 3c).

through social interactions to which they were integrated (Gosden and Marshall 1999), it is viable to think that the identified plants, and the resulting end products, would have different meanings as a result of the varying social environments in which they were utilized, as would appear to be the case of the two sites here considered. The lithic implements do not present use histories that would indicate a particular, specialized plant-specific processing function. Rather, the artifacts' wear patterns and starch residues displayed multiple functions: they were used to macerate tubers, roots, corns, and tuberous trunks and, as well, used to grind mature green seeds. The identified plants can provide opportunities to discuss the production processes they represent, to offer insights about the subsistence system that furnished the raw plant products at each site, and to inform about the intra- and interregional and diachronic plant-human interactions.

Discussion

For reasons of space we will concentrate the discussion on the relative importance of some of the identified plants, which contrast with the accepted general perception that dominates the current understanding of subsistence strategies deployed by the natives of the Greater Antilles.

Even though several early Spanish chroniclers (e.g., Las Casas 1909) commented on the existence of several distinct agricultural systems, and on their floral components, there is no certainty about how these systems operated in different areas, much less in prehispanic time periods. Despite its limitations, this study suggests a tantalizingly different scenario than that contemplated by many Caribbean scholars. For example, the high ubiquity of *Zamia* starch in both sites alludes to a much more prominent economic role for this plant in nurturing societies, including those with more complex forms of sociopolitical organization (i.e., *cacicazgos;* Curet 2003).

The range of tuberous and seed plants obtained from the tools analyzed here are indicative of a broad spectrum of potentially high-yield food plants, countering the Spanish colonial insistence that the Taíno staples were manioc and *ajes* (varieties of sweet potato). The varied floral assemblage deduced from lithic implements points to the underlying complexity of both the productive and nutritional systems in operation in Puerto Rico.

On the basis of the identified plants, we suggest a continuity in some of the culinary practices that extends from the Archaic period until the end of the fifteenth century (Newsom and Wing 2004; Pagán Jiménez et al. 2005). The presence of starch grains of *zamia,* maize, beans, sweet potato, yam, *gruya* (*achira*), *yautía,* manioc, and *corozo* (a palm seed) in the Ostiones and Capá (A.D. 700–1450) contexts are most revealing. Other plants, like arrowroot and *lerén* (a root crop), have been identified by Pagán Jiménez (2005b) for the Huecoid tradition (ca. 200 B.C.

onward) of Puerto Rico and Vieques (see Figure 11.1), which refutes Sturtevant's (1969) argument that the introduction of arrowroot (*Maranta arundinacea*) occurred during the European contact period (Rodríguez Suárez and Pagán Jiménez this volume).

Using other techniques besides starch residue (De France and Newsom 2005; Newsom and Wing 2004), several other plants, such as *annatto,* or *achiote,* have been documented for sites of exclusively "Taíno" (A.D. 1250–1500) affiliation. The use of maize, which until very recently was deemed of little agro-economic or nutritional consequence, seems now to have played a more prominent dietary role. Newsom and Deagan (1994) and Deagan (2004) have suggested the social and ritual importance of maize as an elite-controlled plant at the protohistoric Taíno site of En Bas Saline, Haiti. But maize, while controlled by elites is, nonetheless, still regarded as a minor component in the overall diet at En Bas Saline.

Starch grain evidence indicative of maize cultivation now appears to have had an early presence and ubiquity in Puerto Rico, as attested at the Archaic sites of Maruca on Puerto Rico and Puerto Ferro on Vieques Island. While its presence alone is insufficient to propose maize as a staple diet, the consistency with which its starch grains has been detected in stone implements in Puerto Rico from the Archaic onward, and in clay griddles from Cuba (Macambo II and Laguna de Limones), calls for caution (Pagán Jiménez 2005b; Rodríguez Suárez and Pagán Jiménez this volume). The presence of maize starch in a burial cave (SR-1), in a dispersed farmstead (Utu-27), in the villages of Macambo II and Laguna de Limones, and the large nucleated En Bas Saline village of chief (presumably) Guacanagarí, also suggest a wider range of social contexts in which maize was processed and consumed.

Manioc, still regarded to be *the* staple "supercrop" that underpinned the development of complex societies (*cacicazgos*) in the Caribbean, seems to have a lower than expected visibility in this study. That does not mean that manioc was insignificant or marginal, particularly since the lithic implements that were most likely involved in processing, such as the triangular flakes inserted on wood boards (i.e., *güayos*), are absent from the tool sample analyzed.

From the "optimal foraging" theoretical perspective among other things invoked to evaluate the changing conditions of sociocultural development as different food resources enter a diet (Keegan 1986; Oliver 2001; Piperno and Pearsall 1998), the starch evidence from the Utuado-Caguana sites and others in Puerto Rico (Pagán Jiménez 2005b) raises the question of why some of the indigenous groups in the Caribbean did not develop "sophisticated" social structures much earlier, given that a good proportion of the economic plants were available well before the process of emerging complex societies began around A.D. 900.

Given the available information, it seems plausible to think that the changes that resulted in the social and organizational complexity of the Taíno populations would have more to do with the "optimization" of the "operative chain" of the systems of production and redistribution (with their implications in the different sociocultural spheres), than with the specific plants that are considered high yield, such as manioc or maize. In this regard, and considering the aggregate value that *Zamia* spp. had—as a carbohydrate and also a protein source (Las Casas 1909)—it is notable the high esteem that the meals prepared from this tuberous had. Las Casas (1909) described that since *Zamia* contains lethal toxins (analogous to bitter manioc) insect larvae were added and encouraged by the natives to nest and develop in the grated pulp mass (dough) and thus fulfill their role in eradicating these toxins (Veloz Maggiolo 1980:89, 1992, 1996:101–114). The presence of larvae in the rich carbohydrate dough may have positively favored the intensification of this endogenous plant over that of other plants with high protein value, like maize, legumes. Although an educated guess, because the effects and technological means of neutralizing the toxicity of the endogenous *Zamia* must have been well understood by Archaic times (as evidenced at Puerto Ferro, Vieques, and El Porvenir sites) this knowledge may well also have readily predisposed Archaic societies to adopt and incorporate the exogenous and likewise toxic manioc plant.

The Reliability and Confidence of Starch Grain Analysis

The presence of archaeological starch grains in the lithic implements studied has led to skepticism on the level of confidence placed on this method; namely, that: (a) the starch morphology cannot be a secure source to ascribe a taxon (taxonomic viability); (b) the recovered starch grains are not representative of all the plants processed by the tools (preservation); and (c) the starch present in the tools may be incidental or intrusive and adhered to the tool during or after they processed plant (pedology, soil contamination). For quite some time, experts in microbotany have determined that the starch coming from different sources exhibits sufficient morphological and bidimensional traits that allow their taxonomic differentiation (e.g., Banks and Greenwood 1975; Bello and Paredes 1999; Buléon et al. 1998; Cortella and Pochettino 1994; Reichert 1913). We have assembled a comparative reference botanical that is sufficiently detailed (using 12 metric and morphological variables) to allow us to establish the diagnostic traits of the different groups of starches (e.g., Pagán Jiménez 2005b).

Researchers like Haslam (2004) have demonstrated that the molecular variation in starch has a direct relationship to the differential preservation of one over another starch grain. Therefore, we think it is possible that the analyzed starch grains represent a limited range of the full spectrum of processed plants. Nevertheless, the starch grains that have been recovered were found in the tools precisely because while processing plants, starch grains were embedded in the tools.

In contrast to other microbotanical remains, starch does not participate in the natural processes of dispersion, similar to pollen "rain" or the integration of phytoliths into the sediments. In the case of pollen, "rain" is a natural mechanism of plants to insure species diversity during reproduction, while for phytoliths it is the result of the mineral acquisition and remodeling on the part of the plant and its eventual disposal into the soil due to the decomposition of the organism. Starch, however, is produced within the plants from the polymerization of glucose residues during photosynthesis. Hence, these are subcellular bodies (grains) that remain in the interior of the plant. During their natural growth process, the plant uses the starches to fulfill determined processes of development. In this process the starch undergoes, through oxidation, a transformation into carbon dioxide and water. In their natural state plants do not deposit starch in the soil, or become airborne, or disperse through other mechanisms. Starch grains could only reach the soil if they are intentionally liberated from the plant's organs by exogenous mechanisms, such as human or animal interventions, or as a consequence of natural "accidents" (e.g., a plant squashed by rock-fall). Even when such events occurred, Therin's (1998) study demonstrated how insignificant the dispersal of starch is in different types of sediment regimes and under different mechanical (force) conditions. Ultimately, some starch specialists (e.g., Fullagar et al. 1998; Pearsall et al. 2004; Perry 2004) argue that the presence of these residues (outside the tools) is due to various reasons: the contamination of the sediments on the part of the tools themselves and the contamination of the soils as a result of the intentional processing of plant sources over or on a particular surface of a terrain.

Final Remarks

An examination of Tables 11.3 and 11.4 shows the relative importance that *Zamia*, maize, legumes, and *yautía* processing had, along with the presence of a fairly broad range of edible cultivars. The data minimally account for which kinds of plants were indeed gathered or cultivated during two consequent periods of human occupation and processed in two different kinds of sites. That *Zamia*, maize, and beans turn out to be so preponderant at both sites may well be a function of our limited tool sample (size, type). The differences in plants between the two sites cannot be taken as representative of the full range of plant-human interactions and plant processing activities at either. This study is an initial effort in testing whether starch grains were present and identifiable from processing tools. Our initial results provide an avenue for further fruitful research to complement other archaeobotanical methods. Starch residue analysis remains the one method that allows a direct plant-use (via implements) correlation. The next phase would be to assemble a larger and statistically meaningful tool sample that encompasses a fuller range of artifacts and from a wider variety of contexts amenable for interpreting the social behaviors involved in plant preparation.

Table 11.4. Comparative Summary of Total Starch Grains and Ubiquity per Taxa.

Taxa/Site	LOS MUERTOS CAVE ca. A.D. 680–1190 Total number of grains *Ubiquity %* (ubiquity within 8 point samples)		VEGA DE NELO VARGAS cal. A.D. 1280–1430 Total number of grains *Ubiquity %* (ubiquity within 7 point samples)	
Zea mays	12	*62.5*	7	*42.86*
cf. *Zea mays*	6	*62.5*	2	*28.57*
Phaseolus vulgaris	1	*12.5*		
Fabaceae	10	*50.0*	6	*42.86*
cf. *Canavalia* sp.			1	*14.29*
Zamia amblyphyllidia	26	*62.5*	2	*28.57*
cf. *Zamia* sp.	2	*25.0*	3	14.29
Zamia sp.	3	*25.0*	11	14.29
cf. *Xanthosoma undipes*	~491	*50.0*	~331	14.29
Xanthosoma sagittifolium	3	*25.0*	4	28.57
Ipomoea batatas	4	*25.0*		
cf. *Ipomoea batatas*	2	*25.0*	1	14.29
cf. *Ipomoea* sp.	1	*12.5*		
Manihot esculenta	4	*25.0*		
cf. *Manihot esculenta*	5	*25.0*	1	14.29
Calathea allouia	7	37.5		
cf. *Calathea allouia*	2	*25.0*		
Canna cf. *indica*			4 (MN fragments)	14.29

Dioscorea sp. (pos. domest.)	1	12.5		
Dioscorea sp. (wild)			1	14.29
Maranta arundinacea	3	*25.0*		
cf. *Acrocomia media*	2	*25.0*		
Non-edible/industrial				
cf. *Bixa orellana*	1	*12.5*		
Not identified	8		2	
Total grains	~594		≈376	
Species richness per site	11		8	

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