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UNMASKING AN ARTIFACT TECHNOLOGY: TEXTILE-CLAY COMPOSITES FROM ANCIENT MESOAMERICA

Harriet F. Beaubien

I. Introduction

Two sites in the Petexbatún region of the Petén in lowland Guatemala have recently yielded fragments of an artifact material type that has not been previously documented in the Maya archaeological literature. In 1993, several "sherds" were excavated at Las Pacayas from unstratified ceremonial deposits in a cave underlying the site's center, called Cueva de los Quetzales (Fig. 1; Brady and Rodas 1995). The deposits range in date from the Late Preclassic to the Late Classic Maya period (before AD 250 to AD 900). Although not conjoining and too few to determine artifact form, the three Las Pacayas fragments were the first to provide analytical results that suggested the use of a composite material, in research carried out at the Smithsonian Institution's Conservation Analytical Laboratory (now the Smithsonian Center for Materials Research and Education [SCMRE]; Kaplan 1994).

In 1998, excavations at Aguateca yielded significant fragment clusters of a similar material (Inomata et al. 1998). These were part of fragmented, burned but otherwise undisturbed floor assemblages from a probable royal palace located in the site's elite center. The destruction event which ended Aguateca's occupation has been dated to the Late Classic period (around AD 800). The Aguateca fragments, analysis of which has expanded our understanding of this material (Shah 2000a), have additionally provided information about artifact forms (Fig. 2). Conservation involvement from the time of excavation and during all subsequent processing has contributed to their identification [1]; two of the skillfully crafted objects appear to be a mask and possible headdress elements.

Although there are differences in appearance, both the Las Pacayas and Aguateca fragments are composed of multiple layers of woven textile embedded in a clay matrix, based on careful examination and materials analysis [Kaplan 1994; Shah 2000a; Beaubien and Kaplan (in press)] (Figs. 3, 4). In the absence of later ethnohistorical information and other excavated examples, little else is known about this unusual material beyond what can be inferred from the analyses. Because of these limits, replication studies carried out in the laboratory have proven to be particularly useful in developing and testing hypotheses about how the composites were assembled and shaped into objects. The results of these studies are the focus of this paper.

II. Background Information on Composites

The term "composite" best describes the material from which the Petexbatún objects were made, and modern industrial practice provides a useful framework for examining aspects of fabrication. A composite is defined as the material that results from the synthetic assembly of two or more materials (Rosato 1982). These are typically a filler, which functions as the principal reinforcing or load bearing element, and a matrix or binder, in which the filler is embedded and which provides overall support and protection. The composite's characteristic format is a layered arrangement of filler in matrix, termed a lamina as a single layer or a laminate when several of these are stacked, often with changing orientations and usually bound together with the same matrix material as is used in the individual laminae (Jones 1975).

Composites are typically assembled and the end-product fabricated in the same process. This process is called lay-up, which can be done by hand, using sprays, by injection, etc. All of these methods require a mold, which enables a specific shape to be formed and supported during curing of the composite. The molds can be open forms (either convex or concave) or closed. In modern practice the side in contact with the mold is meant to be a finished surface; a parting agent is necessary and pigments or other surface finishes are usually incorporated in it (Wittman and Shook 1982; Hancox 1983). An enormous variety has been tailored industrially, and many are characterized by high structural efficiency, exceptional strength and light weight (Rosato 1982; Jones 1975). Examples include laminated fiber-reinforced plastics for helicopter blades and many aerospace applications, cast materials for setting broken limbs, fabrics for air mattresses, tennis rackets, etc.

There are several noteworthy antecedents to these modern composites. Light-weight sturdy objects, such as globes, were mass-produced in the 19th century using *papier-mâché*. Paper pulp or paper sheet, saturated in various glues and drying oils, was built up in thin layers on a mold and then decoratively finished once dried (van der Reyden 1986). In late-period Egypt, inner mummy cases were often made of *cartonnage*, a composite of linen (sometimes papyrus) soaked in gum. Layers were built up on a core ("former") of mud or straw and then finished with a layer of fine gesso plaster as a base for applied decoration or painting (Adams 1966). The previously unknown composite type used by the artisans in creating the objects excavated at Las Pacayas and Aguateca shares many aspects of production with these.

III. Fabrication of the Petexbatún Artifacts

A. Component selection

A. 1. Textile filler

Woven cloth functions as the filler in the Petexbatún composites. It is known almost entirely through imprints of individual threads and woven structures in the clay matrix, where outermost surfaces are abraded or, in cross-section at break edges, as a regular array of voids once occupied by the yarns (Figs. 3, 4). In a few instances, the Las Pacayas fragments preserve what look to be actual fibers (Fig. 5). Several of these generated Fourier Transform infrared spectra comparable to cellulosic materials (Fig. 6), although most registered a high silica content by energy-dispersive spectroscopy (EDS) analysis suggesting that the fiber structure had been replaced through a silicification process. In scanning electron microscope (SEM) images, individual fibers were too degraded to identify, but their size (~10μm diameter) suggested cotton or bast (Kaplan 1994).

Both Las Pacayas and Aguateca textiles utilized Z-spun threads (Fig. 5). The predominant yarn diameter is about 0.5-0.75mm, although both thicker and finer yarns also occur. Aguateca textiles are primarily variations of plain weaves, but one possible twill weave may be present. These were studied easily using polyvinyl siloxane casts taken from impressions in the clay matrix of approximately twenty fragments (Shah 2000a)[2]. The plain weaves are primarily balanced types of several densities. Most common are an open variety at ~6 x 8 threads per cm (Fig. 7a) and an intermediate variety at ~11 x 12 threads per cm (Fig. 7b); one example of a fine variety, at ~17 x 20 threads per cm, was noted. Warp- or weft-faced plain weaves (at ~6 x 15 threads per cm) are also common (Fig. 7c). All Las Pacayas textiles, studied from impressions in the clay matrix, are plain woven with paired yarns in one of the directions (at ~8 single x 12 paired threads per cm) (Fig. 7d) (Kaplan 1994).

To explore aspects of cloth selection, replicas were made in the laboratory using modern textiles of various fiber types and weave densities, including a fine cotton cheesecloth, various densities of plain woven fabric in cotton, linen and agave, and a coarse burlap (Fig. 8a). Pieces measuring several centimeters in each dimension were dipped in a clay slip and stacked in three or four layers on a wooden surface [3]. Samples in one group were manipulated into folds to see how the fabrics responded. All cotton fabrics proved malleable and responsive to shaping, while linen and particularly agave and burlap fabrics remained stiff.

Using a woven textile as filler offered the artisan several advantages, notably a thin unified structure and an ability to drape. While various plant fibers, such as cotton and agave, were available to the Maya for cloth production, the results from replication argue for cotton as the cloth fiber used, at least in the case of the Aguateca mask.

A. 2. Clay matrix

Elemental analyses by EDS on small samples from the Las Pacayas fragments produced a profile that would be expected of clays, with prominent silicon and aluminum, and smaller amounts of calcium, magnesium, potassium and iron (Fig. 9); these were similar to EDS results obtained on an Aguateca sample (Kaplan 1994; Shah 2000a). SEM images of several Las Pacayas samples showed a glassy material with fused particles, typical of a fired ceramic (Fig. 10), although x-ray diffraction analysis also suggested the presence of some unfired clay (Kaplan 1994).

The colors exhibited by fragments from both sites were typical of ceramic, ranging from orange to black. The notable exceptions were internal layers of Las Pacayas fragments, visible in freshly cut cross-sectional surfaces; these appeared white, becoming black where adjacent to textile voids (Fig. 11). After a sample was heated, however, these color differences disappeared: at 700°C the layers began changing color, becoming a uniform orange terra-cotta color at 850°C in an oxidizing environment (Kaplan 1994). This supports the identification of the matrix as a clay. The matrix in samples from both sites appears homogeneous and fine-textured, suggesting use of a well-levigated slip. Replicas produced with an unmodified slip made from fine clay exhibited a smooth-textured surface that reflected the topography of the underlying textile weave, and produced clear textile imprints, similar to features of original samples (Fig. 8a).

B. Composite assembly

Although the Las Pacayas fragments are notably thicker than those from Aguateca (up to 1 cm vs. 1-2 millimeters, respectively), the composite assembly appears to be the same. In cross-section, the clay layers are relatively regular in thickness and closely follow the contours of the cloth (Figs. 4, 11). The laminate is well-melded, with no separations apparent within the clay layers or evidence of delamination at the textile surfaces. These features suggest that the textile pieces were coated in slip first before layering, creating even clay layers that fused during assembly. Comparable results were obtained by replicas made in this manner. Those made by first layering dry or water-wetted cloth pieces, and then applying slip, produced irregular clay layers. Folded shapes collapsed, unless textile pieces were pre-coated in slip to provide necessary support.

Laminate cohesiveness appears to have been affected by other aspects of the cloth. Those replicas that exhibited delamination problems during subsequent handling were made with burlap, where the fabric was too thick relative to the slip layer, or with fabrics whose weave was much tighter than that of documented imprints (Fig. 8b). Sound laminates were produced by a good quality cheesecloth whose weave density fell within the ranges measured on original pieces, although the individual threads were thinner.

Applying replication results to the Petexbatún composites, cotton was the most likely fiber used, and as a textile, provided an effective way to create thin sculptural forms, offering ample surface area to distribute the shrinkage stresses that the clay slip would develop during drying. The relative openness of the handwoven structure permitted the clay slip to penetrate from one side to the other, and wet-on-wet application of individual layers resulted in an effective laminate.

C. Artifact shaping

The Petexbatún composites would have required a form (or mold) to support the textile-clay layers as they were built up and until they had dried. Several aspects of the Aguateca mask proved useful in hypothesizing how the layering process progressed and the type of mold used. In general, fragment interiors tended to show more loss of the surface clay layer than the exteriors. In replicas formed with both concave and convex molds, this feature was noted on the side in contact with the mold surface; the exposed surface, where slip tended to pool, retained an undisturbed clay layer. This suggests that the interior was the side in contact with the mold, based on surface disruption; if so, then fine striations preserved in surviving surface slip may be impressions from the mold itself (Fig. 12). Because these features were noted on concave surfaces, this argues for use of a convex mold, possibly made of wood.

Replication supported this hypothesis with respect to another notable aspect of the Aguateca mask. The exterior topography is more complex than that of the interior, with elaborate folding patterns particularly around the eyes (Figs. 13a, 13b). A concave molding process would have required initial production of the artifact shape as a negative. To investigate this approach, similar shapes were modeled in plasticene, then cast in plaster; slip-dipped textile layers were tamped into the plaster mold and allowed to dry (Fig. 14). The resulting shapes on the exterior surface had neither the dimensional folded quality nor the weave distortion apparent on the Aguateca mask (refer to Figs. 2, 13b). These features were produced more easily in replicas built on convex forms, where folds could be freely formed in the exposed outer surface (Fig. 15).

While concave molds are known to have been used in the production of ceramic figurines, these objects do not have the sculptural quality seen in the mask. The indications of a convex mold are more convincing. It would have been relatively easy to carve a simple convex shape in wood, and layer the composite from inside to outside. Folded shapes and grooves could then have been freely worked into the still wet outermost layers.

D. Finishing

Some of the details seen in the Aguateca mask were not successfully reproduced as part of initial shaping. Eye openings, created by folding separate textile pieces to form upper and lower rims, bulged awkwardly and the surrounding mask surface was marred by the patchwork effect of the textile pieces beneath the clay layer. Tucking or aligning textile edges still produced messy outer borders that contrasted with the smooth lines of the original.

Instead, it became clear during replication that these details could be made as a finishing step once the composite had dried. Removed from the mold in a leather-hard state, the replicas could be handled quite easily. The thinness of the laminate, the pliable textile and the weak dry slip allowed edges to be scissor-cut (Figs. 16a, 16b). Cracks and sharp edges that occurred during this process were easily reintegrated and rounded with a brush wetted with either water or more slip. Eye holes were cut out of plain areas, and the edges rewetted and folded inward to form rims. Circular perforations, seen near the edges of the mask were made with an awl and then neatened by rewetting. At this stage, lean surfaces were easily repaired with the addition of more slip, as long as not too much was wetted up at once. This suggests an alternate explanation for the fine striations on the Aguateca fragment reverses; these may be brush marks from the reapplication of slip to the surface potentially abraded by contact with the mold. The comparability of results achieved in these replicas with details seen in the mask strongly suggests that the artisan, using appropriate tools, created the eye openings and trimmed the mask's edges once it had dried.

The final finishing step was the application of color. The exterior surface of the mask has a red pigmented slip, visible in cross-section as a thin layer (Fig. 17). EDS results indicate an iron-bearing compound, such as hematite [Shah 2000a]. Some of the decorative grooves appear to have been scored into the surface after this last colored slip was applied.

E. Hardening with heat

Tests carried out on Las Pacayas samples indicated that the clay matrix most resembled a fired ceramic, from physical properties such as hardness, ability to withstand immersion in water, and inertness to solvent and acid wetting (Kaplan 1994), as well microstructural information from SEM (Fig. 10); the material's lighter weight, compared with conventional ceramics, is due to porosity from the burnt-out textile layers. The Aguateca matrix was even more clearly a fired ceramic. Unfortunately, depositional events at both sites prevent our ability to say with certainty that heat-hardening occurred as a stage of fabrication. The Las Pacayas material may have been burned as part of ritual activity, and the Aguateca material was subjected to a devastating fire from an attack on the site's core. Until additional composite samples are located for which use-related or post-depositional heating can be eliminated, then the specifics of heat-hardening as a stage of manufacture remain conjectural.

In order to evaluate how heating might have affected the components and laminate structure, replicas were heated in an oven from temperatures of 350° to over 1150°C, at 100°C increments (Fig. 18). Fibers were charred by 350°C but detectable in some samples heated to 450°C. Samples up to this point disaggregated when wetted with water. Above this temperature, fibers disappeared coinciding with the point at which greatest weight loss occurred. Samples still showed some water-sensitivity at temperatures of 600°C; but above that, the clay became sufficiently sintered to remain intact.

In contrast to the earlier stages of its manufacture, the fired product (both original and replica) cannot be considered a composite, since the textile component was no longer present to contribute structural reinforcement. Ultimately the material's properties were a function of the surviving clay network. As the replicas demonstrated, once heat exposure began degrading the fibers, weaknesses in the laminate structure (such as those noted in Section III.B) were exacerbated. For example, delamination occurred along the planes of now-disintegrated textile layers wherever there were insufficient interlayer clay links, a problem resulting from tightly woven fabrics (Fig. 8b). This was rarely noted in the archaeological examples, where the looser handweaves permitted formation of a good clay network.

In order for such a composite material to be practical for use, I do think that the artifacts were deliberately heat-hardened as a final stage of manufacture. My working hypothesis is that the composite was processed as ceramics from the Petén region would have been, that is, fired in pits to temperatures up to approximately 650°C (Rice 1985; Bishop 2000); uneven firing environments would not be unusual and might account for color differences and rare fiber evidence.

IV. Conclusion

The skillful manipulation of textile and clay that the Petexbatún artifacts display is a good indication that they were the product of a well-developed technique. The composite's presence in ceremonial contexts and, as demonstrated by the Aguateca finds, specific use in making ceremonial gear are noteworthy. From a material standpoint, it would have been a highly suitable choice for making such items: easily shaped, rigid and water-resistant, yet lightweight enough to be worn for periods of time. The modern craft practice of *cartonería* or *papel maché* in Mexico and Central America presents an intriguing analogue to this ancient technology, sharing similarities in fabrication and in association even today with the production of ceremonial gear (Masuoka 1994).

Unfortunately, ethnohistorical sources, such as Diego de Landa's *Relación de las Cosas de Yucatán* (Tozzer 1941), do not include references to use of a textile-clay composite. Thus far, our knowledge about it is based upon an extremely small data set. To supplement information gathered from examination and analysis, replication studies have proven to be invaluable in developing hypotheses about technological choices and about the specific production steps for these objects.

Testing these hypotheses, however, will ultimately depend on finding other excavated examples. While one might assume that the fired product would be relatively robust and thus recoverable archaeologically, even conventional ceramics have been found to be susceptible to crumbling after long-term exposure to groundwater during burial or from post-excavation washing. The fact that this textile-clay composite has only been reported in these two instances may underscore its inherent preservation issues, above and beyond rarity that may be ascribed to context and to a craft practice organized to produce unique objects rather than multiples. The delicate ceramic structure and high porosity created by degraded or fired-out textiles could easily promote a degree of disintegration beyond what similarly low-fired ceramics might experience in normal archaeological contexts. Nonetheless, it is a hope that greater awareness of the existence of this composite material will result in recognition and recovery of more examples. These may help us to unmask aspects of fabrication that remain something of a mystery.

Acknowledgments

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Endnotes

1. On site, temporary facings were applied to the fragile groups to preserve their orientation and aid in the lifting process. In the project's lab in Guatemala City, small samples were tested to determine the best methods for cleaning and consolidation. Fragments were treated with a dilute acid solution to remove accretions, followed by rinsing; Acryloid B-72 in acetone was used for consolidation and reconstruction of fragments (Beaubien et al. 1998; Beaubien and Boyer 1999; Shah 2000b).

2. Impressions were made with Coltène-Whaledent No. 4805, a polyvinyl siloxane impression compound applied through a self-mixing dispenser. Original surfaces were first protected with a dilute solution of Acryloid B-72.

3. Red Clay 103 (a cone 06 terra-cotta clay, supplied by Clayworks Supplies, Inc., Baltimore, MD) was used for the replicas.

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Figure 1. Fragments from Cueva de los Quetzales, Las Pacayas
[CQ 1-18-8, CQ 1-13-10, CQ 1-13-6].

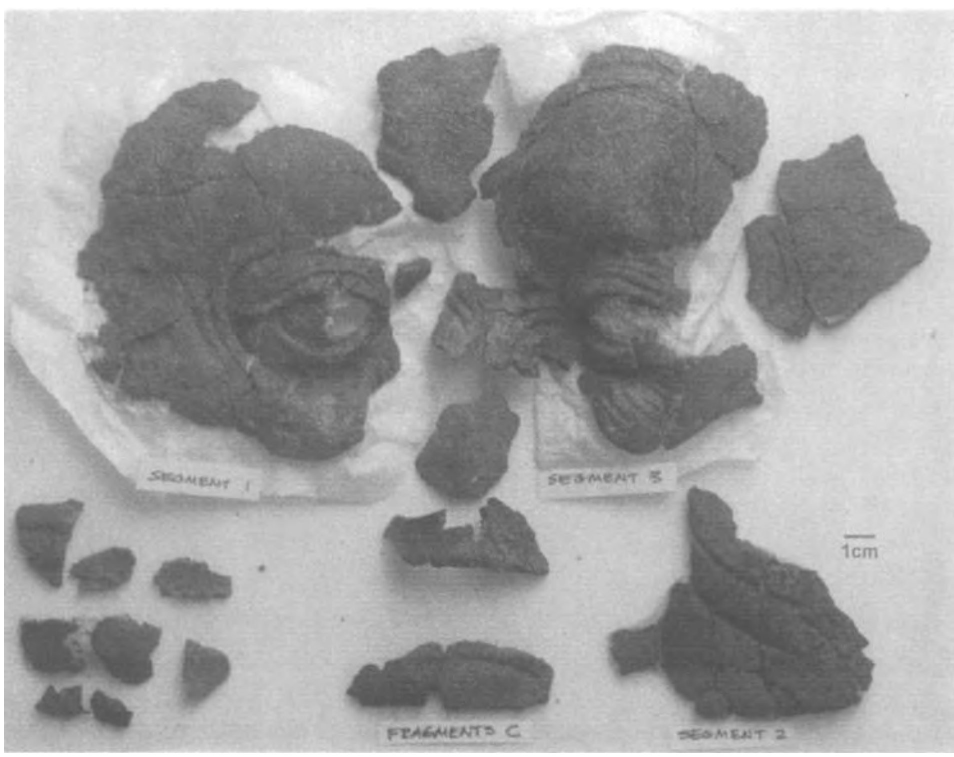


Figure 2. Mask Fragments from Aguateca [AG 22A #862].

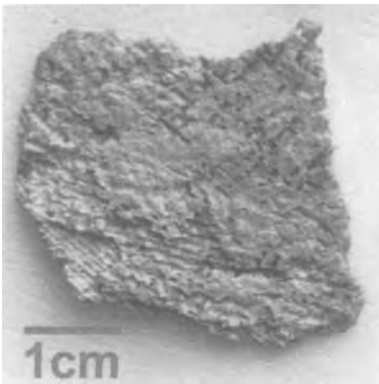


Figure 3. Interior surface showing impressions of a least three textile layers in different orientations [AG 22A #861].

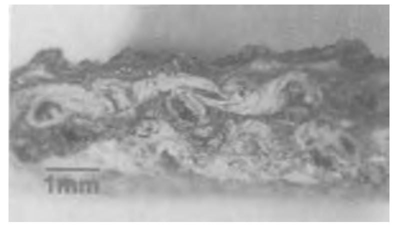


Figure 4. Laminate structure in cross-section [CQ 1-11-8].

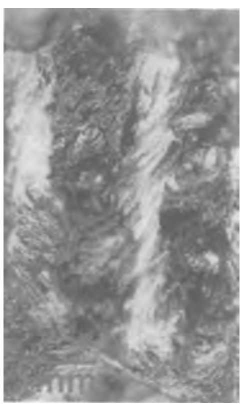


Figure 5. Z-spun thread [CQ 1-11-8].

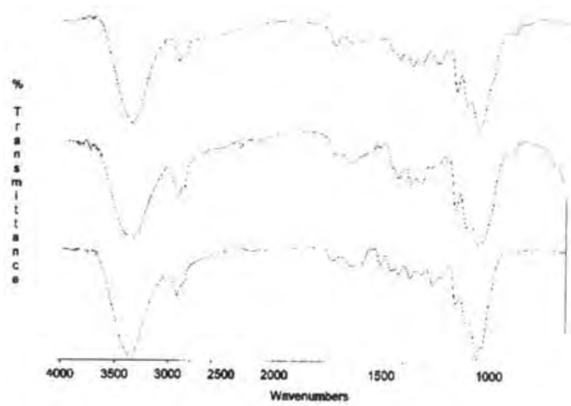
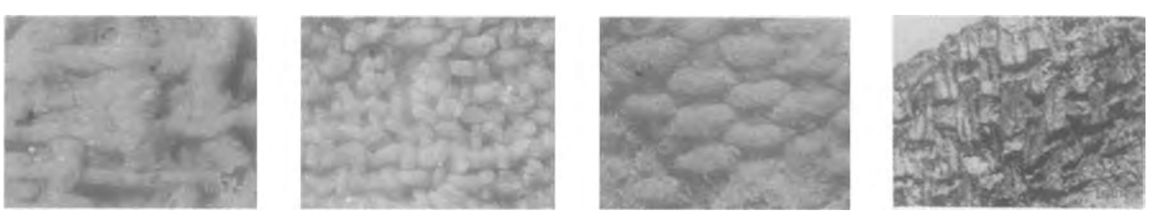
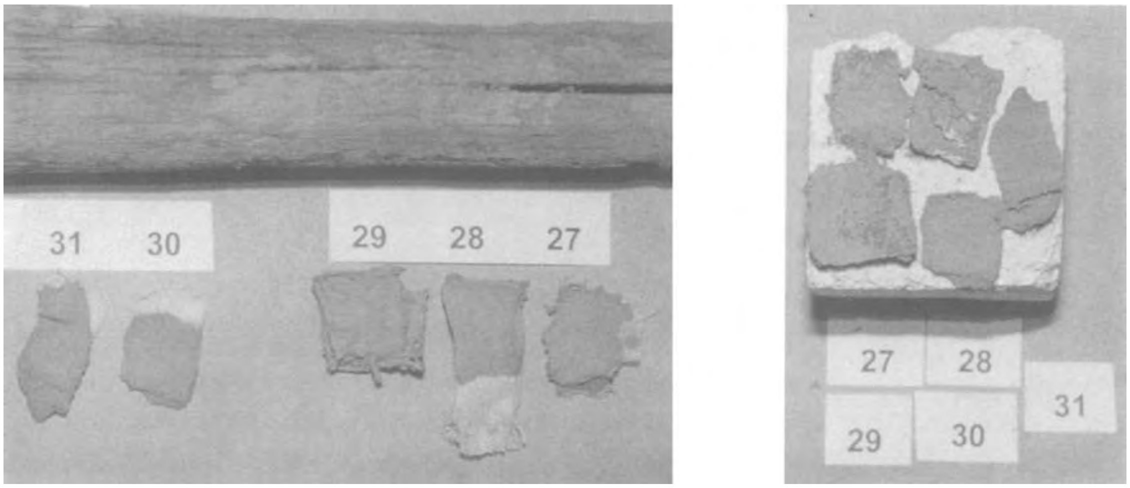


Figure 6. FTIR spectra of thread fiber (CQ 1-11-8, bottom) and comparable cellulosic materials (modern agave , top; cellulose standard, middle), indicating use of a plant fiber.



(a) (b) (c) (d)

Figure 7. (a) plain weave, open, @6x8threads/cm [AG 22A #331 cast]; (b) plain weave, @11x12 threads/cm [AG 22A #331 cast]; (c) plain weave, warp/weft faced, @6x15 threads/cm [AG 22A #331 cast]; (d) plain weave, paired warp/weft, @8x24 (12 pr) threads/cm [CQ 1-11-8].



(a) (b)

Figure 8. Replicas made with cotton cheesecloth (27, 30, 31), linen (28) and burlap (29), and with clay slip; (a) dried and removed from wodden form, and (b) after heating to650 degC. Delamination was most severe in samples 28 and 29.

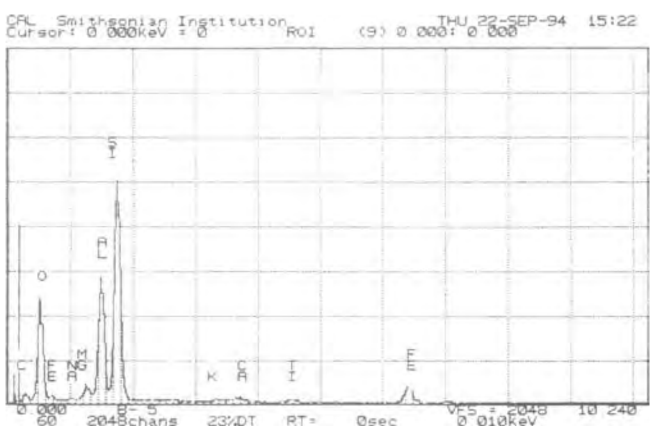


Figure 9. EDS spectrum of matrix elements, comparable to clays [CQ 1-11-8].

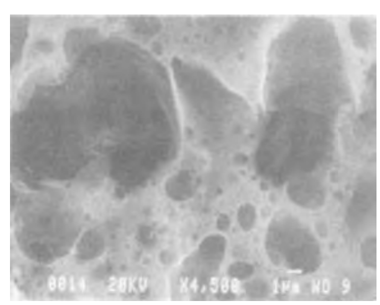


Figure 10. SEM image of glassy matrix material, comparable to fired clay [CQ 1-11-18].

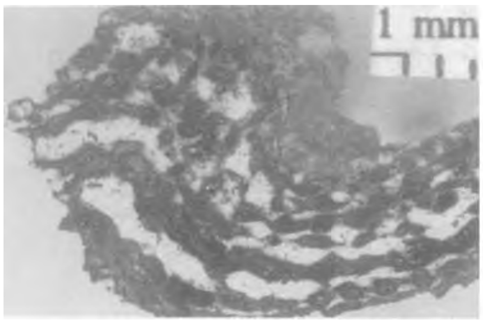


Figure 11. Well-bonded laminate structure in cross-section [CQ 1-11-8]. White matrix layers are visible in the interior.

Figure 12. Concave interior surface with striations, possibly impressions of a wooden mold [AG 22A].

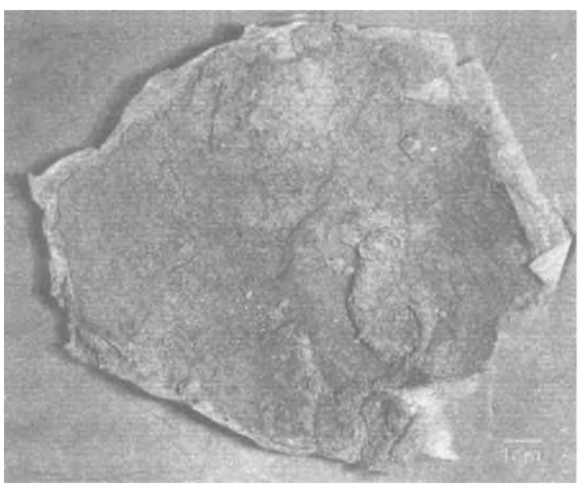


Figure 13a. Interior surface of mask fragment, concave with simple topography [AG 22A #862].

Figure 13b. Exterior surface of mask fragment, with decorative details of folds, incised grooves and red coloration [AG 22A #862].

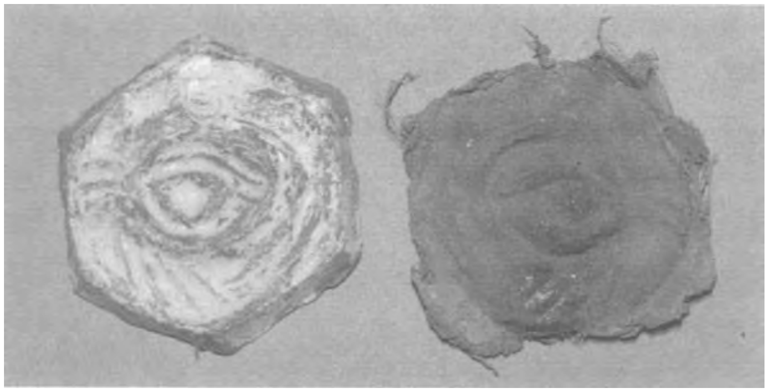


Figure 14. Concave plaster form (mold), and dried replica (obverse). Molded folds exhibit little weave distortion.

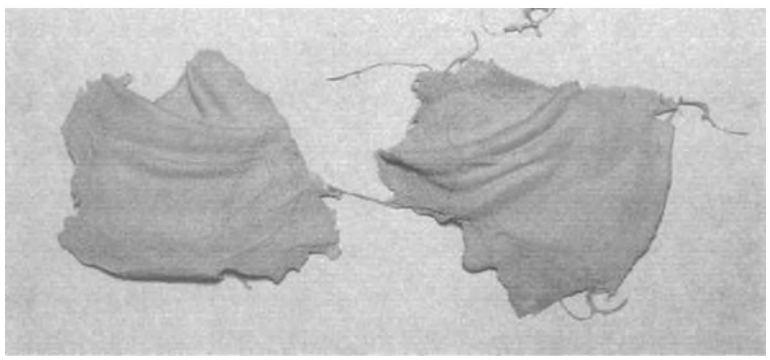


Figure 15. Replicas with freely formed folds, shaped on a simple convex form.

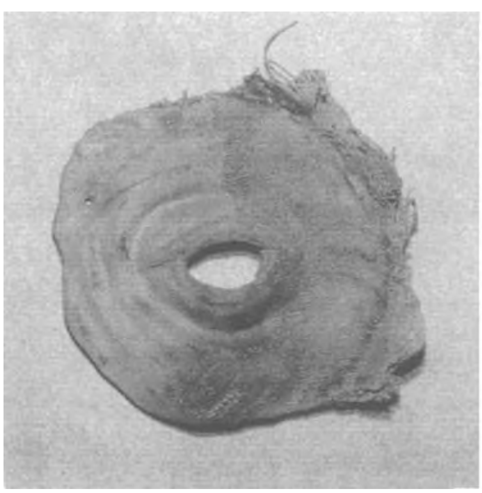


Figure 16a. Replica obverse (same as Fig. 14), with left half finished: replenished surface slip, neat edges, perforation and eye opening.

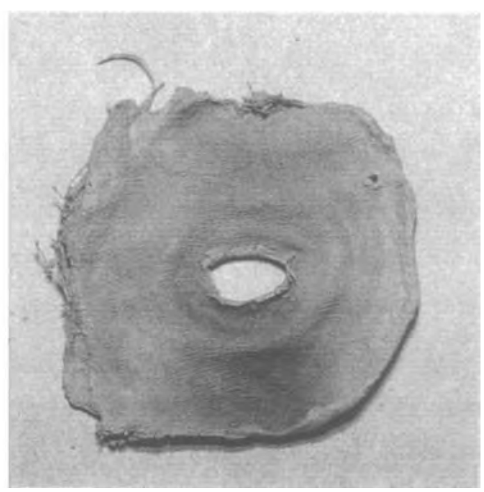


Figure 16b. Replica reverse, with finished edge on the right side.

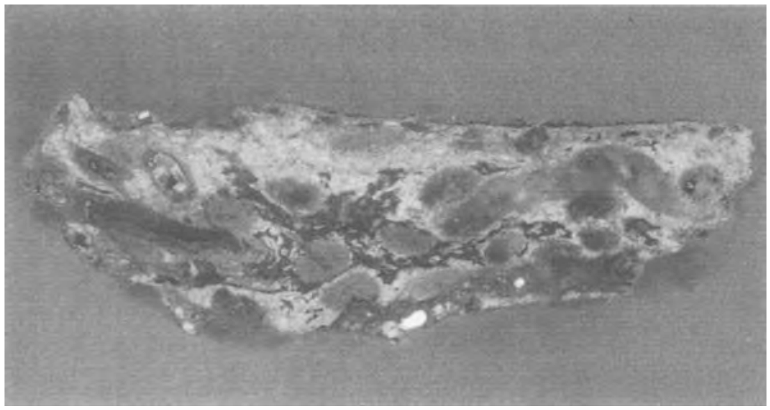


Figure 17. Polished cross-section, showing thin layer of colored slip applied to exterior surface (top) [AG 22A].

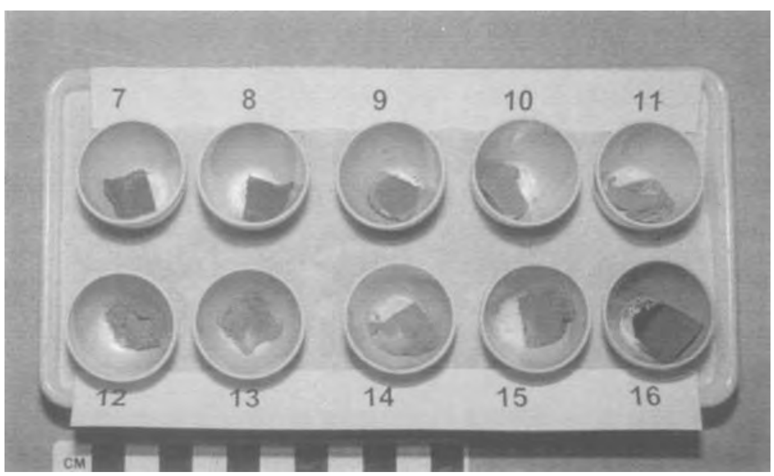


Figure 18. Group of replicas heated to temperatures from 350 degC (16) to 1150 degC (7 and 8) at 100 degC intervals, from right to left.