GUANGALA UNEARTHED: USE-WEAR ANALYSIS AND EXPERIMENTAL ARCHAEOLOGY IN A STUDY OF ECUADORIAN ARTIFACTS

Stephanie Bohaczuk, Doris Chen, Raj Dave, Christopher Geissler, Shriya Kaneriya, Zachary Maher, Marie Smithgall, Meghan Sosnowski, Peiyi Su, Joanna Venator, Lucas Zavala

Advisor: Maria Masucci
Assistant: Alison Koser

ABSTRACT

Archaeometry, a relatively new approach to archaeology, implements experimental replication and analysis through comparison of simulated and original artifacts. This method was utilized to study the Guangalan people of southwestern Ecuador in the Regional Developmental Period (500 BC – AD 800). Through microscopy and use-wear analysis, artifacts from the El Azúcar River Valley were examined to piece together aspects of Guangalan culture. Through the study of markings and other evidence on stone, shell, and ceramic artifacts, facets of Guangalan life, such as ceremonial and daily rituals, could be deduced.

INTRODUCTION

Presentation of Problem

The discipline of archaeology experienced a revolution in the late twentieth century. Previously, artifacts were assigned functions based primarily on morphological characteristics. This was due to a lack of sophisticated instrumentation to examine artifacts and archaeology's position as a discipline between history and the social sciences. The advent of digital technology, high-resolution imagery, and chemical analyses provided better methodologies, allowing for a new advance in ideas regarding the examination of artifacts. This new approach to archaeology, termed archaeometry, involves testing hypotheses, replicating artifacts for experimental purposes, and deriving interpretations from multiple lines of evidence. The scientific aspects of archaeology were thus made more explicit while still maintaining ties with history, anthropology, and art. Ultimately, the revolution enhanced the use of the scientific method in archaeological study.

The Guangalan culture was first discovered in the early, non-scientific phase of archaeology. These ancient people lived in southwestern Ecuador from 300 BC to 600 AD and had a diverse economy and complex society. Due to the Guangalan culture's relative obscurity and outdated methods of archaeological study, the Guangalan culture has remained largely enigmatic. The little analysis of their artifacts that has been done is largely morphological. Consequently, the primary objective of our project is the application of the scientific method in a study of the Guangalan people. More specific goals followed from this general focus.

In implementing scientific methodologies, three distinct groups of artifacts were targeted. Polished and shaped shells, smoothed stone artifacts, and ceramic sherds from pottery were examined using microscopic analysis, experimental replication, and use-wear studies. Through

these methods, a better idea of the possible functions of the artifacts was formed. These analyses cannot definitely prove how and why things were done, but rather assert how and why they could have been done. Specific artifacts of Guangalan culture were examined in order to extend the results to form a general picture of this ancient society. More importantly, the conclusions are the results of a novel approach to the archaeological study of Guangalan culture.

Background

Time Period

The Guangalan people lived in a time period of Ecuadorian history known as the Regional Developmental Period, which spanned 500 BC to 500 AD. [8] The Guangala phase, which began in about 100 BC and continued until about 700 AD to 800 AD, is thought to have shown an increase in the social complexity of the native people of Ecuador. The period is characterized by an expansion of settlements and evolution of tools and pottery, both stylistically and developmentally. Different materials began to be experimented with, such as metal and shells. In addition, the physical characteristics of the artifacts from the time period differ from those of previous ones. [11]

Location

The Guangalan people lived in a region of the world rarely studied in detail by the archaeological community. Their culture was located in the central region of the southwestern coastal area of Ecuador. A large set of archaeologically significant sites of the Guangala are situated near the modern town of El Azúcar. Today, El Azúcar is a small village located in the Guayas province of Ecuador (Figure 1**)**. The small town is in the constricted valley along the Zapotal River near the base of the Colonche Hills. As a result, many of the Guangalan archaeological sites are located around the river, with individual homesteads based on the tops of hills. Two sites in the El Azúcar Valley, Sites 30 and 47 were particularly significant due to the presence of deep well preserved midden areas. The “midden” represents the trash deposits from Guangalan farmsteads spanning 600 years of occupation. The artifacts analyzed in this paper are drawn from these sites by Dr. Maria Masucci.

Figure 1. Map of Ecuador. The region in which El Azúcar is located is circled in red.

The climate within this area is dry and tropical, with the Guangalan sites lying in the lowlands near the coast and west of the Andes Mountains. The coast is heavily affected by the cyclic pattern of seasons. Winter and summer, for instance, correspond to wet and dry seasons,

respectively. [8] This pattern is critical to our analysis of the Guangalan people, as it contributes to the potential for agriculture in the area. [11] The ample amount of yearly rainfall in the area implies that crop cultivation was possible. The region as a whole is very diverse, with distinct regions, such as river zones, hill regions and coastal plain environments. [8] As previously stated, the Guangalan sites are situated in a river environment conducive to agricultural development, which also provided easy access to the sea, hills, and corresponding resources such as stone and marine shell. [11]

The coastal portion of the area is home to diverse wildlife. The area's proximity to the coast and the presence of the remains of marine fish at the archaeological sites indicate coastal fishing was important. In addition, the inland rivers are not stable year-round water courses and therefore it is likely that freshwater fishing was not part of Guangalan life. As primarily inland farmers the Guangala of El Azúcar also had access to terrestrial mammals such as deer, kept domestic guinea pigs and likely traded with marine fisherpeople for marine fish. [10] Inferences about Guangalan daily life are based on studying the typical settlement design and associated artifacts. The location of their towns provided access to fertile farmland and hunting and marine resources. Recovery of plant and faunal remains, stone tools, ceramics vessels, worked shell, and metal artifacts indicate that the Guangala farmed diverse crops such as maize, squash, manioc, and peppers.

Culture

Figure 2. *Anadara grandis*

Guangalan life centered on coastal trade and agriculture. The location of the Guangalan communities facilitated this trade. With homesteads dispersed throughout coastal valleys the ocean provided Guangaln people with both items to trade and avenues by which to trade them. The most notable of these raw materials are *Spondylus princeps*, *Strombus gracilior* and *Anadara grandis* (Figure 2). These unique shells are common to the Pacific coast [12]. During this time period, Guangala was one of the main exporters of these shells and manufactured shell ornaments and objects. These objects could also have been used as trade items or currency for obtaining valued non-local products such as gold and copper ornaments and obsidian tools which were recovered from the sites [9]. Evidence of these highly coveted shells and worked shell objects have been found throughout Ecuador and Peru. It is also believed that the *Spondylus* and *Strombus* shells were considered symbolic items to the Guangalan people. Pendants, hooks, and figurines made of this shell have been found at burial sites, thus indicating sacred significance [8].

During this period of the Guangalan culture, many Ecuadorian communities became socially stratified and conglomerated into small regional chiefdoms [10]. The *Spondylus* trade circuit, which is thought to have employed force to maintain boundaries, might have contributed to the creation of such chiefdoms [8]. Archaeologists, however, maintain that although the Guangala were a central part of the trade network, they remained separate and independent of these complex societies. In addition, there is no archaeological evidence of a social hierarchy in Guangalan culture. Figurines of neighboring cultures demonstrated to have such a social order, such as Jama-coaque, depict high-class chieftains, distinctly recognizable due to elaborate

ornamentation (Figure 3). Comparable Guangalan figures, however, display no such characteristics (Figure 3). Guangalan figurines, however, are not devoid of dress or decoration [8]. Many figurines were stylized [11] with various adornments and jewelry, such as necklaces, nose rings, and earrings [11]. Additionally, studies of Guangalan burial sites verify the absence of a social hierarchy. Burial sites provide "no clear evidence of differences in status or rank" [11]. Such findings have prompted archaeologists to believe that the Guangalan social structure suggests a complex culture centered on trade, agriculture and community.

Figure 3. A Jama-coaque figurine (left) compared to a Guangalan figurine (right)

Use and Form of Tools

In the region of Ecuador where Guangala was located, evidence of pottery making such as firing areas and pottery making tools is extremely rare. Mineralogical and chemical analysis of local raw materials as compared to that of Guangalan pottery demonstrates, however, that the pottery is made of the materials available in the area. This is a major issue in Guangalan studies; the evidence of local pottery manufacture but the scarcity of physical evidence or facilities seem to contradict each other. Pottery making tools can take a variety of forms due to the many uses, such as smoothing, polishing, scraping, and boring necessary to produce the Guangalan pottery. Through investigation of a pottery making area at the Mayan site of K'axob, archaeologists, López Varela, van Gijn, and Jacobs have suggested that certain recycled pottery sherds may have been used as tools to help fashion pottery. Guangalan potters may have also used recycled sherds in the manufacture of pottery [2]. According to López Varela et al. such tools exhibit specific wear marks, such as striations running in various directions. Polishing tools have a stronger luster and multi-directional striations, whereas smoothing tools usually have unidirectional marks [7].

Stone artifacts at Guangalan sites are usually grouped as either grinding tools, hammers, or axes based on material and morphological characteristics. However, these labels imply function based solely on form of the artifacts, rather than on evidence of their use. For example, stone artifacts discovered in both burials and farmstead settings within the Guangalan region have been labeled as axes. Archaeologists have conjectured that these polished stone artifacts also referred to as "celts", were used for tree clearing and woodworking and thus demonstrate the presence of an agricultural lifestyle; however, no evidence beyond the shape of the artifacts has been presented to support these assumptions [5]. These artifacts have a characteristic "t-shape", which is a wedge shape with a flattened, ovular head and a sharpened straight edge [4]. Figure 5 demonstrates these physical characteristics. This shape was used in time periods previous to the Guangala Phase, as early as the Valdivia Phase dating back to 3,000 BC. Similar shaped

Figure 5. Stone Ax (47-W1-5)

stones are still utilized today in South America to clear tropical forest areas for agricultural purposes, [5] while those found in ancient burials are thought to be ceremonial items, not used for actual labor. “Burials are associated with grave goods, such as shell spoons, shell ornaments, polished stone axes, red ochre, and round stones.” [2] The use of unverified functional labels perpetuates cultural reconstructions which may not be accurate. It is possible that not all stone axes were used to fell trees and work wood or even would have functioned well for these uses. Also, some may haven ceremonial and never intended for non-ritual function. Copper axes were recorded by the Spanish to have been status items and were used as currency among the coastal Ecuadorian peoples during the later contact period. Microscopic use-wear analysis of the edges have demonstrated that they were never actually used (Hosler et al).

Shaped *Anadara* shells in the form similar to that of stone “axes” have also been discovered within Guangalan sites and assumed to have been used for woodworking [11]. As mentioned previously, Guangala had three types of thick white shell material available to them; *Spondylus princeps, Strombus gracilior* and *Anadara grandis.* Site 47 contains a shell working area in which it has been demonstrated that shell beads were produced [9]. The shell working area also contains worked shell artifacts which match what had been previously labeled “shell axes”. Similar to stone axes, shells shaped in a similar form have been found as pendants in burials. Typically, evidence correlating with Guangalan shell work deals with the shells’ use as sacred objects and trade items. In addition, there have been no investigations into use evidence or functionality of these formed shells.

METHODOLOGY

Shell Artifacts

The shell artifacts (Table 1) were first sketched by hand and documented using the digital camera in order to preserve the integrity of the study. The shell artifacts were then analyzed for wear patterns from formation and possible use using a light microscope. An unshaped piece of shell from the same archaeological site as the artifacts was observed and documented using a digital camera as well as a light microscope.

In order to implement use-wear analysis, an experimental tool had to be formed. Using a sandstone block, the unshaped shell fragment was smoothed into a shape similar to those of the original artifacts. After the formation of the experimental replica, both the replica and the original artifact were analyzed for similar markings using a light microscope. Digital photographs were then taken of both pieces, and the photographs were compared. A segment of the experimental replica was cut using a gem saw and observed under the SEM.

Use-wear analysis was performed to determine whether markings on the shell axe artifacts were from formation or from use. To test for possible use-wear markings, the replica was used to chop manioc, hard wood, and a rough hard-shelled nut. After each test, markings on the replica were recorded using a light microscope. Analysis was performed by comparing light microscope photographs for similar use patterns on the replica and the original artifacts. A portion of the experimental shell tool containing use-wear markings was cut and observed under the SEM. The two SEM pictures were compared.

Table 1	
Artifact	Description
47-W3-14	Fragmented, square edge
47-W3-2	Fragmented, square edge, burnt
47-W3-14	Experimental replica

Stone “Axes”

The stone artifacts were analyzed for use-wear by scraping, slicing, and chopping with the “blade” end of the tool. In addition, the blunt posterior end of the tool was tested for use-wear marks caused by grinding and/or pounding. The practicality of the tool for a designated function was also considered. An unsharpened chert stone artifact (designated 527-0) with a blunt edge was used as an experimental tool for grinding since it had a similar shape to those of artifacts believed to be potential grinding instruments. A chert stone artifact (designated 521-0), which exhibited a partially formed “blade" end, was used as an experimental tool for edge-wear. Before experimentation, both experimental axes (527-0 and 521-0) were documented with digital photography and a light microscope for pre-use markings.

Edge-wear analysis was completed on experimental axe 521-0 by observing markings from formation and use. Before experimentation could be done, all existing wear on axe 521-0 was removed, and the axe’s edge was honed. This was done using a sandstone file. Wear created from sharpening was documented using digital photography and microscopy. This wear pattern was then compared to wear from experimentation, testing the axe on materials of varying hardness.

Axe 521-0 was tested on several materials through different techniques, including scraping, slicing, and chopping, to simulate possible uses. Manioc root was peeled using a forward scraping motion. The next test on the manioc was a slicing motion that went back and forth across the width of the manioc. Edge-wear on axe 521-0 was carefully documented using a light microscope. After, the “blade” of the axe was sharpened using the sandstone file to remove any traces of edge-wear and to create a more acute edge. This newly sharpened edge was then documented using a light microscope, and was found to be identical to the original sharpened experimental axe before the testing on the manioc. The experimental axe was then used on balsa wood, softwood pine, and hardwood oak with the same scraping, slicing, and chopping motions as in the manioc experiment. Edge-wear was then analyzed with the light microscope.

Use-wear from pounding and grinding was simulated on chert test artifact 527-0 after first removing existing wear by polishing against sandstone. The posterior end of the test artifact was pounded against a sandstone slab, then repolished and used to grind leaves and black walnut. Light microscope photography was taken after each trial combination of ground substance and grinding surfaces. Marks were later compared to marks on the original tool for similarities.

Pottery Sherds

Two types of ceramic sherds were selected for analysis: round worked sherds and others which appeared to have functioned as pottery-making tools. Light microscopy and experimental replication were used; given the porosity of ceramics, SEM microscopy was not used, as use-wear marks could be confused with the natural surface imperfections of the material.

The artifacts collected included several round, apparently worked sherds. After these sherds were photographed with digital photography and light microscopy, a similar clay sherd was reshaped into a roughly oval shape. To imitate the observed scratches perpendicular to the wall of the piece, the sherd was formed into an oval shape on a large piece of sandstone. This experimental sherd was subsequently photographed with light microscopy and compared to the original sherds and their formation markings.

Two sherds, similar in size, shape, and composition (and appearing to have no use as tools) were tested for their utility as pottery tools; the similarities between the two allowed for a well controlled experiment . Both were photographed using light microscopy and smoothed by stroking one edge of each along a piece of sandstone until visibly smooth. They were then photographed with a light microscope.

The formation of the artifacts discovered at the sites was simulated using similar pottery techniques. The Guangalan clay was recreated by mixing standard, commercially-available potter's clay with sand. This was fashioned into rolled coils of clay about 1.5 cm in diameter. Five coils were then attached, but not thoroughly smoothed together, to replicate a section of a piece of pottery. Two simulated walls were built, and their coils were smoothed together with the smooth edge of the first sherd. The second sherd was tested on a series of walls for a total time of one hour. The sherds were lightly rinsed with water and photographed with light microscopy. The before-and-after images of the experimental sherds were then compared with each other, and the original Guangalan sherds for evidence of wear and use as pottery tools. The two simulated walls on which the smoothed tool was used were dried and fired to 700 °C; smoothing marks were compared to those on original artifacts.

RESULTS

Shell Artifact Results

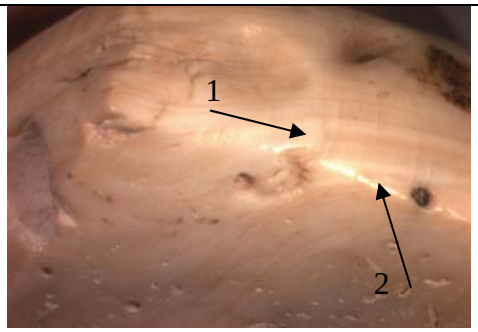
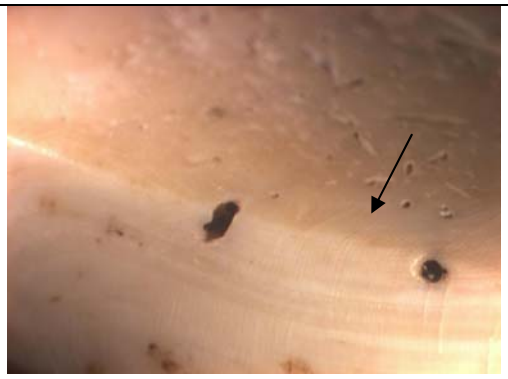
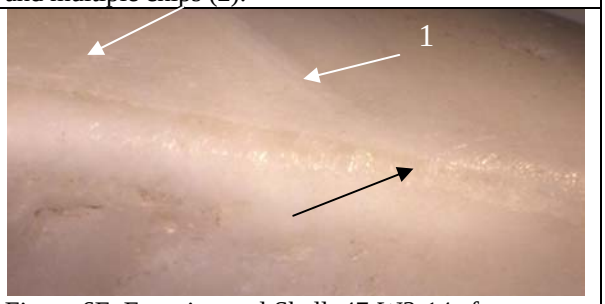
Shell Data- Artifacts and Observations	
 Figure 6A: Artifact 47-W3-14; Magnification 5x. Two types of striations, potential growth rings, appear perpendicular to each other with thinner lines (2) running vertical and thicker lines (1) running horizontally.	 Figure 6B: Magnification 5x. This depicts vertical markings which run over the edge from one surface to the other.
 Figure 6C: Magnification 31x. This displays the densely aligned vertical striations in comparison to the thick horizontal rings.	 Figure 6D: Artifact 47-W3-2; Magnification 5x. Despite its burnt discoloration, Artifact 47-W3-2 showed striations running in various directions (1) and multiple chips (2).
 Figure 6E: Shell fragment 47-W3-14; Magnification 5x. This image shows the experimental shell before being polished.	 Figure 6F: Experimental Shell, 47-W3-14 after polishing; Magnification 5x. The shell displayed thin vertical striations after rounding the edges of the shell.

Figure 6G: Magnification 5x. A secondary depiction of the lines running over the edge due to polishing.

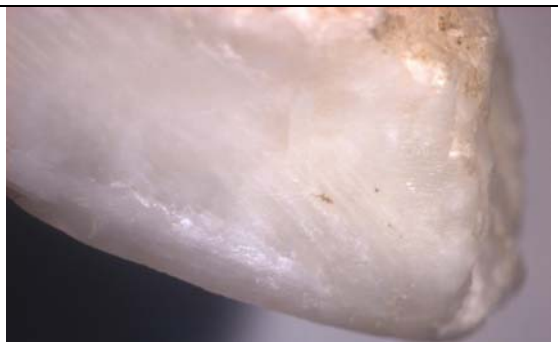


Figure 6H: Artifact 47-W3-14, Magnification 5x. Image of experimental shell tool after use on the manioc. No use-wear marks were apparent.

Figure 6I: Artifact 47-W3-14, Magnification 5x. Image of the experimental shell tool after use on the oak. Grooves appeared in the shell on the flat surface parallel to the edge; these can be seen due to remnants of bark in the grooves.

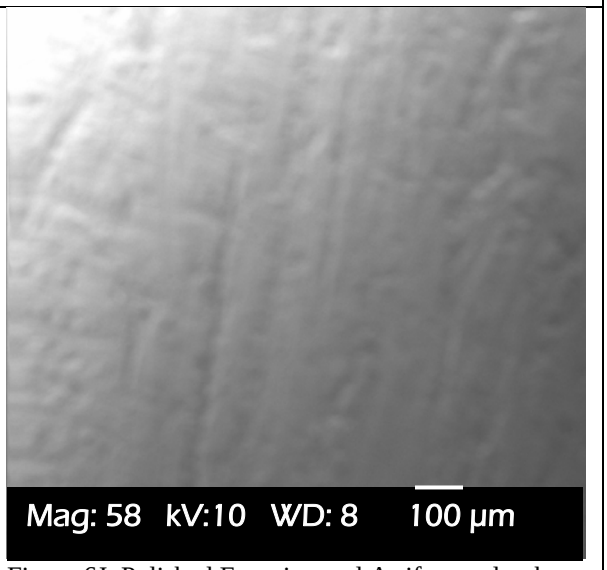


Figure 6J: Polished Experimental Artifact under the SEM, Magnification 58. Image shows indistinct striations.

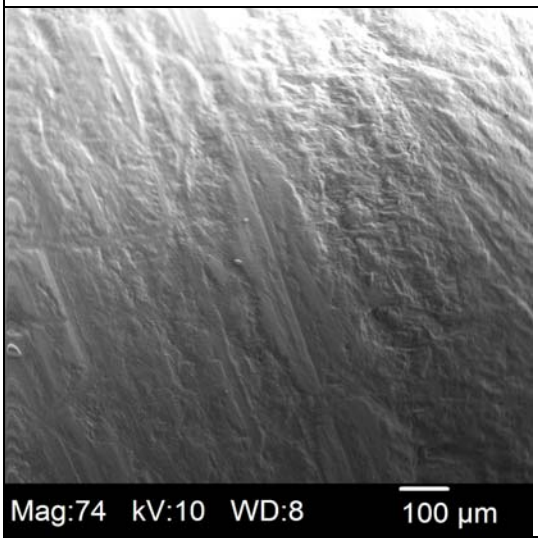


Figure 6K: Experimental Artifact after use-wear experiments under SEM, Magnification 74. Image shows more pronounced striations and ridges.

Summary of Shell Results

After examination of the shell artifacts with the light microscope, several key characteristics were observed. Shell 47-W3-14 had unidirectional lines parallel and perpendicular to the edge (Figures 2A, 2B, and 2C). Shell fragment 47-W3-2, the only artifact with cracks, was grayed, indicative of burning. On the entire artifact, there appeared to be multi-directional chipping and striations (Figure 6D). As described in the methodology, a non-shaped shell fragment (47-X3-13) found at the archaeological site was polished for experimental purposes (Figure 6E). The shell was polished on finely grained sandstone using both parallel and perpendicular strokes to mimic the flat surface and rounded edges on the artifacts (Figure 6F). Under the light microscope, the experimental shell displayed subtle lines on the surface parallel to the edge (Figure 6G). Using a gem saw, a segment of the experimental shell was cut off to be viewed under the Scanning Electron Microscope (SEM). Under this magnification, the striations were easier to see (Figure 6J).

The experimental shell was used on different materials of varying hardness; manioc, oak, and nut. The manioc represented a possible Guangalan food. After chopping the manioc, no significant markings were left on the experimental shell (Figure 6H). The oak represented hard wood that the Guangala might have felled. Contrastingly, after using the shell on the oak, use-wear marks appeared on the shell in the form of unidirectional lines indicated by oak debris (Figure 6I). However, the striations were not as pronounced as the lines seen on shell 47-W3-2. The nut represented another food with a harder outer coating available in Guangala. This experiment produced un-patterned chips in the shell edge's surface. Under the SEM, the damage from the oak seemed to represent deeper grooves, which contrasted with previous viewings of the polished shell under the SEM (Figure 6K).

<u>Ceramics Artifact Results</u>

Ceramic Data- Artifacts and Observations

Figure 7A: Left, original worked sherd; at right, replica made using a similar Guangalan sherd from the same site.

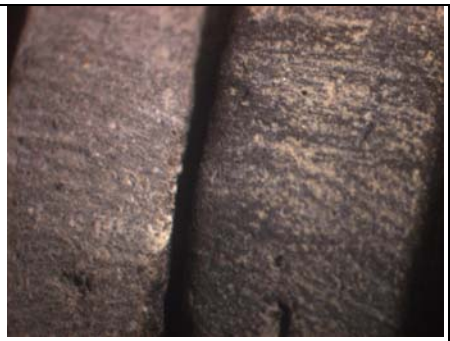


Figure 7B: Magnification 5x, viewing area 3.7 cm. Replica (left) and original (right) oval worked sherds. Note the very similar wear patterns.

Figure 7C: Replica pottery tool made from potsherd, concave side, photographed after use. The curve at right was smoothed on sandstone and actually contacted the experimental clay.

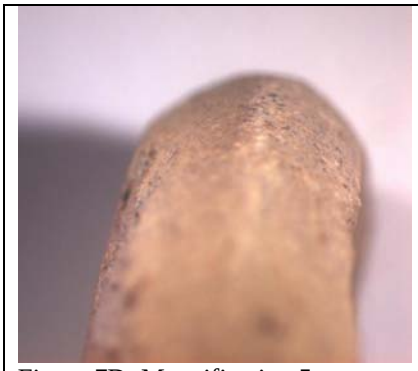


Figure 7D: Magnification 5x, viewing area 3.7 cm. Replica pottery tool made from potsherd, before use. Note the visible ridge running down the length of the tool, as well as the angular concave edge at right.

Figure 7E: Magnification 5x, viewing area 3.7 cm. Same replica potsherd tool, after use. Note the more rounded ridge along the center and the curved, not angular, concave edge at right. White spots are natural pits in the porous ceramic which have been filled with clay as a result of use.

Figure 7F: Magnification 5x, viewing area 3.7 cm. Surface of replica wall, after firing. Horizontal smoothing marks are clearly visible.

Figure 7G: Magnification 5x, viewing area 3.7 cm. Interior (concave) surface of an original Guangalan sherd. Note the horizontal smoothing marks.

One sherd appeared to have been worked into an oval shape. Another sherd, not worked but composed of a similar clay body, was shaped into an oval shape by rubbing the sherd's edge against a piece of sandstone (Figure 7A). When viewed with a light microscope, the original and replica sherds both exhibited repeated scratch marks perpendicular to the plane of the sherd (Figure 7B). No additional patterns of markings were noticed on either sherd.

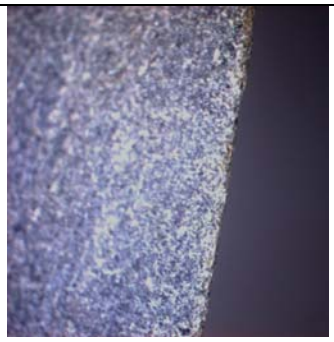
The next experiment involved recreation of two pottery tools (Figure 7C). One edge on each of two potsherds was smoothed by rubbing the tool longitudinally along a flat piece of sandstone. Both tools performed well in smoothing the replica coil-built clay walls. After use, the sherds exhibited distinct wear on their edges. The line which formed the concave edge was reshaped into a smoother, gentle curve (Figure 7D). In addition, the pointed groove on the middle of the edge of one sherd was smoothed into a curve (Figure 7E). These patterns were not seen on the original Guangalan sherds.

The tool easily smoothed the rough surface of the wall into an even, slight curve. The smoothing pattern included thin, regular lines. These continued to be visible after drying and firing of the clay (Figure 7F). The lines found on the replica images resemble those found on original Guangalan sherds (Figure 7G).

Summary of Ceramics Results

Experimental recreation of the oval worked sherd formed similar formation marks to those on the original sherd. No additional patterns of wear were detected on the original. The replica pottery tool performed well, creating smoothing marks which resembled those found on Guangalan potsherds. The tools themselves exhibited distinct use-wear patterns in the rounding of ridges formed in their creation.

Stone Artifacts Results

Stone Data- Artifacts and Observations	
Testing Stone Axe 521-0	
 Figure 8A: Magnification 10x. Smoothed axe edge before testing. Scratch marks parallel to the blade due to sharpening visible.	 Figure 8B: Magnification 10x. Axe edge after scraping, slicing, and chopping manioc. Little to no wear visible.
 Figure 8C: Magnification 10x. Axe edge after scraping, slicing, and chopping softwood and hardwood. Red-brown discoloration, white pitting, and notches perpendicular to the blade visible. Blade significantly dulled by the testing process.	 Figure 8D: Magnification 10x. Opposite side of axe edge after wood tests. Discoloration, one notch on the blade, and small white pits visible. Blade is dull.

Unburied artifact designated an axe

Figure 8E: Magnification 10x. Notches perpendicular to the blade, white pits, and slight red-brown discoloration visible. Blade is dull.

Figure 8F: Magnification 10x. Red-brown discoloration along edge and some notches perpendicular to the blade visible. Blade is dull.

Testing Stone Axe 527-0

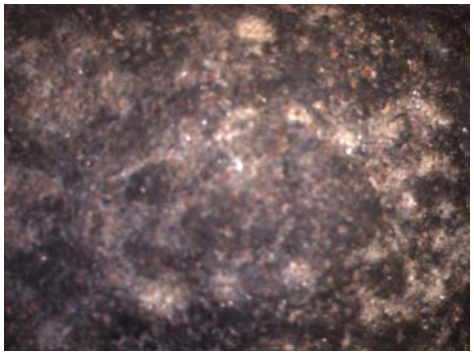


Figure 8G: Magnification 5x. Posterior end after grinding on sandstone to erase edge wear. Slight flattening seems to have occurred.

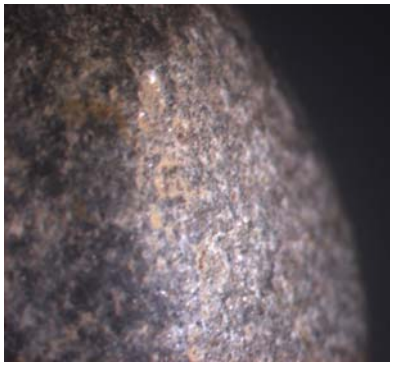


Figure 8H: Magnification 5x. Posterior end after pounding against sandstone slab and some angular stone. Surface has become flattened and smooth.

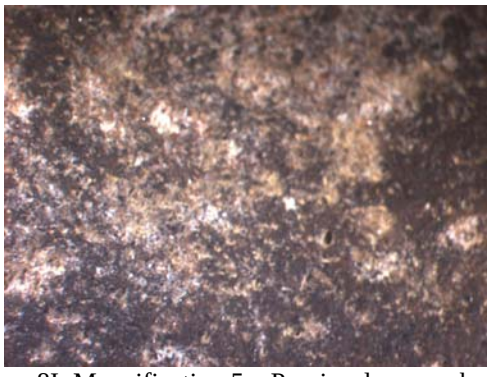


Figure 8I: Magnification 5x. Previously unworked side after pounding against posterior of 521-0. Pitting consistent with pattern found on the posterior of sample artifacts (See Figures A10, A11)

Artifact Posterior Wear Patterns

Figure 8J: Magnification 5x. Wear on posterior of chert stone "axe" 52-310. Region is roughened and pitted.

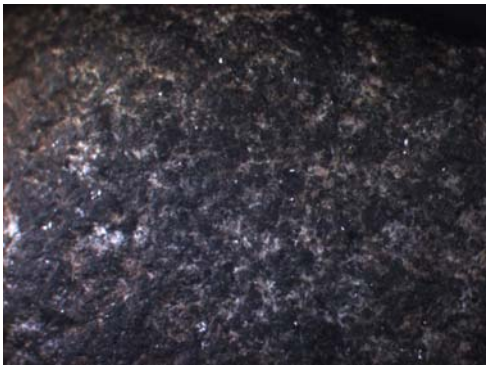


Figure 8K: Magnification 5x. Wear on posterior of unmarked surface fine chert stone "axe." Region is roughened and pitted.

Grinding of Experimental Axe 527-0

Figure 8L: Magnification 5x. Posterior after grinding wet oak leaves against sandstone. Some pitting visible.

Figure 8N: Magnification 5x. Side after grinding leaves against stone. Slightly increased amount of pitting visible.

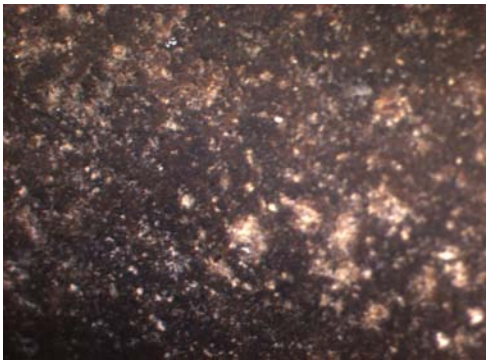


Figure 8M: Magnification 5x. Side before testing. Some pitting visible

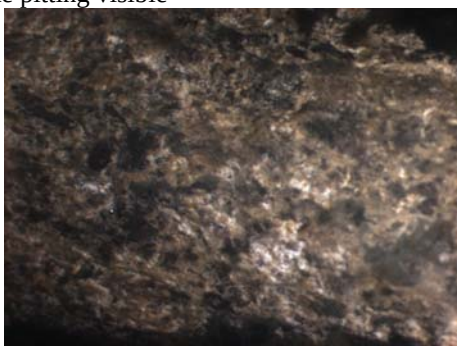


Figure 8O: Magnification 5x. Side of stone "axe" 52-120. Roughening and pitting visible.

Summary of Stone Results

Microscopic examination of the stone axes revealed several key characteristics. The experimental axe in Figure 8A showed striations parallel with the axe blade, which was caused by sharpening the axe and removing existing wear. Experiments in chopping, slicing, and scraping were conducted on manioc, producing little to no wear (Figure 8B). The two sides of an axe which were used on wood in scraping, slicing, and chopping experiments revealed distinct wear patterns, including notches, white pits, and dulled edges (Figure 8C and Figure 8D). The edges showed a red-brown discoloration. Examination of two sides of the original stone artifact in Figure 8E and 8F revealed similar wear patterns to the experimental axe in Figure 8C and Figure 8D.

Additionally, use-wear tests have shown results that simulate the wear patterns on the posterior and edge of the axes. Pounding against the posterior merely flattened the surface (Figure 8H), rather than creating a rough wear pattern, while pounding against one side did produce a rough wear pattern (Figure 8I). Grinding wet leaves resulted in slightly increased amounts of pitting and rough appearance on both the posterior (Figure 8L) and edge (Figure 8N), but the wear was not performed over a long enough period of time to observe any definite correlation.

DISCUSSION

Shell Artifacts

In order to analyze the potential purpose of shell artifacts found at the El Azúcar River Valley Site 47, use-wear analysis was employed to compare an experimental replica to the original artifacts. This process led to several conclusions. Upon first examination, markings appeared to be smoothing marks from the manufacture of the object. Due to the smooth texture of the shell surface, it can be reasonably concluded that the edge was man-made and polished. However, upon further investigation it was discovered that cross sections of shells showed these striations and marks to be annual growth rings (Figures 6A-6C). [1] The *Anadara* shell species naturally exhibits an irregular form, making it difficult to discern between natural growth rings and smoothing striations. Thus, although in this case further investigation demonstrated that the marks were man-made, archeologists should be warned against misconstruing man-made marks and natural processes.

After the experimental trials with the polished shell replica, the shell displayed no visible damage after use on the manioc (Figure 6H). In contrast, the oak did produce slight use-wear marking on the shell (Figure 6I). These experiments showed how difficult it was to inflict damage on the shell surface. However, the shell replica was ineffective in chopping the manioc and oak. Therefore, it probably did not serve as a functional tool. Additionally, the only original artifacts with potential use-wear markings were burnt. These markings did not follow a pattern, were multidirectional, covered the entire shell, and did not match the use-wear striations on the experimental shell (Figure 6D). In fact, the use-wear cracks could have potentially resulted from burning.

The impracticality of the shell as a functional tool correlates with the accepted significance of shells in Guangalan culture. A material of this value would not have been used for a job that a stone could have completed more efficiently. Therefore it can be inferred that worked-shells might have been used in a more ritualistic or ceremonial context. Archeologists have concluded that *Strombus* and *Spondylus* shells were considered sacred items used for ceremonial purposes such as burials. In addition, these shells were the Guangalan's staple export, often traded over long distances and used as currency. The shells found at Site 47 were from a shell-working area. It can be presumed that these shells were in the process of being manufactured. Therefore, they may not exhibit use-wear marks. Many of the artifacts found were of the *Anadara* species of shell, a slightly less valuable shell type. However, Guangalan people could have worked *Anadara* shells in an attempt to imitate *Strombus* and *Spondylus* shells [9]. Considering the experimental results and the cultural context, it can be concluded that the shell fragments found at Site 47 did not have a functional use and instead may have been utilized in rituals and trade.

Ceramic Artifacts

Use-wear analysis of ceramic artifacts resulted in several conclusions. Patterns of wear consistent with the formation marks on a replica were observed on the oval-shaped pottery sherd. No other marks were found on this piece, which implies that the artifact was deliberately shaped but was never used as a tool. The object may have still had a functional purpose, but not one which would produce any wear on the tool.

Several observations result in the conclusion that some of the pottery sherds found at sites 30 and 47 could have been used as pottery-making tools. The first piece of evidence is the effectiveness of the slightly shaped pottery sherd as a tool. When used to smooth clay, the piece worked efficiently and created a smooth finish. The availability of pottery sherds as well as the ease of working the pottery sherd into a tool makes this method a practical approach to shaping pottery. Additionally, marks in the surface of the clay made using the pottery sherd tool were consistent with striated markings found on unpolished Guangalan pottery, which provides additional evidence for their use of pottery sherds as pottery shaping tools. The body of sherds studied did not include any which exhibited wear patterns consistent with pottery-making; this does not offer conclusive evidence in itself that the sherds were used as pottery making tools. However, the results of the experiments conducted using replicas of the pottery demonstrate that such pottery tool use was possible.

These results support the conclusions of López Varela and van Gijn [7], applying their findings to the artifacts found in southwestern Ecuador. Although their work focused on different types of sherds from a different part of the world, the results of our experiment in conjunction with their conclusions support in the general idea that potsherds could have been used as effective tools for making pottery.

Stone Artifacts

An examination of stone axes unearthed from Sites 30 and 47 revealed striking evidence regarding the nature of Guangalan culture. Two Guangalan stone artifacts were used to mimic

wear that could have been done on the original artifacts, and the results of the experiments could be used to extrapolate whether the axes could have been used in the ways tested.

Use-Wear by Grinding and Pounding

The pounding test resulted in the creation of a smooth, flat surface rather than the chipped, irregular surface observed on the artifacts (Figure 8H). This inconsistency in use-wear calls to question Bushnell's hypothesis that the "axes" were really wedges that were pounded on the back [3]. However, when the side of 527-0 was pounded against the posterior of test axe 521-0, the chipped pattern did emerge (Figure 8I). This leads to several potential explanations and lines of further study:

(1) The process of erasing the wear from 527-0 slightly flattened out the rear, which could have conditioned the wear toward further flattening.

(2) The Guangala might have used very angular rocks to pound against the back of the stones, though this is questionable considering the fact that the hammer-stone would also round out and would be more difficult to use accurately.

(3) The wear pattern was produced by something other than pounding by another stone, perhaps not from pounding at all.

The other most likely source of the rough use-wear pattern is through grinding. The posterior of test artifact 521-0 was very effective in grinding black walnut and mildly effective in grinding leaves. The longer edge was very effective in grinding the leaves since it covered a broader area. The use-wear produced by these test did not clearly show significant amounts of roughness and pitting; however, the tests were performed for a relatively short period of time in comparison to the long amount of time spent grinding foods and herbs by the Guangala. Therefore, if longer tests were performed the amount of wear may have been more consistent with the wear observed on the artifacts. Also, grinding against a rougher stone may have produced more significant wear. This indicates that objects referred to as "stone axes" could actually have been used as pestles. This concept is supported by worn Guangalan dental remains, possibly damaged by the grit of such grinding.

Tests of the "Sharp" Edge

Scraping tests on manioc were ineffective in removing the skin, implying that using the "axes" to chop vegetation would result in loss of starch and nutrients. A slicing motion proved to be impractical as well; rather than making a clean cut or semi-clean cut manioc by splitting it, the axe had a mashing effect. Without flaky rocks to create into sharp edges, a clean cleave would be virtually impossible with the axes found at the site. In addition, the manioc was so soft that it did not create significant wear patterns (Figure 8B). It can be concluded that the "axe" was not used to prepare soft vegetation.

The edge of the axe was tested on different woods because it is unknown what type of wood would have been gathered. It is important the note, however, that the dominant tree species in the area excavated yielded hardwood, as the Guangala lived in a dry rainforest ecosystem. It was possible to chop through balsa and soft wood, and thus such use can be considered practical. Chopping through hard wood was difficult but plausible. However, experiments were only

completed on branches, not trunks, leading to possible error. The wear patterns observed on the axe looked similar to the wear patterns on the artifacts. Though the wear was not as extensive as the actual artifacts, the results were comparable to the actual model.

In conclusion, it is very difficult to determine the exact function of these stone implements. Some have wear patterns consistent with use on wood, meaning that the label "stone axe" could correct. However, the label "axe" does not explain the wear on the posterior and edges of the stones. Indeed, "axe" 52-310 showed no wear on the pointed edge but still exhibited the grinding and pounding wear on the posterior and edge. Assuming that these implements were indeed axes is not only overreaching; it can lead to further incorrect conclusions dealing with the agricultural nature of the Guangala phase.

CONCLUSION

The results of the stone, shell, and ceramic artifact use-wear experimentation revealed insight into the Guangalan culture. Shell use-wear experimentation revealed that the shell artifacts from the El Azúcar site were not employed as tools. However, their exact purpose, possibly ritualistic or for trade, cannot yet be determined. The stone artifacts revealed signs of wear similar to wear on the replica, suggesting that axes were used for a functional purpose. Experimentation on pottery sherds leads to the conclusion that the oval shape sherd was not used as a tool but that pottery sherds were plausibly used as pottery-making tools. However, none of the pottery sherds found at the El Azúcar site suggest signs of use as pottery tools.

Future studies should employ the techniques of experimental archaeology, as it has proven useful in this application. Use-wear analysis and experimental replication were ideal for this purpose because they allowed designation of artifacts based upon evidence of use as opposed to morphological characteristics. Challenging assumptions and eliminating unlikely possibilities through continued use of such methods will provide stronger evidence for a more accurate understanding of the past.

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