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BAHAMIAN CLAYS AND THEIR PROCESSING INTO PALMETTO WARE CERAMICS: AN EXPERIMENTAL ARCHAEOLOGY PROJECT

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Questions have been asked for many years concerning the clay resources in the Bahama archipelago, given that these islands are composed of calcium carbonate sediments. The origin of these clays and their local sources will be described. Successful tests were conducted utilizing the available techniques and tools of the Lucayans to determine the possible way the local clays were cleaned, the temper processed, and the firing methods used to make Palmetto Ware (Palmettan Ostionoid) ceramics.

Han sido muchas las preguntas hechas, por años, con respecto a los recursos de arcilla en las Bahamas, dado que estas islas están formadas de sedimentos de carbonato de calcio. Se describirá el origen de estas arcillas y sus fuentes locales. Se realizaron excelentes pruebas utilizando las técnicas disponibles y herramientas de los Lucayans para determinar, posiblemente, la forma como las arcillas locales fueron limpiadas, el proceso de templado y los métodos de cocción usados para fabricar la cerámica Palmetto Ware.

Pendant des années, de nombreuses questions ont été posées à propos des ressources d'argile aux Bahamas puisque que ces îles sont composées de sédiments de carbonate de calcium. L'origine et les sources locales de ces argiles vont être ici décrites. Plusieurs tests, utilisant les techniques et les outils en usage chez les Lucayens, ont été menés avec succès afin de retrouver le mode de nettoyage des argiles locaux, le procédé de dégraissage et les méthodes de cuisson possiblement employés par eux pour créer la céramique de Palmetto.

Introduction

Palmetto Ware (also known as Palmettan Ostionoid) is the shell-tempered ceramic made by the Lucayan Indians, the indigenous people of the Bahama archipelago (Hoffman 1967; Granberry and Winter 1995; Sears and Sullivan 1978). Bahama Red Loam, a type of red soil is referenced as the type of clay used in its manufacture. Some may question this attribution, as the Bahama archipelago was formed from recent marine sediments, an unlikely place to find clay. Moreover, shell temper poses many problems during ceramic firing and use. Thus, the purpose of this paper is to describe what the authors have learned about Bahamian clays, the use of shell tempering, and the means of firing in the making of Palmetto Ware pottery.

The authors question the use of Bahama Red Loam for ceramic production. Bahama Red Loam was first described by Mooney (1905), who stated it contained from 18.0-33.5 percent clay. He did not describe any other soils with higher clay content. Because no real clay deposits had been described in the scientific literature for the archipelago and because Palmetto Ware pottery is reddish in color, the authors believe archaeologists presumed the Lucayans utilized Bahama Red Loam in the making of their ceramics. A soil scientist would not use the term "loam" for describing any soil that had sufficient clay molecules for the making of ceramics. As Figure 1 shows, the term "clay" is used to describe a soil that has a much higher percent of clay molecules then is found in loam.

Since 1972 the lead author has been concerned about how the Lucayans made their pottery from Bahama Red Loam. In 1973, we asked Roberta Griffin, a ceramics professor from Hartwick College to duplicate Palmetto ware from Bahama Red Loam in order to test whether it could be, in fact, produced. After working with the materials, she found it near impossible, saying the material "was not clay and it was a waste of time to try to make anything from it." Subsequently, the lead author tried to fire Bahama Red Loam, but it was a complete failure. Based on these unsuccessful attempts to work with Bahamas Red Loam, it was thought by the authors that the clays must have been imported by the Lucayans from the Antilles through trade networks. [1]

Figure 1. Soil Texture Diagram (Tarbuck and Lutgens 2009).

Clay and Clay Sources

Because of their and others' failures with trying to mold and fire Bahama Red Loam, the authors of this paper believe the materials used by the Lucayans to make their pottery was not Bahama Red Loam, but came from the islands' concentrated clay sources located in depressions and inland lakes and ponds. In other parts of the world, it is not uncommon to find clay in the bottom of lakes, ponds, rivers, and streambeds. These are referred to as secondary clay formations caused by erosional processes. There the clay settles outs and accumulates into more concentrated clay sources.

Mann (1986) found that the clay minerals present in Bahamian soils originated from wind-blown dust from Africa. His analysis indicates that the mineralogy of African dust is similar to the non-calcium carbonate mineralogy of Bahamian soils, with the major difference being the weathering into kaolin of the illitic and chloritic clays and feldspar found in African dust by the subtropical climate of the Bahamas. Thus Bahamian soils do contain amounts of clay, the result of aeolian deposition. Mann analyzed a soil sample from a solution depression near the Pigeon Creek dune #1 site on San Salvador Island. Mann identified this sample as Bahama Red Loam, and found it contained 73 percent clay. He did not define this as a clay sample nor did he distinguish it from that described by Mooney (1905) that was no more than 33.5 per cent clay. The sample analyzed by Mann came from a solution depression, where the soil had been naturally sorted and cleaned by rainwater. Rain would have washed the fine clay particles from the soils and suspended them in the rainwater.

During his many years of fieldwork on San Salvador, Winter has located numerous pockets of clay, principally in the island's inland lakes and ponds. These raw clays differ in color and quality. In this study, the lead author worked with four clay samples to duplicate Lucayan pottery. The clays are identified by color as beige, dark brown, tan, and white (Figure 2). Of these clays, only the tan clay was found usable in its natural state. Its body was plastic and workable, but very sticky. A small tile made from the tan clay was air dried and fired to 650^{o} C, a temperature within the range obtained in pit firing. The resulting tile held up well. When the lead author tried to form tiles from the other three clay samples to fire them, the results were not satisfactory. They were not plastic enough to be worked easily, nor did they hold up even after they were fired at low temperatures. While the body held together while air-drying, the tiles crumbled into small pieces soon after removal from the kiln, where they, too, had been fired to 650^{o} C. No attempt was made to try to clean or process the Bahama Red Loam, as the authors feel the Lucayans would have utilized the better clay resources that were available to them.

Processing the Clay

One of the stages in readying clay to be fired is to remove its impurities, and the Lucayans, much like modern ceramicists, would have processed or cleaned the clays that contained impurities. While we do not know the impurities of the clays used by the Lucayans, we suppose they were similar to the ones in the clays that Winter secured on San Salvador. Based on his experience as a potter, the senior author notes that one way that a contemporary potter might remove impurities would be to take freshly dug clay, dry it, and then break it up into smaller particles. The clay would then be made into a slip by putting it into a container of water, allowing it to slake for several hours. Then, the resulting clay slip would be stirred and sieved through at least a 40-mesh screen. After screening, the liquid slip would be allowed to settle for several hours, and then the excess water would be removed from the top. The remaining clay slip would then be allowed to dry to the right consistency for wedging. We theorize that the Lucayans cleaned or processed their clays in a different way than a modern potter would because they lacked fine mesh screens. Clay particles are about two microns in size, and many of the impurities we observed in the clays are also very small, ranging from about six to eight microns. The removal of these small impurities requires a fine screening technique. Although the Lucayans of the Late Lucayan period produced finely woven baskets, none of them observed so far by way of molds and casts from basketry-impressed Palmetto Ware, appeared to have been suitable for sieving (Berman and Hutcheson 2000). (That is not to say that sieves did not exist, but no evidence has yet been found). Therefore, the lead author employed a clay suspension process in order to obtain suitable clay.

Figure 2. Four clay samples taken from various San Salvador lakes, ponds and depressions.

Three clay sediments (beige, dark brown, and white) were put into a shallow bowl and covered with twice as much water as clay sediment. For each sample the clay sediment was broken up by hand, releasing the fine clay particles into a colloidal suspension in the water (Figure 3A). The water, with the suspended clay in it, was then poured off into another shallow vessel (Figure 3B) where it sat for a period of time until the clay particles settled to the bottom (Figure 3C). Any remaining water was then poured off, leaving behind the cleaned, pure, clay slurry, which was allowed to dry until it could be wedged (Figure 3D).

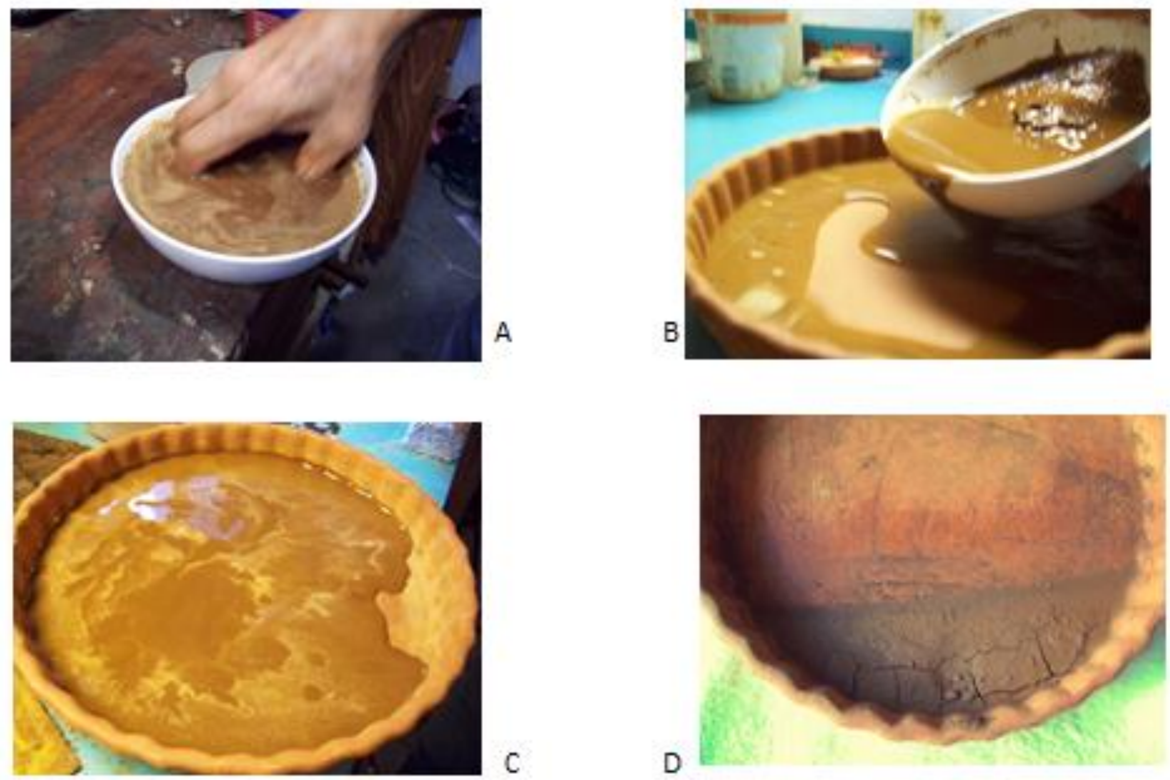
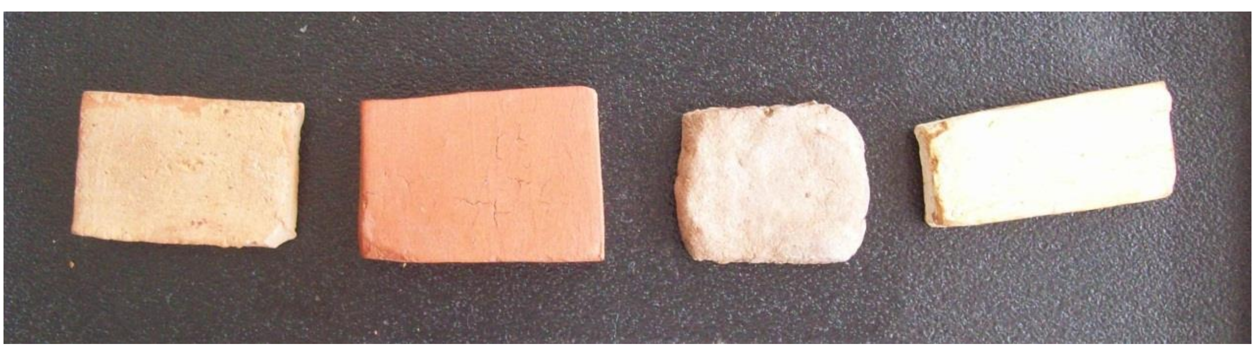


Figure 3. Cleaning or Refining Process for San Salvador Clays: (a) dissolving or washing the clay; (b) pouring off the suspended clay; (c) letting the suspended clay settle out; (d) cleaned clay, ready for wedging.



A **B** **C** **D**

Figure 4. Four fired tiles from different clay sources: (A) beige clay, cleaned twice; (B) dark brown clay, cleaned once, fired red; (C) tan clay, uncleaned; (D) white clay, cleaned once.

Experimenting with the Firing Process

Tiles of this cleaned clay, with no temper added, were fired at 650^o C. This resulted in the production of flawless tiles, but after sitting a few days, the beige tile began to craze. It was assumed that there was still too much calcium carbonate and other impurities remaining in the beige clay body. In an effort to improve the clay body, the cleaning process as described above was repeated to remove any fine impurities from the beige clay. The resulting clay slurry was then allowed to dry until it could be wedged. A second beige clay tile was then formed and fired at 650^o C. The resulting tiles of all four clays, after eight months, did not craze, though a few fine superficial cracks have formed (Figure 4). After nearly two years, the red clay tile formed from the cleaned dark brown clay soil did craze and became friable (Figure 5).

Figure 5. Crazed clay tile made from dark brown clay, after two years.

The Addition of Shell Temper, Sea Water, and Salt

The senior author found it difficult to make pottery from the San Salvador clays because they lacked workability due to their stickiness, especially the tan clay. It also was found that shrinkage was a significant problem. The test tiles made from this clay often formed small cracks when air-drying or after firing. A skilled potter would have corrected this problem by adding temper to the clay body. As we know from the pottery we find at Lucayan sites, the Lucayans added crushed shell temper to their clay.

The coralline limestone geology of the Bahama archipelago limited the Lucayan's choice of temper, but offered readily available sources such as beach sand or shell, which the Lucayans crushed to make temper. Unlike the neighboring islands of Cuba and Hispaniola to the south, the Bahamas lack metamorphic and igneous rocks. Beach sand in the Bahama archipelago is composed almost exclusively of calcium carbonate in the form of ooids, broken shells and corals, shell tests of one-celled animals such as foraminifera, and the remnants of calcium producing algae. The few silicate remains include sponge spicules and worm jaws. Most of the sand grains have been water worn, giving them rounded edges; thus, they lack the binding qualities for use as temper. Freshly broken shell, on the other hand, is uniform in its chemical composition ($CaC0_3$), while the variety of materials in beach sand makes it less suitable. Furthermore, crushed shell has angular edges allowing it to be better incorporated into the clay body (Mann 1986).

The problems associated with using shell temper have been well studied by many archaeologists, chemists, and ceramists because shell tempering has been and is used widely by numerous peoples from around the world (Rye 1976; Feathers 2006; Cogswell et al., 1998; Michelaki 2007). Shell ($CaCO_3$) calcinates when heated to a temperature between 620^o C and 900^o C, turning into carbon dioxide (CO_2) and calcium oxide (CaO). This chemical reaction can easily take place in ceramics that are fired in an open pit, which develops heat in this same temperature range. When the ceramics are removed from the pit fire and let to cool in moist or humid air, the water in the air (H_2O) will combine with the CaO, forming calcium hydroxide (CaOH), a larger molecule, which upon expansion causes cracking of the pottery as it cools (Rye 1986). This is the major reason why many contemporary ceramists would never consider using shell temper in their pottery. However, there is a good reason, other than its availability, why numerous peoples, like the Lucayans, used shell temper. Such temper provides thermal shock resistance in ceramics used for cooking; for the Lucayans this included vessels and griddles. As any modern cook knows, you cannot put most ceramic pots, bowls, or pans directly onto a gas flame or electric element without that pot breaking. Such ceramic pieces, like bread pans, pizza stones, or bean pots, are used only in ovens where they can be slowly brought up to temperature to avoid thermal shock. Given this scenario, how were the Lucayans able to bake cassava and/or maize on griddles, which would have been placed directly on a wood fire and not in an oven?

First, Lucayan pots are rounded and low sided (Figure 6), and the griddles are flat. Both shapes reduce crazing due to thermal expansion (Rye 1976). Second, temper that has a thermal expansion similar to that of the clay body will be better able to withstand direct heating from a cooking fire (300^o to 500^o C) without cracking (Rye 1976). The use of finely broken shell meets this requirement, as calcite has a thermal expansion close to that of clay fired at low temperatures (Rye 1976). The use of burned shell as temper is thought to work well, as it has the same expansion rate as the clay (Michelaki 2007). By burning the shell, its hydroxal water is driven off, resulting in the shell breaking into a platy shape, which allows easy orientation of the temper in the pot's wall. This makes the walls stronger, allowing for thinner walls and thus higher heat conductivity (Michelaki 2007). Most Palmetto Ware sherds observed by the authors consist of 35 percent or more shell tempering; often the shell temper fragments are gray-black and platy, which may indicate the use of burnt shell as temper.[2]

Figure 6. Lucayan Palmetto Ware bowl – rounded and low sided.

Using microprobe analysis, Mann (1986) found that seawater was most likely used in the making of Lucayan ceramics. Use of seawater in the making of shell-tempered pottery has been well documented by various researchers (Matson 1971; Arnold 1971; Laird and Worcester 1956; Rye 1976). The addition of saline water or salt to pottery when using shell as temper serves two purposes. First, the temperature range for the firing of the clay is significantly extended, to above $1{,}000^o$ C, before calcination takes place, forming CaO and CO_2. Secondly, the post-firing damage due to the formation of CaOH is reduced (Mann 1986, Rye 1976). The clay in the pottery can thus come closer to reaching full maturity because it is being fired at a higher temperature.

The senior author performed an experiment using twice-cleaned beige clay to which he added fresh crushed shell temper. These shells were not burnt or calcined; they were collected from the beach and were crushed using a hammer and anvil. Two tiles were made. Seawater was added to one tile and fresh water was used in forming the other. Both were fired to 900^{o} C, as this would be the highest temperature that a pit fire would reach. Both turned a reddish color and looked similar, but after sitting for two days, the one made with fresh water crumbled, while the one made with seawater revealed only minor crazing (Figure 7). The senior author also fired a tile made from unclean tan clay that was tempered with crushed shell.[3] It was fired at 650^{o} C. The resulting tile was later broken to compare it in cross section to a Palmetto ware sherd. They looked very similar (Figure 8).

All of the clays found by Winter came from inland lakes and ponds that contained saline or hypersaline waters. Seawater has an average salinity of 35 parts per thousand, while some of San Salvador's lakes have salinities as high as 60 to 70 parts per thousand. Thus the clays contain salt in varying amounts, even before seawater was used in processing the clays.

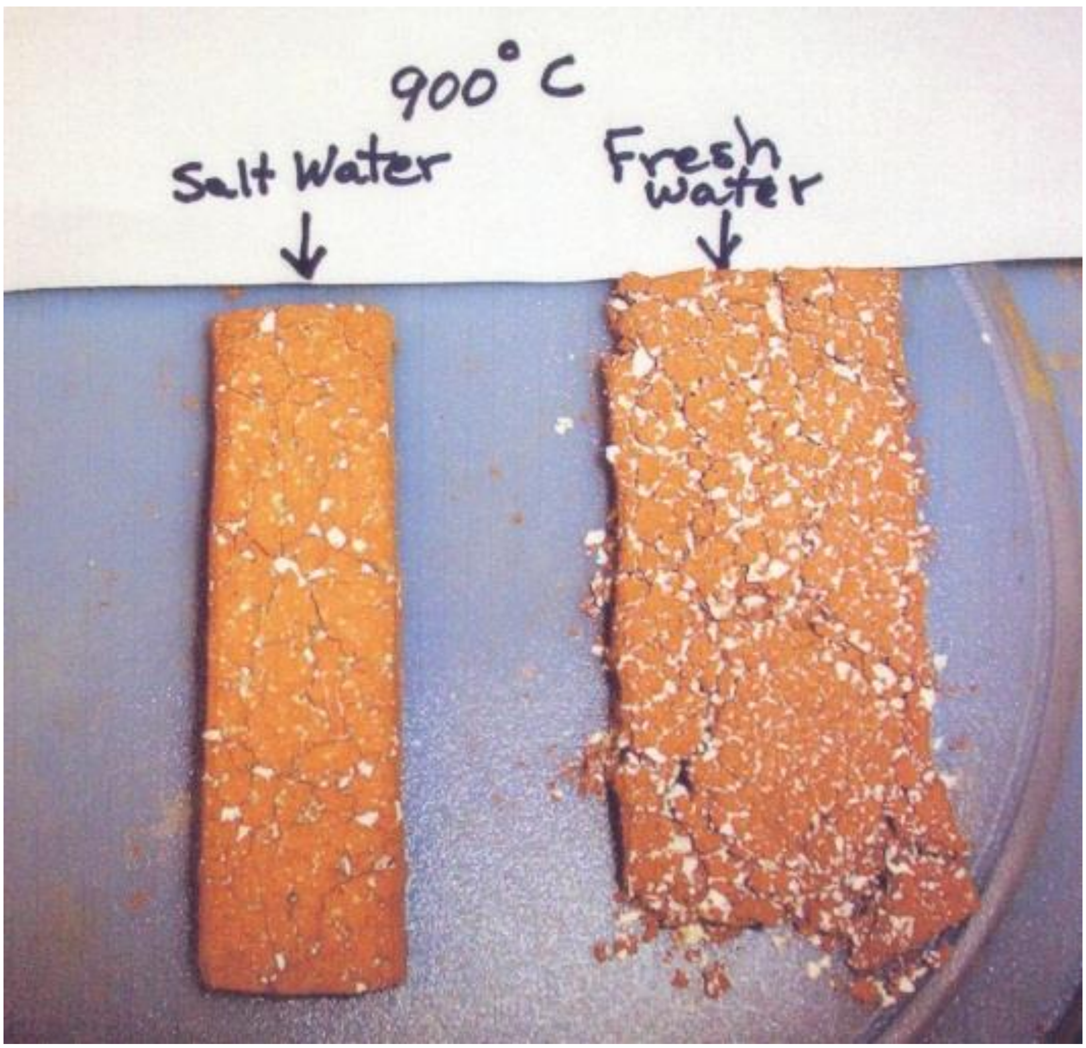


Figure 7. Tiles made of cleaned beige clay, both with shell temper, fired to 900^{o}C, and left to sit for two days. Left tile made with salt water, right tile made with fresh water.

Figure 8. Top sherd is Palmetto Ware. Bottom sherd made from Bahama clay.

Slipping the Clay

Slip is clay slurry about the consistency of heavy cream. Slip can be applied in several ways, either before or after a vessel is fired. The Lucayans applied slip to some of their vessels (Berman 2012; Sears and Sullivan 1978) (Figure 8). When the slip is put on green-ware (pottery that is fully formed and air dried but not yet fired), the slip will diffuse into the clay body. After air-drying, the slipped pot can be fired. Slip can also be applied to a vessel that has been bisqued; pottery that has been fired to the point where the clay body can no longer be returned to a plastic state. This method can be identified on those sherds of Palmetto Ware where a sharp delineation can be seen between the body of the pot and the slip when the broken edge of a sherd is viewed (Figure 9). Shell was observed in the slip, so it can be assumed that the same-wedged clay was used for vessel construction and making the slip.

Lucayan sherds that show slip were most likely from pots that held liquids. To test the porosity of the various fired clays, the lead author took each fired clay tile and held the edge of each in a bowl of water. All but the dark brown clay tile that fired to a red color, were found to be very porous, as the water seeped quickly into the clay and by capillary action moved up the tile (Figure

10). The red tile from the dark brown clay did not absorb the water very quickly, and no capillary action was observed. For this reason it is proposed that the dark brown clay was used as a slip covering on at least some Palmetto ware vessels. We have also seen one case of a white slip on a Palmetto ware sherd, which means the white clay could have also been used as a slip, as it does not change color when fired (Figure 11).

Figure 9. Two different applications of slip shown on one sherd. Slip on left side of sherd was put on the inside of the pot when it was green-ware. It was then fired or bisqued. Slip on right side of sherd was poured on the outside of the bisqued pot and fired a second time.

Firing

An open pit for the firing of pottery is constructed by digging a shallow pit in the ground, filling it with wood, laying unfired pottery on the top of that wood, and then adding more wood on top, which is then set ablaze (Rye 1976). A potter can change the temperature by using different woods. Soft woods would be used for lower temperatures, while harder woods would be used to achieve higher temperatures. Open-pit fires are naturally reduction fires, since there is an imperfect arrangement for burning the fuel (Rhodes 1959). Such reduction firing can produce temperatures up to 900^{o} C, but blackens the pottery during firing due to its smoky environment (Rhodes 1959). In porous pottery the smoke from the fire goes throughout the clay body, blackening the interior fabric of the vessels as well as the outside. This blackening of the pottery can be seen on broken sherds of Palmetto Ware, many of which are very porous.

Figure 10. Testing of porosity of beige clay after firing.

When an open pit is used, the pottery is subject to numerous risks. The fire can be too hot or too cold to achieve the desired result. Unexpected wind or rain can alter the temperature of the fire. The Lucayan potters would have been skilled in how and when to use an open pit for the firing of their ceramics. The potter has a choice as to when to remove the pottery from the open-pit fire. The ceramic can be retrieved once the potter feels it is finished or the pit can be covered once the fire has burned low to allow the pottery to cool more slowly. Because open pit firing only reaches maximum temperatures of about 900^{o} C, Lucayan ceramics were not fired to the point of vitrification, which takes place at temperatures over 1000^{o} C.

In the making of pottery there are two types of water that must be removed, interstitial and hydroxyl. Interstitial water is that found between the clay and temper molecules and is removed first by air-drying the pottery. If the air is humid, the amount of interstitial water remaining will be higher, resulting in more porosity or air spaces between molecules once the interstitial water is driven off during firing. The hydroxyl water is the water of crystallization, or the water that is actually part of the molecular structure of the clay. This water is also driven off during firing, allowing the clay to decompose and fill the pores left by the removal of the interstitial water. Because of the low temperatures of open pit firing (600^{o} to 900^{o} C), not all of the pores will be filled (Rye 1976:111). This under-fired pottery does not have the strength of those fired to total maturity or vitrification. To compensate for this lack of strength, the Lucayans made their pots and griddles thick. Sears and Sullivan (1978:12) note, for example, that griddles found on several islands in the central and southern islands, including the Turks & Caicos, range in thickness from 16-32 mm, with an average of 20 mm.

Having pottery with larger pores has some advantages, however. First, the pot is less apt to crack or break, since if a small crack does develop, it is stopped when it reaches a large pore. This is similar to stopping a crack in a large, plate glass window by drilling a hole at the end of the crack so it cannot expand further. Secondly, a pot with more pores will have higher thermal shock resistance. The larger pores allow the heat to be distributed more evenly throughout the vessel when it is placed on a cooking fire (Rye 1976). There is, however a disadvantage to having large pores, and that is the vessel's permeability to water. One way of making a pottery vessel better able to hold water or other liquids is to apply a slip to the body.

Figure 11. Left - Palmetto Ware shard with white slip. Right - Fired white clay tile.

Clay as a Trade Item

We believe clean, wedged clay was a product that may have been a highly valued item used in inter-island trade and exchange. San Salvador Island would have been a place where good clay resources could have been found more easily then on other islands in the archipelago. First, San Salvador is one of the easternmost islands in the Bahama archipelago, and thus closer to the aeolian clay source, Africa. Secondly, the vast inland lake network, which is not as common on other islands, would have provided a natural area where the clay particles would have concentrated as they were sorted out of the calcium carbonate soils by rain water. The lakes would have provided easier accessibility to larger amounts of clay then would be found in smaller sinkholes and solution depressions. Columbus, in his diary on October 15, 1492, wrote of a red soil that could be kneaded:

> …I found a man who was passing alone in a dugout from the island of Santa Maria (Rum Cay) and Fernandina (Long Island) and who was bringing a small amount of their bread, which was about the size of a fist, and a calabash of water and a piece of red earth made into dust and then kneaded and some dry leaves, which must be something highly esteemed among them, because earlier, in San Salvador, they brought some of them to me as a present. And he was bringing a little native basket in which he had a string of small glass beads and two *blancas;* because of which I recognized that he was coming from the island of San Salvador… (Dunn and Kelley 1989:85).

While the bread and water carried by the traveler would have been for his own use, it is obvious that the other items he carried in his dugout were valuable items to be exchanged; these included the glass beads and *blancas* that Columbus had traded with the Lucayans a few days before. Was it possible that the "piece of red earth" referred to clay? Could it be that clay, too, was such a trade item? Also, Columbus describes this piece of red earth as something "made into dust and then kneaded." This suggests he may have seen clay being processed on San Salvador or was familiar with potters' work from his other travels or experiences in Europe and Africa.

Conclusions

For years the authors questioned the making of Palmetto Ware from Bahama Red Loam. They believed that clay or finished pots may have been brought to the Bahamas from the Greater Antilles, since local clay sources had not been found on the islands. Winter's discoveries of numerous clay sources changed these perceptions and contributed to a finer grained understanding of the islands' geological composition. Those who conducted the early soil studies of The Bahamas were not aware of the clay deposits in the inland lakes, so they were never described in the literature.

From this study, we suggest that Palmetto Ware ceramics were not made from Bahama Red Loam, but were manufactured from local clays found in solution depressions and other collecting basins of the islands, such as inland lakes and ponds. The clays themselves are the result of aeolian dust from Africa, which were water sorted and deposited by rain into these lower levels of the island. The authors believe that archaeologists working in the Bahama archipelago should consider redefining Palmetto Ware pottery as being made from Bahama clay or clays and not Bahama Red Loam.

These clay resources were often usable as found, but may have had to be cleaned and processed by the Lucayans. This could have been accomplished by using a slurry suspension method to produce wedged clay. Because of the stickiness of the clays, a great deal of temper was required to produce clay suitable for wedging. The Lucayans used crushed shell, which was probably burnt before it was added to the clay as temper. Shell was readily available and its use would insure that the finished pot or griddle could be used for cooking on an open wood fire without damaging the pot.

Most of the Bahama clays come from inland lakes and ponds that are naturally hypersaline. This salinity in the clay allows for the use of shell temper without the shell calcinating when the pottery is fired. The Lucayans also may have used seawater in the making of their pottery as it was readily available and would not dilute the original salinity of the clay. Some of the clays were found to be less porous then others, so these would have better served as slip, which was applied onto Palmetto Ware vessels that were to be used to hold water and other liquids.

We theorize that there were extensive clay resources on San Salvador when the Lucayans first arrived, but these resources became depleted. This may be proved by comparing the quality of Lucayan ceramics from Early and Late Lucayan period sites. Granberry and Winter (1995) have found, for example, that hardness and amount of shell temper varies among different varieties (or styles as they call them) of Palmetto Ware. Berman (2012) has observed that pottery from Early Lucayan period sites is thinner and harder and contains less shell temper than Late Lucayan period pottery.

There are numerous studies that can be conducted to further test the findings presented in this paper. Exploration for clay resources on other islands in the Bahama archipelago should be undertaken, the locations should be noted and mapped, and X-ray diffraction of the clay resources should be made to determine their percentages of clay. Thin-section and mineralogical studies could be performed, especially comparing clay deposits and Lucayan pottery, with an emphasis on known early and late archaeological sites to determine if clay resources were becoming limited over time, and thus more valuable.

Notes

1. The senior author was shown a piece of dried, wedged, tan colored clay in the early 1970’s by the Commissioner on Great Exuma. It had been found in a cave there, and the Commissioner, knowing of the archaeological work at the field station on San Salvador, offered to give it to the field station. Feeling it should remain on the island on which it was found, the offer was refused, but at this time an analysis of that wedged clay would have been helpful in this study.

2. Sears and Sullivan (1978:12) observed that crushed shell temper constitutes 10-25 per cent of the clay matrix. However, the assemblages they studied came from numerous islands in the Bahama archipelago, not one island.

3. Martin Fuess (1987) replicated Lucayan pottery for his Hartwick College B.A. honors thesis in anthropology. He used clays from an inland lake and a solution depression. By using these clays and adding calcined shell temper and salt water, he succeeded in firing tiles that closely replicated the ceramics of the Lucayans.

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