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# Underwater Excavations of Two Ancient Maya Salt Works, Paynes Creek National Park, Belize

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UNDERWATER EXCAVATIONS OF TWO  
ANCIENT MAYA SALT WORKS,  
PAYNES CREEK NATIONAL PARK, BELIZE

A Dissertation

Submitted to the Graduate Faculty of the  
Louisiana State University and  
Agricultural and Mechanical College  
in partial fulfillment of the  
requirements for the degree of  
Doctor of Philosophy

in

The Department of Geography and Anthropology

By  
Elizabeth Cory Sills  
B.A., University of Texas at Austin, 1999  
M.A., Louisiana State University, 2007  
May 2013

*In Memory of John Jefferson MacKinnon*

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## **Abstract**

Underwater excavations were conducted at an Early Classic (A.D. 300-600) and a Late Classic (A.D. 600-900) submerged ancient Maya salt works in Paynes Creek National Park, Belize. The archaeological investigations included underwater excavations, artifact analysis, marine sediment chemical testing, and source identification of obsidian—an important indicator of trade. The excavation and analysis of the salt works in Paynes Creek add a new perspective on ancient Maya craft production and the economies of other ancient civilizations.

The archaeological excavations reveal activity areas associated with a substantial salt industry for distribution to the southern Maya inland inhabitants, where this biological requirement was scarce. The salt works intensified production related to the dramatic population increase from the Early to Late Classic. Analysis of obsidian blades from the salt works by portable X-ray fluorescence indicates that the salt makers took advantage of their coastal location to trade inland to the large cities and along the coast.

The salt works are associated with the only known ancient Maya wooden architecture forming rectangular buildings. Transect excavations placed to extend through the interior and exterior of buildings reveal an abundance of briquetage—ceramic vessels used to evaporate brine over fires to make salt. The plethora of briquetage and charcoal and the scarcity of domestic artifacts indicate that the sites were specialized and not physically attached to households. The briquetage is located within and surrounding the wooden building indicating that salt production was an indoor activity.

Sea-level rise submerged the Paynes Creek salt works and preserved wooden architecture in a red mangrove peat bog. The slightly acidic peat preserved wood and other botanical remains but is not conducive to the preservation of bone. Consequently, the examination of the artifacts

may be biased against the preservation of animal food remains and human burials which are typically found at Maya settlements. The results of chemical sediment analysis indicate activity locations inside and outside of wooden architecture not shown by the artifact assemblage.

## **Chapter 1**

### **Introduction**

For my dissertation, I conducted a comparative study of two ancient Maya salt works to evaluate past Maya activity patterns in Paynes Creek National Park, Belize. Underwater excavations were carried at the submerged salt works of Early Classic (A.D. 300-600) site Chan B'i and Late Classic (A.D. 600-900) site Atz'aam Na. The investigations were conducted at the place of salt production to evaluate spatial activity patterns inside and outside of wooden buildings. I report the methodology and results of transect excavations, artifact analysis, and sediment analysis.

The salt works are underwater in a shallow salt-water lagoon system, Punta Ycacos Lagoon, in Paynes Creek National Park (Figure 1). Relative sea-level rise submerged the Paynes Creek sites and preserved wooden architecture, as well as large fragments of briquetage—pottery used to evaporate brine in pots over fires to make salt (McKillop 1995, 2002, 2005a, 2007; Sills and McKillop 2010). The peat preserved wood and other botanical remains, but is not conducive to the preservation of bone. Consequently, the artifactual record may be biased against the preservation of animal food remains and human burials typically found at Maya settlements.

Wooden architecture is rarely preserved from ancient times in the Maya area (McKillop 2005a). Organic artifacts at terrestrial sites in the tropics usually have poor preservation. In contrast, sites submerged underwater can yield preserved organic artifacts as well as large non-perishable goods (McKillop 2007). Evidence of physical architecture in the Maya area includes the urban center temples made from limestone and sandstone, post molds located below the topsoil during excavation, and rarely, as at Cerén where a village is preserved by volcanic tephra, actual wood (Sheets 2002). The underwater sites in Paynes Creek National Park have the wooden architecture preserved because they are buried in anaerobic peat. Sea-level increased



Figure 1. Map of Maya area showing the location of Paynes Creek National Park.

after the Late Classic abandonment and inundated the salt works, protecting them in mangrove peat and saline water. The submersion of these sites preserved the wooden architecture, as well as large fragments of briquetage.

Previous research (McKillop 1995, 2002, 2005a) indicates the sites were salt works—and may be specialized and not associated with households—an interpretation that will add a new



dimension to our understanding of economic production and distribution in ancient civilizations such as the Maya. Within the Maya area and Mesoamerica, productions of subsistence products like salt are viewed as part of the household economy. In contrast, the salt works in Paynes Creek do not conform to the standard layout of workshops found at urban centers (McKillop 2005a, 2007; Sills 2007; Sills and McKillop 2010; Somers 2007). The salt workshops in Paynes Creek are not connected physically to urban centers, such as Aguateca, where attached workshops produced goods for the royal elite (Aoyama 2007; Emery and Aoyama 2007; Emery 2009; Inomata 2001). The salt works are distinct from the household workshops at Colha in northern Belize where stone tools were mass produced (Shafer and Hester 1983).

### **Situating the Research**

This dissertation project is part of a NSF funded project, “Ancient Maya Wooden Architecture and the Salt Industry,” directed by Dr. Heather McKillop and colleagues (Harry Roberts, Karen McKee, and Terance Winemiller). The current research in the lagoon is a continuation of previous projects conducted along the coast in southern Belize (McKillop 1995, 1996, 2002, 2004, 2005b, 2007; McKillop and Healy 1989). Research at the Paynes Creek salt works began with the discovery and excavation of three submerged sites—Stingray Lagoon, David Westby, and Orlando’s—and one terrestrial site, Killer Bee (Braud 1996; McKillop 1995, 2002). Attribute analysis of the briquetage from these sites found that the salt pots were standardized leading to an interpretation that salt was mass produced. This interpretation differed from previous discussions regarding salt production where the main producers were said to be from the Yucatan and that the southern Maya lowlands were not sufficient in meeting the dietary demands on the inland city dwelling Maya (Andrews 1983; MacKinnon and Kepecs 1989).

In 2003 and 2004, return visits to Paynes Creek found additional salt works and in 2004 discovered the only known ancient Maya wooden architecture (McKillop 2005a). During systematic survey at the site of K'ak' Naab', an ancient Maya canoe paddle dating from A.D. 680-880 was discovered. The remarkable preservation of wooden architecture and a wooden canoe paddle led to a NSF funded multi-year investigation "Mapping Ancient Maya Wooden Architecture on the Seafloor," of which I was a member. I completed my M.A. thesis on the project (Sills 2007; Sills and McKillop 2010). Spatial analysis of the wooden posts at the Paynes Creek salt works indicates they form rectangular structures and other ancillary structures associated with salt making (McKillop 2005a, 2007; Sills 2007; Sills and McKillop 2010; Somers 2007).

Mapping the wooden architecture at the site of Chak Sak Ha Nal revealed exterior and interior walls of buildings (McKillop 2005a). The wooden architecture consists of robust hardwood posts forming buildings and lines of palmetto palm posts that are spatially separated from the hardwoods. The palmetto palms tend to occur at equally spaced intervals. They have been interpreted as retaining walls (Sills 2007; Sills and McKillop 2010; Rosado, McKillop, and Sills n.d.). Recent research on the marine sediment on either side of the lines of palmetto palm posts from sites Chan B'i and Atz'aam Na indicates that occupation levels are identified between 35 cm and 60 cm depth from the sea floor (Rosado, McKillop, and Sills n.d.).

The mapping of wooden architecture and piece plotting of artifacts at the site of K'ak' Naab' reveal the interior of buildings were swept clean of debris that was subsequently discarded outside the building (McKillop 2007). The ceramic analysis of collected artifacts including types such as "unit stamped" pottery linking the salt works to the inland cities of Lubaantun, Seibal, Altar de Sacrificios, and the Petexbatun region (McKillop 2002).

For my dissertation fieldwork, transect excavations were carried out in June 2010 to evaluate the spatial patterning of artifacts and their relationship to wooden architecture. Two transects were placed across Chan B'i and Atz'aam Na, forming a cross shape. The transects were placed to extend across the site—as defined by the surface distribution of artifacts—and to include inside and outside areas of buildings. The artifacts—mostly briquetage—were analyzed to determine the degree of standardization. Chemical marine sediment analysis was conducted to find and locate any additional activities that might have occurred at the salt works not shown by the artifact assemblage or wooden architecture. Obsidian sourcing was accomplished to link the salt works with the wider ancient Maya economy.

### **Research Questions**

The salt works in Paynes Creek were found by the presence of artifacts and embedded wooden posts that form buildings on the surface of the sea floor. The clustering of features and artifact scatters can provide information on workshops, households, and activity areas (Parsons 1971; Sanders et al. 1979; Spence 1981). Usually a high density of artifacts in one area can be used to interpret the function of structural features and workshops (Leventhal and Baxter 1988). However, artifacts after use are often discarded in a midden or reused. The transect excavations at Chan B'i and Atz'aam Na were directed to distinguish different types of activities inside and outside of buildings. Were the salt works dedicated to the single activity of salt making? Or were the salt works part of household workshops or engaged in “multi-crafting”? Is there evidence of other activities at the salt works? The research focused on determining whether the Paynes Creek salt works focused on producing enough quantities of salt to meet the dietary needs of the inland Maya—alternatively, were there other activities or even settlement? Salt does not preserve in the archaeological record. Instead, archaeologists use the material remains left

behind at salt works to investigate concepts of trade and the role of the salt works in the larger ancient Maya economy. Based on the artifact assemblage can we distinguish trade relationships?

The two sites chosen for this study include Chan B'i dating to the Early Classic (A.D. 300-600) and Atz'aam Na dating to the Late Classic (A.D. 600-900). Are there any changes in the material deposits between the two sites? If so, was there an intensification of production related to the dramatic population increase from the Early Classic to the Late Classic. The Late Classic period experienced a boom in population. Turner (1990:186) estimates that at the height of the Late Classic, Maya populations reached between 2,663,000 and 3,435,000.

Uxbenka is the only known site in southern Belize established in the interior during the Early Classic period. Wild Cane Cay and Pelican Cay had settlements that were established during the Early Classic (McKillop 1987, 2002, 2005b). Southern Belize experienced an increase in settlements during the Late Classic. They include the larger interior settlements of Lubaantun, Nim li punit, and Pulsilha. Wild Cane Cay became a major trading port in the Late Classic, expanding further throughout the Postclassic (McKillop 2005b). Other coastal communities dated to the Late Classic in southern Belize include Village Farm, Frenchman's Cay, and Pork and Doughboy Point, among others (McKillop 1996, 2005b).

In order to answer some of these questions, this dissertation is organized using the journal style. After the introductory chapter, Chapter 2 presents an article manuscript describing the environmental context and physical landscape at the two Paynes Creek salt works. The fieldwork methods are discussed focusing on strategies used to investigate submerged archaeological sites. The article concludes with a description of the artifact assemblage.

Chapter 3 includes discussion of the activity areas associated with the substantial salt industry in Paynes Creek based on the wooden architecture and salt making artifacts. The

excavations recovered an abundance of briquetage—ceramic vessels used to evaporate brine by heating over fires to make salt. The spatial distribution of briquetage is evaluated in relation to the interior and exterior of buildings and lines of palmetto palms posts.

Chapter 4 includes a discussion of the results of chemical analysis and trace element testing undertaken on marine sediment samples from Chan B'i. Chemical soil testing such as inductively coupled plasma-optical emission spectroscopy (ICP-OES) and inductively coupled plasma-mass spectroscopy (ICP-MS) have been used at other sites by researchers to detect concentrations of chemical elements that allow the identification of activity areas. The chemical analyses were carried out on marine sediment samples along two excavated transects at Early Classic salt work Chan B'i to detect evidence not found in the artifactual record.

Geochemical analysis of obsidian blades recovered from the Paynes Creek salt works is examined in Chapter 5. The results of assaying 40 obsidian blades using portable X-ray fluorescence are presented as well as the sourcing the results with principal component analysis. The source results from the obsidian blades are used to develop concepts concerning trade and the role of the salt works in the larger ancient Maya economy.

The final chapter includes the conclusion of my dissertation by answering the posed research questions. The chapter concludes with a brief discussion of current and future research to be initiated based on the findings including exhibits of artifact replicas from the underwater sites (McKillop and Sills 2013).

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**Chapter 2**  
**Underwater Excavations of Classic Period Salt Works, Paynes Creek National Park, Belize**  
Elizabeth C. Sills and Heather McKillop

**Introduction**

Classic Maya wooden architecture is preserved underwater in a peat bog below the seafloor in Punta Ycacos Lagoon—a shallow lagoon system in Paynes Creek National Park, southern Belize (Figure 2). The wooden architecture forms buildings and structures for workshop production of a biological necessity, salt (McKillop 1995, 2002, 2005a; Sills and McKillop 2010). Underwater excavations were undertaken at two ancient Maya salt works. These sites are Early Classic (A.D. 300-600) Chan B'i and Late Classic (A.D. 600-900) Atz'aam Na. The salt works are associated with the Classic Maya salt industry that produced salt for inland trade. With the only known preserved ancient Maya wooden buildings, the underwater excavations have the advantage of exploring salt production inside and around actual structures.

Organic artifacts in the tropics usually have poor preservation due to exposure to warm, moist, and unprotected environments. However, underwater environments can preserve artifacts such as wood and other organics not commonly found at terrestrial archaeological sites. Underwater archaeology in the Maya area has focused on cenotes on the Yucatán Peninsula, coastal islands, and nautical investigations (Andrews and Corletta 1995). These particular environments have preserved extinct animal bones, Paleo-Indian skeletons, and charcoal from hearths in submerged caves near the coast in the Mexican states of Yucatán and Quintana Roo (González et al. 2008). Recent investigations of cenotes in the Yucatan have uncovered numerous well-preserved human skeletons (Rojas et al. 2008). Underwater diving in pools associated with Cara Blanca in Belize yielded well preserved fossilized mega fauna (Lucero et al. 2011).





Figure 2. Map of Belize and surrounding countries showing location of study area. Map by C. Sills adapted from ESRI® ArcMap™ 9.3.1 ©1999-2009.

Submerged archaeological deposits on the coast and cays of southern Belize allows investigation of the nexus of human interaction and the environment. Excavations at the Classic to Postclassic (A.D. 300-1500) trading port on Wild Cane Cay in the Port Honduras nearby the

Paynes Creek underwater sites revealed deeply buried deposits extending to 140 cm below the water table (McKillop 2005b). Offshore excavations at Wild Cane Cay yielded intact buried deposits submerged by eustatic sea-level rise (McKillop 2002, 2005b). Excavations of two mounds on nearby Frenchman's Cay yielded coral architecture platform foundations 80 cm below present-day sea level (McKillop et al. 2004). Transect surveys away from the coral architecture revealed midden deposits well below the water table, as at nearby Wild Cane Cay (McKillop et al. 2004).

Other Classic Maya sites with buried deposits in Port Honduras include Pelican Cay and Pork and Doughboy Point. At the small mangrove island of Pelican Cay, Late Classic deposits are found buried under 40 cm of mangrove peat (McKillop 2002). Stratigraphic excavations revealed mangrove peat underlain by mixed mangrove peat and clay that overlays a base layer of coral sand and finger coral. Sea-level rise occurred before the Late Classic occupation with the formation of mangroves over the base layer and then continued after site abandonment as the mangroves kept pace with rising seas. At the partially inundated coastal site of Pork and Doughboy Point excavations revealed at 55 cm below sea level that the site dates to the Late Classic and Terminal Classic periods (A.D. 600 to 900; Brandehoff-Pracht 1995; McKillop 2002). The presence of intact stratigraphy that is currently below sea-level indicates that sea-level rise occurred after site abandonment.

On the southern coast of Belize, specialized salt making sites are submerged below sea level in Punta Ycacos Lagoon, Paynes Creek National Park. The excavated sites of Stingray Lagoon, David Westby, Orlando's Jewfish, and the Killer Bee site have artifacts embedded in mangrove peat (McKillop 1995, 2002). Stingray Lagoon is at least one meter underwater

whereas David Westby and Orlando's Jewfish are in shallower water. The Killer Bee site is located in a mangrove ecosystem inundated by tidal fluctuations.

Submerged archaeological sites that yield organic artifacts and materials not often found at terrestrial sites can add a new assemblage for interpreting sites that are on dry land. The conjunction of human occupation with environmental data has the ability to integrate different types of data sets for interpreting the archaeological record. Investigations at the underwater salt works in Paynes Creek have yielded an abundance of preserved wooden architecture as well as artifacts and are a good environment to explore the salt makers occupation and environmental conditions before, during, and after occupation.

### **Marine Landscape of Punta Ycacos Lagoon**

Punta Ycacos Lagoon is an estuarine lagoon dominated by a typical mangrove ecosystem. The surface of the sea floor is firm mangrove peat overlain with a layer of loose silt. Rhizophora mangle (red mangrove) is the dominant species found fringing the edges of the lagoon and in isolated stands in the lagoon. Avicennia germinans (black mangrove) and Laguncularia racemosa (white mangrove) are found behind R. mangle away from the fringe of the lagoon. The successional location of mangroves in Punta Ycacos Lagoon is typical of mangrove forest environments (Tomlinson 1986).

The lagoon system is supplied with salt water from the Caribbean Sea to the east and fresh water from Freshwater Creek. In the past, the lagoon system may have been part of the Monkey River deltaic system to the north (McKillop 2002; Wright et al. 1959). Water depths in the lagoon system reported by Purdy and Gischler (2003) range from 20 cm to 6 m in deeper channels. The deepest underwater sites in the lagoon discovered so far are 1.5 m below water at

the seafloor surface of the sites. Field observations at Chan B'i and Atz'aam Na, located in the shallow Eastern Lagoon, recorded an average of 44 cm below sea level.

Microscopic analysis of excavated sediment from below the sea floor at the underwater site of K'ak' Naab' indicates the peat is composed of R. mangle (McKillop, Sills, and Harrison 2010a and b). R. mangle is the dominate species throughout the entire 1.5 m excavated sequence. Loss-on ignition testing of sediment indicates that the organic content of the excavated marine sediment averages over 65%, which is high and typical of mangrove peat sediment. Radiocarbon dating of the uppermost and lowermost samples shows a 4,000 year record of mangrove accumulation. The analysis of excavated sediment resulted in establishing an occupation surface at the time of the Paynes Creek Classic Maya salt industry of approximately 132.7 cm below the current sea level (McKillop, Sills, and Harrison 2010a and b).

Previous investigations of the Paynes Creek sites indicate that the artifacts lie directly on or are embedded in the sea floor (McKillop 2005a, 2007; Sills and McKillop 2010). The peat, an anaerobic sediment, creates an environment that preserves organic remains such as wooden posts and the only known ancient Maya canoe paddle from the site of K'ak' Naab' (McKillop 2005a; McKillop, Sills, and Harrison 2010a and b). The preserved wooden posts are embedded into the peat with only the worm eaten portions of the wood to mark their presence protruding above the seafloor (McKillop 2005a; Sills and McKillop 2010). The slightly acidic quality of the mangrove peat does not provide a suitable matrix for the preservation of bone or shell.

Investigations within Paynes Creek confirm that salt works were close to the source of brackish water required to evaporate in pots over fire to make salt. The presence of artifacts on the surface of the peat and wooden posts driven into mangrove peat indicates that the mangroves

in Paynes Creek National Park were able to keep pace with sea-level rise until sometime after the Late Classic abandonment (McKillop, Sills, and Harrison 2010a and b).

### **Underwater Excavations**

Underwater excavations were undertaken at Chan B'i and Atz'aam Na in 2010 with a team of nine researchers, including the authors. Prior to underwater excavations, Chan B'i and Atz'aam Na were relocated using a GPS unit to find the PVC datum marker for each site. The datum markers had been sunk into the seafloor to hide the sites. Once relocated, the PVC pipes were raised above the water to help relocate posts that had been discovered and mapped in 2007. The wooden posts were relocated by referring to a site map created in our project GIS. The paper map was placed into an archival plastic bag to keep the map dry in the water and attached to a clip board (Figure 3). The map was useful in determining the general location of the wooden posts and by feeling the sea floor for the markers that had been sunk into the seafloor on the north side of each post after discovery and total station mapping. The markers consisted of plastic flags labeled with the post number. The flags were furled and placed inside plastic drinking straws that were sunk into the seafloor. Furling flags into straws and sinking them protected the sites, since their locations were clearly marked by a sea of flags during each field season. Once the posts were relocated we placed a red pin flag into the peat on the north side of each wooden post so the post locations were visible above the water. A systematic flotation survey on research flotation devices (RFDs) was conducted across the site to determine the spatial extent of the artifacts. The boundaries of artifacts were marked by flags. The team snorkeled on the RFDs shoulder to shoulder, pivoting at the end of each row to cover the entire site, marking posts on the way.

Two transects were placed across Chan B'i and Atz'aam Na respectively, forming a cross shape. The transects were placed to extend across the site—as defined by the surface distribution

of artifacts—and to include inside and outside areas of buildings. The transects were laid out using a compass and a 30 m tape. The ends of each transect were marked with long PVC pipes



Figure 3. Relocating wooden posts at Chan B'i (photo by H. McKillop).

pushed into the seafloor. The tape was stretched tight between the two PVC pipes. Short lengths of ¼" PVC pipes were placed into the sea floor at each meter mark (Figure 4). Excavations proceeded along each transect using a metal grid frame measuring one by one meters. The frame was oriented by placing it along the PVC pipes that marked the meter marks. The grid was weighted down with five pound dive weights to keep it in place during excavations. Excavators placed their hands firmly on the seafloor and collected all surface artifacts. The artifacts were placed into a bucket with holes on all sides to drain the water. Each bucket with the excavator was photographed showing the relative amount of artifacts collected before transferring the artifacts into labeled plastic bags (Figure 5). Gross estimates of the excavated material and unit sediment descriptions were written in an underwater notebook. At night at our field camp, the

notes were transferred into our daily field journals. The plastic bags were labeled using a black sharpie and included the site number, unit designation, date, and the collector's initials. Fragile



Figure 4. Setting up a transect at Chan B'i (photo by H. McKillop).



Figure 5. Artifacts collected from a unit on the sea floor (photo by H. McKillop).

artifacts were placed into separate labeled bags. The plastic bags were ordered by unit and placed into the Portable Research Station before transferring them to our larger ocean going vessel. The location of the transects were mapped using a Topcon GTS-725 total station and

downloaded each evening and attached to the GIS GeoMedia® by Intergraph™ for analysis in relation to the previously recorded wooden architecture.

The artifacts were studied at the field lab in Belize. After freshwater rinsing and drying, the artifacts were separated into material classes. The ceramics were sorted according to the type-variety classification for Maya pottery which is useful for developing a site chronology. Most types fit within existing classifications for the Paynes Creek area (McKillop 1995, 2002). All ceramics and stone tools were photographed. All ceramic rim sherds, necks, bases, ceramic vessel supports, sockets, and stone tools were drawn.

Marine sediment was excavated to explore the relationship of the environment to the salt works (Rosado, McKillop, and Sills n.d.). The purpose the study is determine the species composition of the sediment, the amount of organic material, and to establish an occupation level at the time the salt works were in use.

Each sediment column was excavated to a depth of 60 cm. A hole was excavated in the sea floor to expose a vertical face from which to excavate 10 cubic cm blocks of mangrove peat. The mangrove peat was cut in 10 cm levels using a clean stainless steel knife. The depth of each excavated level was measured with a cloth tape (Figure 6). The excavated samples were wrapped in plastic cling wrap and placed into a larger plastic bag marked with provenience. The sediment was exported to the Louisiana State University Coastal Archaeology research lab under permit from the government of Belize Institute of Archaeology.

### **Excavations at Chan B'i and Atz'aam Na**

Chan B'i consists of at least one rectangular building with room divisions. The site also has two lines of palmetto palm posts (*Accelracea wrightii*) that fan out from the building (Figure 7). Two transects were placed perpendicular to each other in order to excavate the inside



and outside of the building. Transect excavations were placed based on the layout of the structure. Observations were recorded during the 2006 systematic survey of the site conducted to locate wooden posts. The abundance of briquetage observed during the 2006 survey suggested that the architecture at the site is associated with a salt production workshop and not a residential structure.



Figure 6. Roberto Rosado excavating a sediment column sample at Chan B'i (photo by H. McKillop).

Transect 1 was 18 m in length, placed to extend across the site in a northeast to southwest direction. The transect covered the inside of the wooden building and extended beyond in both directions to an open area defined on the outside by lines of palmetto palm posts. Transect 2 was 24 meters in length, at a right angle to Transect 1. Transect 2 also included the interior of the structure as well as the outdoor space defined by the two lines of palmetto palm posts.

Five sediment columns were excavated by Roberto Rosado for his M.A. research. Only Column's 1 and 3 were analyzed for research. Four of the sediment columns were excavated on the outside of the two lines of palmetto palm posts and one column was excavated between the two lines.

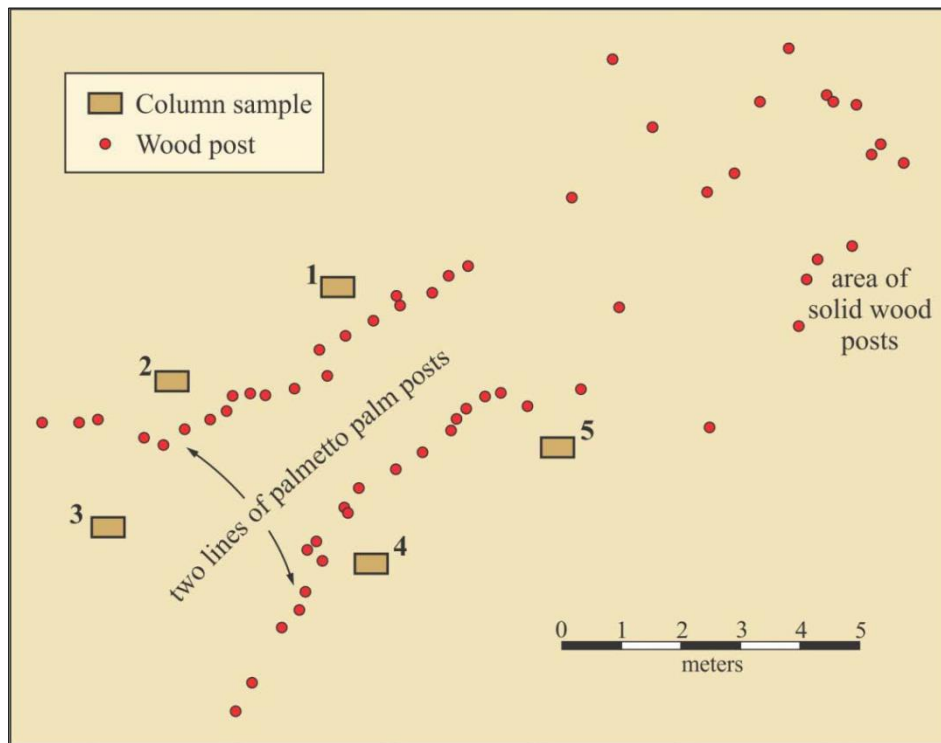


Figure 7. Map of Chan B'i showing wooden architecture and excavation locations of sediment columns (drawing by Mary Lee Eggart from GIS map by H. McKillop).

Atz'aam Na was systematically surveyed for wooden architecture in 2006. The site was determined to be another salt work associated with wooden architecture. The site has one rectangular building with no visible room divisions (Figure 8). Seven palmetto palm posts that form a line were mapped 15 m to the southwest of the building. Underwater excavations were placed to examine differences in the presence, type, and abundance of artifacts inside and outside of the building.

Two long transects were laid out and excavated in 1 x 1 m units. Transect 1 was 15 m in length and placed along the interior of the rectangular wooden building. Transect 2 was placed perpendicular to Transect 1 and was 24 meters long. Transect 2 intersects Transect 1 inside the building and extends to the line of seven palmetto palm posts.

The two sediment columns were excavated directly to the north and the south of the seven palmetto palm posts. As with the sediment column taken from Chan B'i, the two columns were excavated to 60 cm below the sea floor.

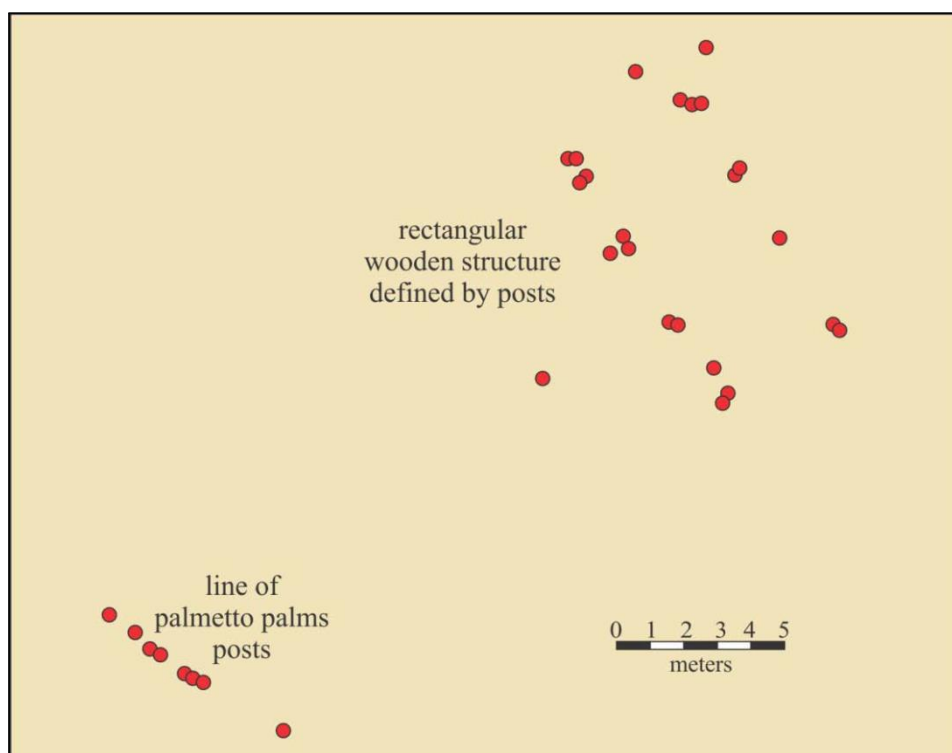


Figure 8. Map of Atz'aam Na showing the rectangular wooden building and the line of palmetto palm posts (drawing by Mary Lee Eggart from GIS map by H. McKillop).

The majority of artifacts at both sites are briquetage—ceramic vessels used to evaporate brine over fires to make salt. Both Chan B'i and Atz'aam Na had an abundance of briquetage inside the buildings. The term briquetage includes ceramics associated with salt production including pottery vessels, cylinders, spacers, sockets, bases, and amorphous clay lumps (ACLs).

The majority of pottery vessels are Punta Ycacos Unslipped jars and bowls that are easily identifiable due to their friable nature and sand temper. There was also an abundance of ACLs that include the fragmentary pieces of the support structure for holding the pots over fires. The solid clay cylinders are vessel supports used to lift the pots over fires and are made from clay that is not well mixed as evidenced from the rolling formation of the cylinders visible in cross sections. Very few spacers, used to separate the individual pots, were collected. Few complete sockets, the part at the top of the cylinder for placing the pot, were recovered. Lacking also are bases which are the clay on the base of the solid clay cylinders. There was abundant charcoal, which was mixed with ACLs that may have been placed in the fires to help retain heat over the slow evaporation process of making salt.

Other types of pottery comprising a minimal amount of the overall assemblage were also found inside of the wooden buildings. The types include Mangrove Unslipped, Warrie Red, and Moho Red (see McKillop 2002 for type descriptions). Mangrove Unslipped and Warrie Red have the function of water jars. They were used as vessels to store water or brine. Moho Red includes serving vessels. There are some artifacts used in ritual such as a figurine whistle fragment, candeleros, and fragments of an incense burner.

There is an absence of briquetage between the wooden buildings and inside the lines of palmetto palm posts. The diminished amount of artifacts in this area is as interesting as the presence of artifacts within the buildings. This absence of artifacts indicates that no fires or salt making was occurring in this area. Instead, we interpret the lines palmetto palm posts as retaining walls to keep water out of the salt works (Sills and McKillop 2010). No artifacts were collected outside the lines of palmetto palm posts.

An NSF dissertation grant is providing funding for ongoing analyses of excavated material and typological analyses of artifacts. The ongoing analysis includes chemical testing of marine sediment, neutron activation analysis of pottery, 3D imaging, and radiocarbon dating. Three-dimensional imaging is under way at Louisiana State University on the Digital Imaging and Visualization (DIVA) Lab in order to scan pottery sherds.

## **Conclusions**

The underwater excavations along with the sediment column excavations demonstrate the benefits of environmental and archaeological research. The artifacts lying on the surface and embedded in the mangrove peat have undergone cultural and environmental transformations. The settling of the salt makers in the lagoon along with rising sea levels and peat development has impacted the environment at the two sites.

Evidence of physical architecture in the Maya area includes the urban center temples made from limestone and sandstone, post molds located below the topsoil during excavation, and rarely, as at Cerén where a village is preserved by volcanic tephra, actual wood (Sheets 2002). The underwater sites in Paynes Creek National Park have the wooden architecture preserved due to peat, an anaerobic sediment. Sea-level increased sometime after the Late Classic period and inundated the salt works, protecting them in mangrove peat and saline water. The submersion of these sites preserved the wooden architecture, as well as large fragments of briquetage, the remains of salt making vessels.

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**Chapter 3**  
**Specialized Salt Production During The Classic Period at Two Paynes Creek Salt Works**  
Elizabeth C. Sills and Heather McKillop

**Introduction**

The remarkable preservation of ceramics and wooden architecture in a peat bog below the sea floor in Paynes Creek National Park, Belize, provides an advantageous opportunity to evaluate the spatial patterns of ancient activities of the ancient Maya, since wood is rarely preserved. We discuss the distribution of artifacts and their relationship to wooden architecture at two ancient Maya salt works in Paynes Creek National Park, Belize (Figure 9). Underwater excavations at Early Classic (A.D. 300-600) Chan B'i and Late Classic (A.D. 600-900) Atz'aam Na reveal activity areas associated with a substantial Classic Maya salt industry. Virtually all of the artifacts are briquetage—ceramic vessels used to evaporate brine in pots over fires to make salt. The infrastructure of the salt works supports an interpretation that the Classic Maya of southern Belize produced salt for distribution to the inland Maya cities, where this biological necessity was scarce.

Underwater excavations were carried out at the two salt works to identify salt production and/or other activities. The excavations were placed to discover the spatial distribution of artifacts in relationship to the wooden architecture. Several research questions guided the project. Were the salt works dedicated to the single activity of salt making? Or were the salt works part of household workshops or engaged in “multi-crafting”? Is there evidence of other activities at the salt works?

People along the coast of the Yucatán peninsula of Mexico and Belize produced salt during historic and prehistoric times for local use and inland trade (Andrews 1983; McKillop 1995, 2002, 2005). The ancient coastal Maya of Belize exploited this natural resource and traded



it to interior cities (Andrews and Mock 2002; MacKinnon and Kepecs 1989; McKillop 1995, 2002, 2005). The discovery of coastal salt works suggests that the southern Maya lowlands were

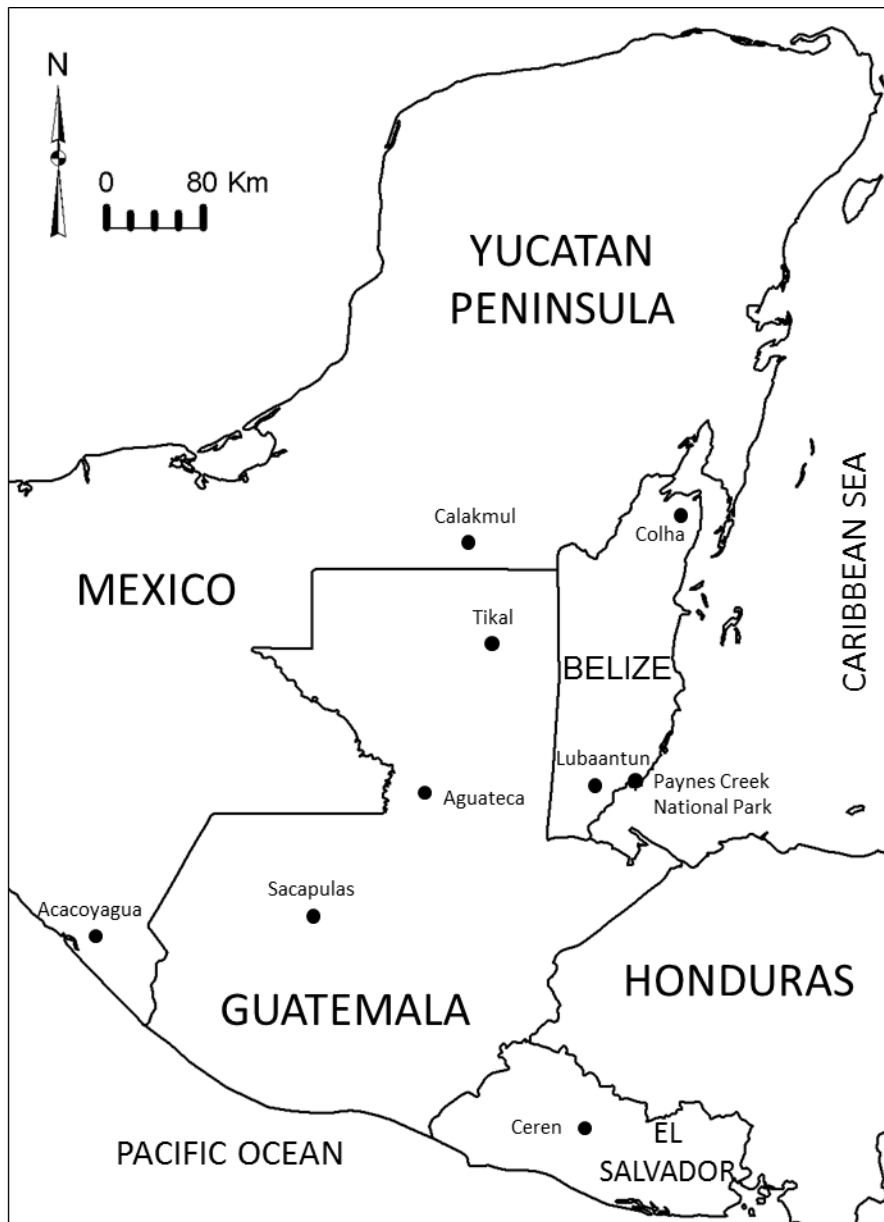


Figure 9. Location Map of the Maya area showing Paynes Creek National Park and sites mentioned in the text (map by C. Sills).

self-sufficient in meeting the biological need for salt at nearby inland cities (McKillop 2005).

Excavations at Calakmul bolster the evidence that salt was a traded commodity. A painted mural

on the exterior of a Late Classic building shows a marketplace with people and goods. Of greatest interest to us is a glyph deciphered as aj atz/aam “salt person” accompanied by an image of a man with a basket and spoon (Vargas et al. 2009). Salt does not preserve in the archaeological record. We used remains of cultural material debris indicative of salt production along with ethnographic analogs to analyze and reconstruct ancient production and distribution.

### **Craft Production and Salt Making**

The study of salt production can add to our understanding regarding the place of craft production for the Classic Maya and other ancient economies. Craft production in the ancient Maya economy is generally discussed by drawing distinctions between household production and workshop production (Aoyama 2007; Emery and Aoyama 2007; Inomata 2001; Moholy-Nagy 1997; Shafer and Hester 1983, 1991). Household production includes goods and services produced mainly for the household and not for market, whereas workshop production is the manufacturing of a product by others for use elsewhere. Both types of production are connected to the greater economy in regards to distribution and consumption (Costin 1991). In ancient societies, craft production occurred from the smallest unit of production, the household, to the largest unit, the workshop (Netting et al. 1984). A continuum of complexity exists between the two units where both types of production worked in concert to distribute goods to consumers.

Within Mesoamerica and especially the Maya cultural area, plazuela groups are the architectural manifestation of a household unit. A plazuela group is two or more buildings facing one another forming a closed space. This architectural layout is observed on a large scale, such as a city center, and at a smaller scale, the household level (Ashmore 1981, 1990; Chase and Chase 2004; Scarborough and Robertson 1986). Households are units that include family and non-relatives who live and contribute to the household economy. Workshops can physically

be connected to a household even if the majority of their product is produced for the outside market and not for household use, such as at Colha (Shafer and Hester 1983, 1991). The Paynes Creek salt works are different from other Classic Maya workshops because they are not planned around plazuela groups (Sills 2007; Sills and McKillop 2010).

Ancient Maya craft production was carried out in attached and independent workshops (Aoyama 2007; Inomata 2001; Moholy-Nagy 1997; Shafer and Hester 1983, 1991). Attached production includes high-value, luxury goods sponsored and managed by the elite that are not widely distributed. In contrast, independent production areas are overseen by specialists producing goods for a general market. The items are utilitarian goods and consumption is driven by supply and demand economics.

Attached workshops in the archaeological record have been identified from the site of Aguateca, Guatemala (Inomata 2001). The site was rapidly abandoned during the end of the Late Classic period when the structures were burned. Intact deposits provided evidence of stored items left by the inhabitants for safe keeping; presumably they expected to return to the site (Aoyama 2007). Excavations of structures in the central portion of the site yielded evidence of attached elite craft production on a part-time basis for luxury items including bone and shell carving and wood carving (Aoyama 2007; Emery and Aoyama 2007; Emery 2009). Elite craftspeople probably did not acquire their own raw materials. Instead, commoners acquired and fashioned raw materials such as chert, obsidian, and clay pots at independent workshops and transferred those materials to attached workshops at the urban centers.

Attached workshops at the elite households at Tikal (A.D. 250-850) provide evidence for the production of stone, shell, and bone goods (Moholy-Nagy 1997). Debitage including chert, obsidian, bone, shell, slate, and jade was recovered from secondary contexts such as construction

fill, from residential architecture, and in middens mixed with domestic trash. Analysis of the types of debitage and spatial analysis of the distribution of debitage indicate that independent specialists engaged in household production worked part-time to supply the elite with luxury high-status goods while producing utilitarian goods for the wider community and themselves (Moholy-Nagy 1997).

The most considered workshops within the Maya cultural area are at the chert producing site of Colha that dates from the Late Preclassic to the Early Postclassic periods (Shafer and Hester 1983, 1991). The workshops were incorporated into household production and were attached to plazuela groups suggesting the workshops were independent and controlled by small-kin group associations (Shafer and Hester 1983, 1991). Mapping and surface collection at the Paynes Creek salt works suggests they differ from the above examples of attached and independent workshops because the salt works are physically detached from the interior urban centers and lack visible evidence of settlement (McKillop 2005).

### **Location and Description of Research Project**

The two sites examined in this study are located underwater in a shallow eastern arm of Punta Ycacos Lagoon, an estuarine lagoon in Paynes Creek National Park (Figure 10).

Rhizophora mangle, known as red mangrove, fringes the edges of the lagoon and occurs in isolated stands within the lagoon. Avicennia germinans (black mangrove) and Laguncularia racemosa (white mangrove) are found behind R. mangle away from the fringe of the lagoon.

The sea floor consists of a firm layer of red mangrove peat overlain by a layer of silt. The peat is formed by red mangrove tissues that are slightly acidic (pH 5.0; McKillop 2005:5631). The peat preserves organic remains such as wooden posts and a canoe paddle from the nearby site of K'ak' Naab (McKillop 2005; McKillop, Sills, and Harrison 2010a, 2010b). Field observations

of water depths in the lagoon range from 36 to 54 cm in depth. The lagoon system is supplied with salt water from the Caribbean Sea to the east and fresh water from Freshwater Creek. In the past, the lagoon system may have been part of the Monkey River deltaic system to the north (McKillop 2002; Wright et al. 1959).



Figure 10. Aerial view of the eastern arm of Punta Ycacos lagoon called the East Lagoon (photo by C. Sills).

At the time of occupation, the Paynes Creek salt works were on dry land close to the source of brackish water required to evaporate brine in pots over fires to make salt. Relative sea-level rise inundated the salt works sometime after in Late Classic abandonment (McKillop 1995, 2002; McKillop et al. 2010a, 2010b). Inundation of the sites protected pottery and preserved wooden posts from trampling and erosional weathering processes commonly found at terrestrial sites (McKillop 2002, 2005, 2007).

Spatial analysis of the wooden posts by project team members indicates that the posts form rectangular buildings and other ancillary structures associated with salt making (McKillop 2005; Sills 2007; Sills and McKillop 2010; Somers 2007). The buildings are similar to the shape and sizes as described by Robert Wauchope in his 1938 book titled “Modern Maya Houses”. The buildings were made of pole and thatch that could have lasted the lifetime of the building as seen from the long lasting structures in Chiapas, Mexico, and Belize. The modern people of Acacoyagua in coastal Chiapas, Mexico replace the palm thatching of their pole and thatch buildings every five to six years and the rafters and crossbeams every six to 10 years (Moore and Gasco 1990). The mainposts, usually made from more durable wood, determine the life of the building and can last up to 20 years. The ethnographic study of the modern Mopan Maya of southern Belize indicates that posts can last up to 15 years. The thatch roof will last up to five years (Steinberg 1999). The use of wooden buildings and structures with the artifactual remains of briquetage suggests that boiling salt was an indoor activity, at least for the salt works in Paynes Creek and as seen from the modern-day salt works at Sacapulas in Guatemala (Reina and Monaghan 1981).

Preliminary identifications of wood species indicate that they include a variety of species from nearby environments, including broadleaf forest, “coconut woodland,” mangrove ecosystem, and pine savannah (McKillop 2009). Field recording of wooden posts divided them into palmetto palms (*Accelorangea wightii*) and solidwood posts. The palmetto palm posts are fragile and are hollow due to decay which leaves only the shell of the bark to note its presence. The solidwood posts were used to form structures whereas the palmetto palm posts form long lines.

A systematic flotation survey of other salt works in Paynes Creek and the piece plotting at the site of K'ak' Naab by the Underwater Maya project reveal that artifacts lie directly on or are embedded in mangrove peat (McKillop 2007). The wooden posts embedded into the peat were found by using our hands placed flat onto the surface of the peat and then marked with a pin flag. Usually, only the worm eaten portions of the wood are above the peat in the silt. The wooden posts are more intact and less degraded in the peat (McKillop 2005; Sills 2007; Sills and McKillop 2010; Somers 2007). The people at the Paynes Creek salt works were comparable to those at other Maya sites in that they frequently kept the floors of their homes and workshops clean by sweeping or removing debris to disposal areas (McKillop 2007). Archaeological sites that experienced rapid abandonment, such as, Aguateca and Cerén, are the exception to this rule and provide good analogies for the Paynes Creek sites (Aoyama 2007; Emery and Aoyama 2007; Inomata 2001; Parnell et al. 2002; Sheets 2002).

### **Wooden Architecture at Classic Period Salt Works**

In 2003 and 2004, underwater survey resulted in the discovery of 41 salt production areas, including Chan B'i and Atz'aam Na, associated with wooden architecture and the discovery of an ancient Maya canoe paddle, dating from A.D. 680-880, from the site of K'ak' Naab (McKillop 2005). Chan B'i and Atz'aam Na were systematically surveyed in 2006 as part of the "Mapping Ancient Maya Wooden Architecture on the Sea Floor Project". At this time, a 100 percent a systematic flotation survey on Research Flotation Devices (RFDs) was conducted across the sites to locate wooden architecture. Each investigator placed their hands flat on the bottom of the sea floor to feel for wooden posts. Once found, a pin flag was placed on the north end of each post to mark its presence above water. All of the flagged wooden architecture was labeled and mapped using a Topcon GTS Total Station and downloaded into the project

Geographic Information System software GIS GeoMedia® by IntergraphTM. A site datum was established using a one quarter inch PVC pipe placed in the center of each site. GPS points were taken from this location. In order to find the wooden posts at a later date, the post number was recorded using an indelible marker on a plastic pin flag. The pin flags were furled and inserted into plastic straws and pushed into the sea floor along the north side of each post.

Chan B'i and Atz'aam Na consist of two different structures. At Chan B'i, one conventional radiocarbon date from a wooden post is dated to 2 sigma calibrated 1510 to 1460 BP and 1430 to 1310 BP. This date places the wood used for construction within the Early Classic (A.D. 300-600) period. The systematic flotation survey at Chan B'i found 34 wooden hardwood posts and two palmetto palm post lines comprised of 38 posts, including twenty on the northern line and 18 on the line to the south (Figure 11). The wooden architecture has a northeast to southwest alignment. The building measures approximately 7.25 m north to south and 5.75 m east to west, forming a rectangular structure. The building has up to 10 room divisions ranging from a floor space of 1m<sup>2</sup> to 6 m<sup>2</sup>. The palmetto palm posts are positioned to the southwest of the hardwood posts and curve outward from the hardwood structures. There is no evidence of stone platforms or preservation of walls as seen on dry land sites and noted as post holes.

The systematic flotation survey of Atz'aam Na revealed 26 hardwoods wooden posts arranged to form a rectangular building (Figure 12). A corner post of this structure is dated to 2 sigma calibrated 1290 to 1060 BP, placing this salt work in the Late Classic (A.D. 600-900) period. There are seven palmetto palm posts forming a line 16.5 m to the southwest of the hardwood post structure. The rectangular wooden structure has a northwest to southeast alignment measuring 9 m in length by 3.25 m in width with a floor space of 29.25 m<sup>2</sup>.



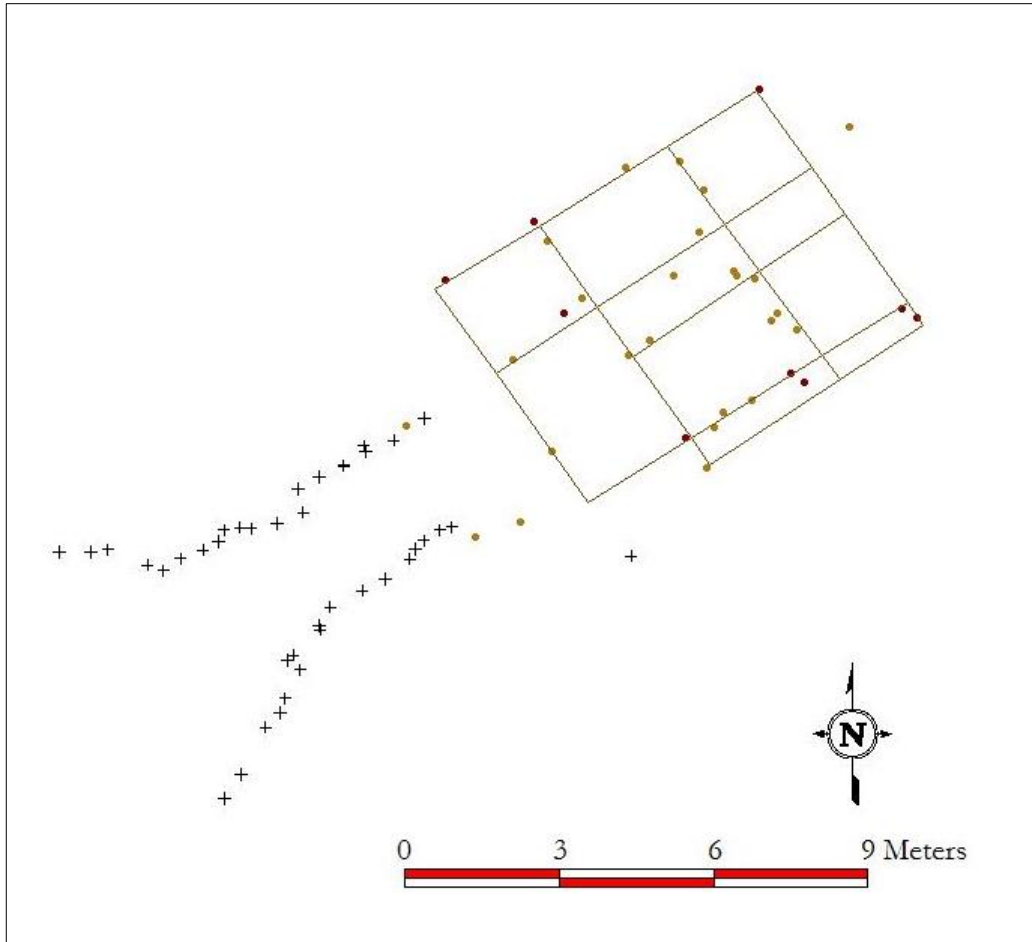


Figure 11. Map of Chan B'i wooden architecture with room divisions (GIS map by H. McKillop). The circles represent hardwood posts and the crosses represent palmetto palm posts.

### **Underwater Excavations at Paynes Creek Salt Works**

Transect excavations were carried out in June, 2010 to evaluate the spatial patterning of artifacts and their relationship to wooden architecture. The field crew consisted of nine Louisiana State University and Belizeans who relocated wooden posts using a site map. Red pin flags were used to mark the wooden posts and yellow pine flags were used to mark the excavation units. Two transects were placed across Chan B'i and Atz'aam Na, forming a cross shape (Figures 12 and 13). The transects were placed to extend across the site—as defined by the surface distribution of artifacts—and to include inside and outside areas of buildings. The

transects were laid out using a compass and a 30 meter tape. The ends of the transects were marked with long PVC pipes pushed into the seafloor. The tape was stretched tight between the two PVC pipes (Figure 14). One quarter inch PVC pipes were placed into the sea floor at each meter mark on the tape.

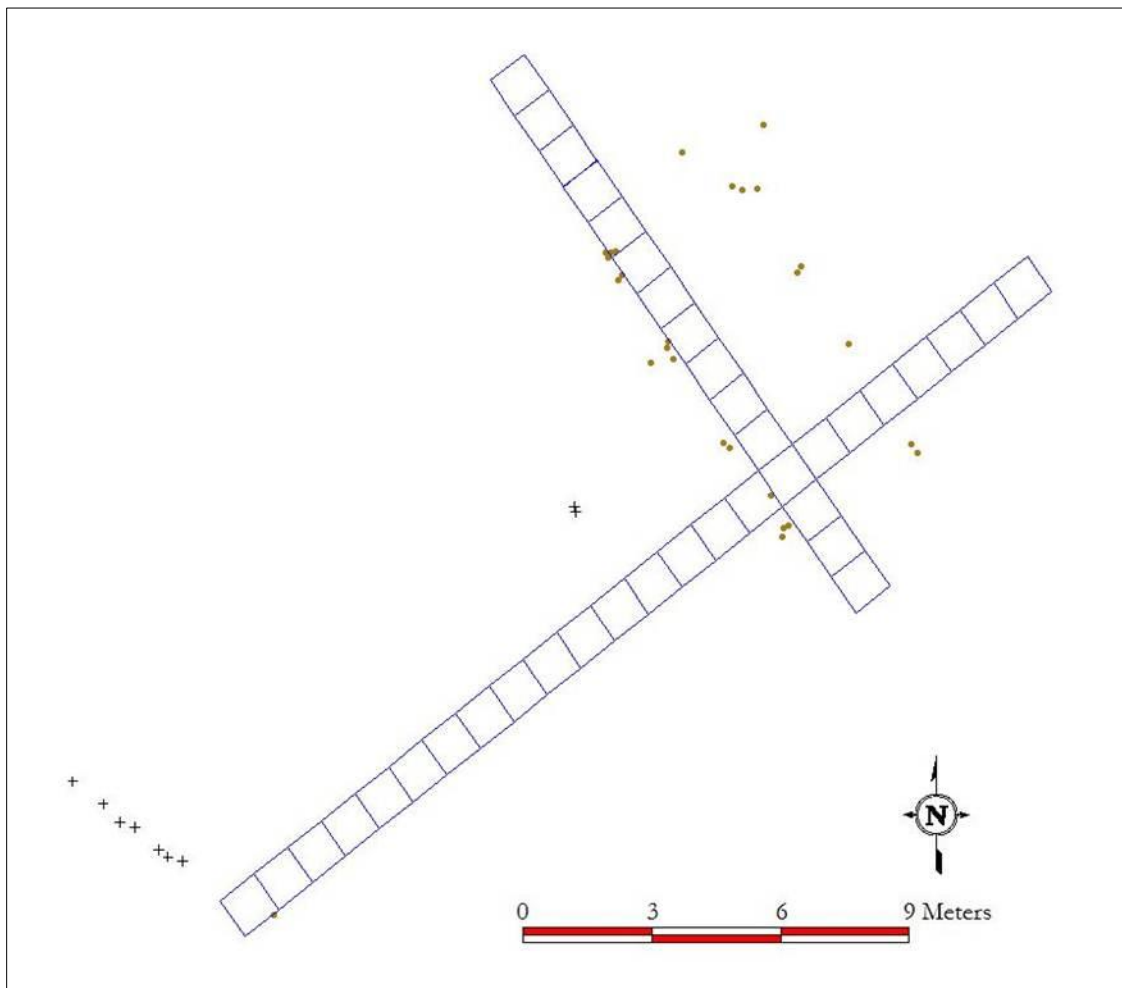


Figure 12. Map of Atz'aam Na showing rectangular wooden building and transects (GIS map by H. McKillop). The transects were divided into one by one meter excavation units. The circles represent hardwood posts and the crosses represent palmetto palm posts.

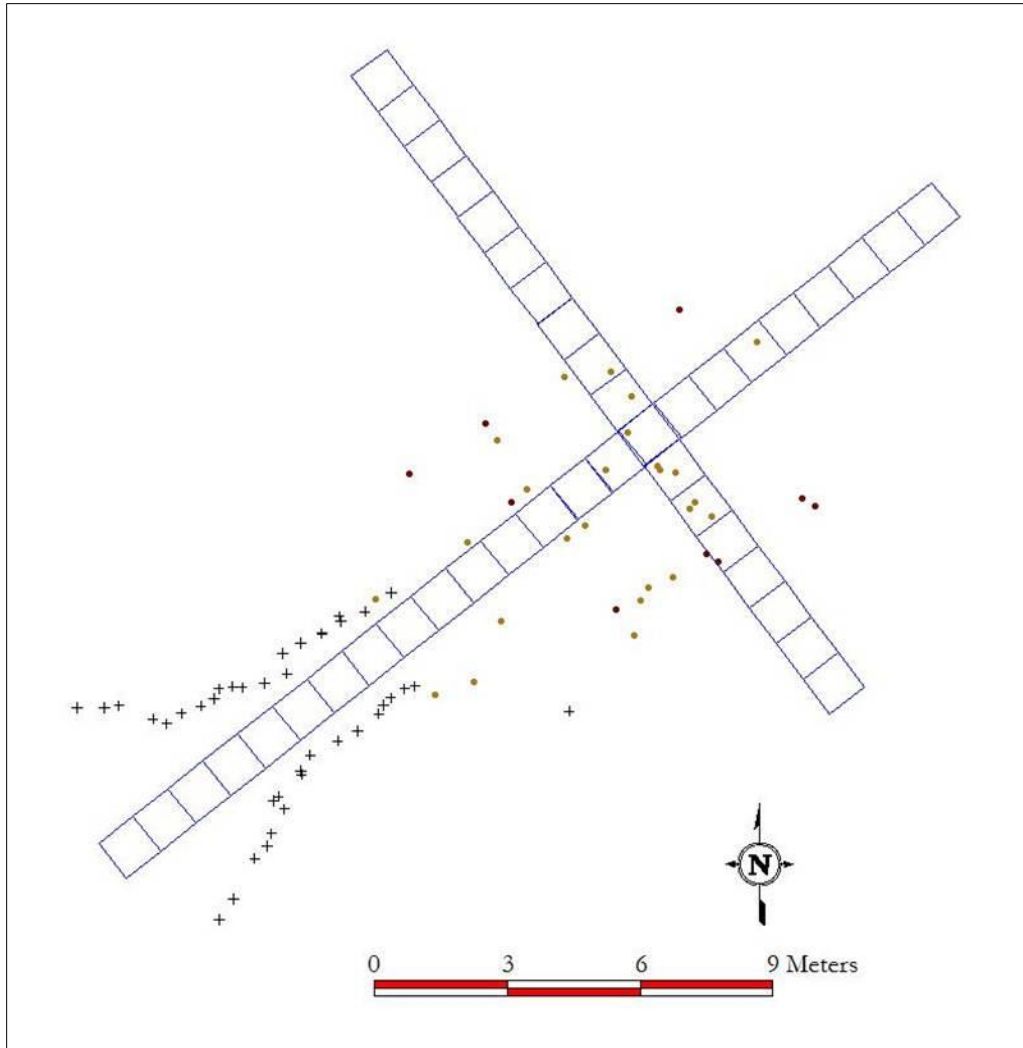


Figure 13. Map of Chan B'i showing wooden architecture and the two transect excavations with one by one meter excavation units (GIS map by H. McKillop). The circles represent hardwood posts and the crosses represent palmetto palm posts.

A metal one by one meter grid frame was laid on the surface of the seafloor within the one meter intervals (Figure 15). The frame was weighted down with five pound dive weights on two of the frame corners to keep the grid from moving underwater. A yellow metal grid frame was preferred over using nails and string or a PVC grid frame because it was easier to see in the murky water and strong enough not to move when underwater. Each excavator placed their hands firmly on the seafloor and collected all surface artifacts. The artifacts were placed into a



Figure 14. Setting up transect 1 at Chan B'i (photo by H. McKillop).



Figure 15. Submerging the 1x1 m grid (photo by H. McKillop).

bucket with holes on all sides to drain the water. Each bucket with the excavator were photographed showing the relative amount of artifacts collected before transferring the artifacts into labeled plastic bags. The plastic bags were then ordered and placed into the Portable Research Station (PRS) before transferring them to our larger ocean going vessel. The one meter units were mapped using a Topcon GTS-725 total station and downloaded and attached to the project GIS for analysis in relation to the previously recorded wooden architecture.

The artifacts were studied at the field lab in Belize. After fresh water rinsing and drying, the artifacts were separated into material class for each unit and level. The ceramics were sorted according to the type-variety classification for Maya pottery which is useful for developing a site chronology. The type-variety classification followed Sabloff's (1975) methods from Seibal and was useful for describing the artifacts and to make comparisons with other ancient Maya sites. The majority of the ceramics fit within existing type-variety descriptions for the Port Honduras region and the coastal area of southern Belize (McKillop 2002). The ceramics were separated into categories commonly found from the Paynes Creek salt works such as amorphous clay lumps (ACLs), clay vessel supports (known as cylinders), spacers, sockets, pottery sherds, and figurines (McKillop 1995, 2002). Similar salt making artifacts, known as briquetage were recovered elsewhere along the coast of Belize (MacKinnon and Kepecs 1989; Mock 2000).

Measurements were taken of each pottery vessel rim and the vessel supports. The diameter of the salt production vessels and vessel supports were used to analysis the degree of pot standardization. The variables calculated to compare the variability of diameters are mean, standard deviation, median, range, coefficient of variation, and average median variation. In order to interpret the degree of standardization, average median variation was used to compare to previous standardization studies at some of the Paynes Creek salt works (McKillop 2002). The

ACLs and clay vessel supports were counted and weighed. The spacers, sockets, pottery sherds, and figurines were counted. All ceramics and stone tools were photographed and video-taped. The ceramic rim sherds, necks, and bases were drawn. Of the briquetage, only sockets and clay vessel supports were drawn. All stone tools were drawn.

## **Data and Results**

At Chan B'i, 18 1x1 m units were excavated along Transect 1. Transect 2 included 24 1x1 m units. Transect 1 was placed northwest to southeast bordering an inside line of a hardwood posts thought to be the middle of a structure. Transect 2 was placed southwest to northeast and extends from outside of a wooden structure, through the structure, and continues south through the middle of two palmetto palm post lines. Both transects extended beyond the bounds of the surface artifact scatter and wooden architecture. The excavations yielded 10,737 artifacts within 42 m<sup>2</sup> equaling a density of 255.6 artifacts per meter. The artifacts include ceramics (n=10,218), groundstone tools (n=3), charcoal (n=370), shell (n=129), and botanicals (n=17). Water depths taken during excavation ranged from 39 cm to 54 cm below sea level with an average depth of 44 cm in this area of microtidal variation. The water depths within and directly outside the wooden buildings are approximately 10 to 15 cm shallower than the water depths farther away from the building including the water depths taken between the palmetto palm posts indicating a slight rise in the vicinity of the structure.

At Atz'aam Na, 15 1x1 m units were excavated along Transect 1 and 24 1x1 m units were excavated along Transect 2. Transect 1 was placed along the interior of the one rectangular wooden building. Transect 2 is perpendicular to Transect 1 and crosses through the width of the rectangular building and passes through the palmetto palm post line 15 m to the southwest. As with Site 24, both transects were placed to extend beyond the bounds of the wooden architecture

and surface artifact scatter. A total of 734 artifacts were collected from 39 m<sup>2</sup> of excavated sediment for a density of 19 artifacts m<sup>2</sup>. The material collected from the excavations include ceramic artifacts (n=698), charcoal (n=32), shell (n=2), and botanicals (n=2). No groundstones or stone tools were recovered from the excavated units.

The density of the artifacts are greater at Chan B'i compared to Atz'aam Na. The building or buildings at Chan B'i are not as well-defined as the rectangular building at Atz'aam Na. The radiocarbon dates obtained from the wooden architecture at both sites indicate that Atz'aam Na was in production during the Late Classic whereas Chan B'i was active during both the Early and Late Classic periods. The large quantity of artifacts collected from Chan B'i compared to Atz'aam Na is due to the longer use of the Chan B'i salt work.

The ceramic artifacts were divided based on types of activities commonly found at salt making sites in the archaeological and ethnographic record and with those activities associated with the ceramic assemblages found at other Paynes Creek salt works. The main divisions are those associated with evaporating brine over fires. They include briquetage, water jars, and finer ware associated with feasting and salt ritual. The artifacts associated with salt making are called briquetage and consist of Punta Ycacos Unslipped jars, basins, and bowls that were placed onto clay cylinder vessel supports, inserted into clumps of clay bases and sockets placed at the top of the vessel support and connected to the pot. Clay spacers were placed between the pots to space them out and steady them over the fire to evaporate the brine and make salt cakes. Also, there are amorphous clay lumps that are the broken pieces of cylinders, sockets, spacers, and bases, as well as other salt making debris that can't be typed to their original form (Figure 16).

At Chan B'i, briquetage comprises approximately 85% of the ceramic assemblage. Out of the briquetage, the majority of the artifacts are ACL's (n=8,531) followed by Punta Ycacos

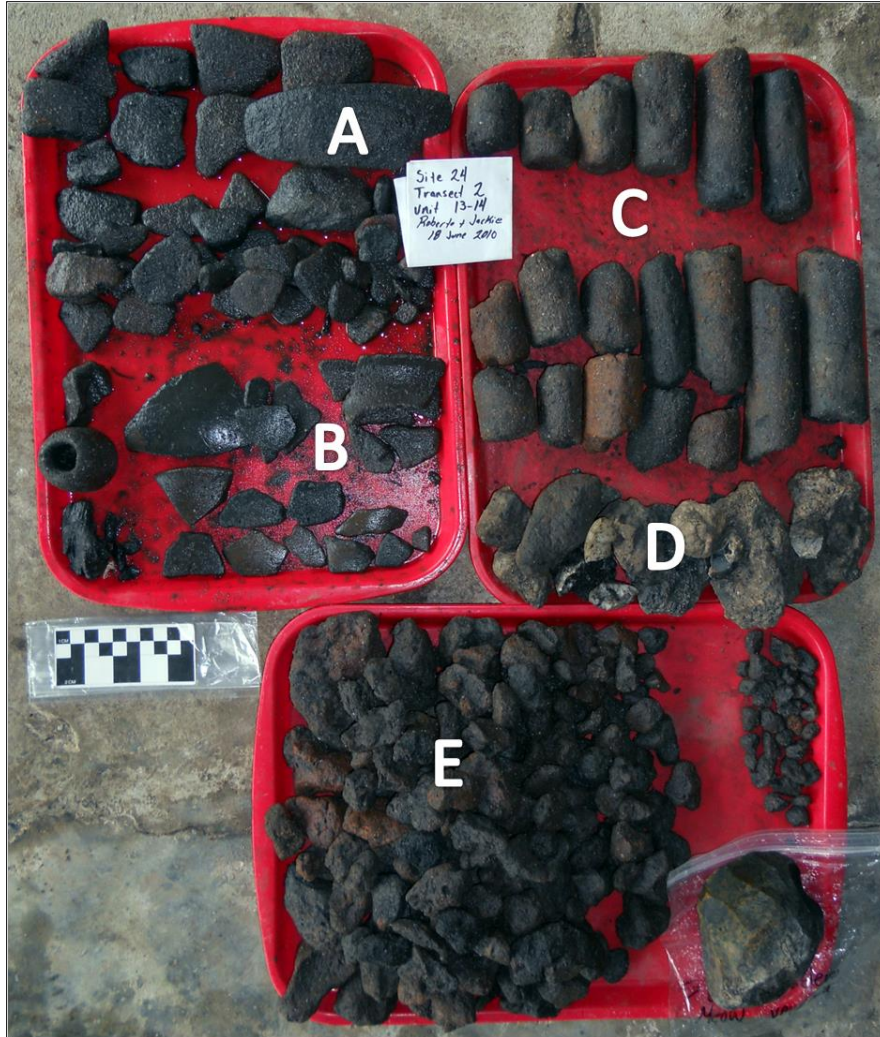


Figure 16. Typical briquetage equipment (A: Punta Ycacos jar rims, B: Water jar sherds, C: cylinders, D: spacers, E: ACLs). Photo by the Underwater Maya Project.

Unslipped pottery sherds (n=542) and rim sherds (n=75). Punta Ycacos Unslipped is defined as the main vessels used in southern Belize to evaporate brine over fires (McKillop 2002). Other recovered briquetage include clay cylinder vessel supports (n=267), clay spacers (n=18), and sockets (n=14). No clay bases were recovered.

Briquetage accounts for 87% of the ceramic assemblage at Atz'aam Na. As with Chan B'i, ACLs (n=577) comprised the majority followed by Punta Ycacos Unslipped body sherds



(n=52) and rims (n=5). Also recovered from the excavations are clay cylinder vessel supports (n=34) clay cylinder supports and sockets (n=2). No clay spacers or clay bases were recovered. A dense amount of briquetage is reflected equally at both salt works. Frequencies of different categories of briquetage were compared at the two sites (Figure 17). The categories are ACLs, clay vessel sherds, clay cylinder supports, spacers, and sockets. No bases of the clay cylinder supports were recovered intact from the excavations. The bases are friable and are rarely recovered intact at any of the Paynes Creek sites (see McKillop 1995: Figure 9b). At both the salt works, ACLs comprise the majority of the briquetage, followed by a small amount of pot sherds, and fewer cylinders, sockets, and spacers. The ACLs are small and can include any of the other categories of briquetage. The briquetage at both Chan B'i and Atz'aam Na surround the wooden architecture with the greatest counts of briquetage excavated from inside the hardwood wooden architecture. At Chan B'i, the briquetage decreases between the two palmetto palm post lines. At Atz'aam Na, the briquetage extends to up to 4 m outside the rectangular structure and then drops off considerably resulting in no briquetage found near the palmetto palm posts. The briquetage at both Classic period sites indicates that it may have been dumped in some abandoned structures or thrown into fires to help retain heat during the evaporation process since large amounts of charcoals were recovered.

The two salt works sites indicate that salt making was the primary activity. The lack of diversity in the artifact assemblages from Chan B'i and Atz'aam Na indicate a limited number of activities. The ceramics were compared by their richness (the number of types) and by their evenness (the number of sherds per type; McKillop 2002; Rice 1981). The majority of the artifacts are Punta Ycacos Unslipped, which comprises the briquetage associated with salt making (Figure 18). The other types of pottery found at both sites include Mangrove Unslipped,

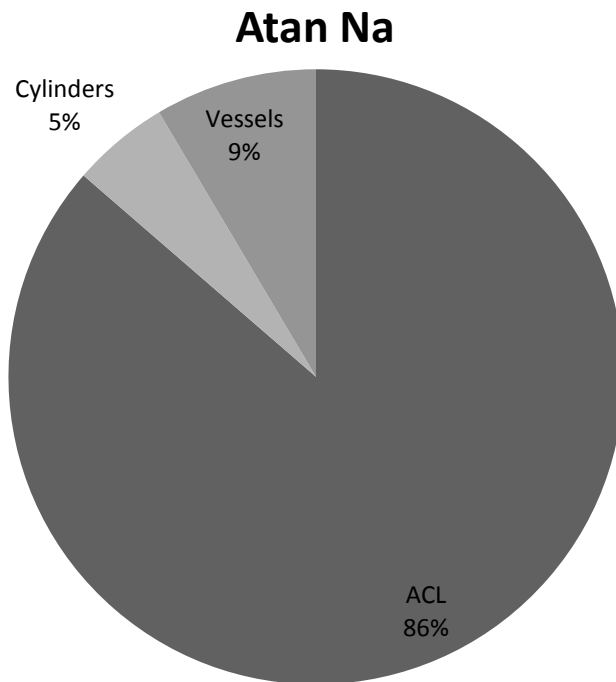
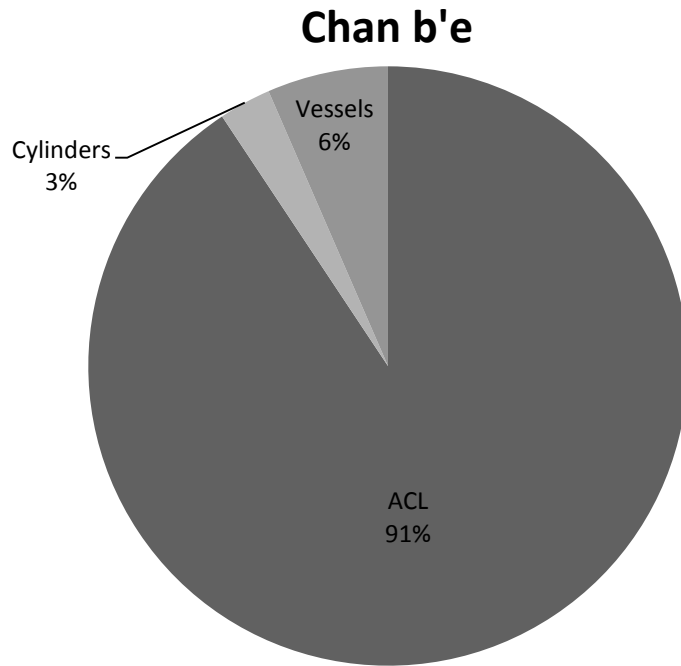


Figure 17. Pie charts showing artifact frequencies of briquetage by site (ACL = Amorphous Clay Lumps).

Warrie Red, and Moho Red. Mangrove Unslipped and Warrie Red have the function of water jars. They were used as vessels to store water or brine. Moho Red serving vessel sherds comprise a minor amount of artifacts. The Moho Red ceramics resemble Belize Red recovered from the nearby site of Lubaantun (Hammond 1975; McKillop 2002). There are some artifacts used in ritual such as a figurine whistle fragment, candeleros, and fragments of an incense burner. Rituals associated with modern salt making have been described at Sacapulas and at other salt works in Paynes Creek and beyond (Andrews 1983; McKillop 2002; Reina and Monaghan 1981). The water jars excavated from Chan B'i are located inside and around the wooden architecture. Most water jars were recovered from the northwestern corner of the wooden architecture placed along the northern wall. Most of the Moho Red ceramics were found inside the southwestern corner of the hardwood wooden architecture. There are a few water jars from Atz'aam Na in discrete locations spaced throughout the wooden rectangular structure. All of the Moho Red ceramics are found within the rectangular structure along the walls and not in the center of the building.

The richness and evenness of pottery types are similar for Chan B'i dating to the Early Classic and Atz'aam Na dating to the Late Classic. In relation to the salt making, both sites have similar assemblages, indicating that the main activity was the production of salt. Both salt works contain similar assemblages indicating that salt making was occurring in this location throughout the Classic period. Artifactual evidence of habitation or that people were acquiring or processing food such as bones from meals, spindle whorls, fishing weights, serving dishes, shell, botanical remains, and stone tools are absent.

The Punta Ycacos Unslipped jars used to evaporate brine over fires to make salt and the vessel supports that held the pots were standardized. Chan B'i yielded 14 measurable jars from

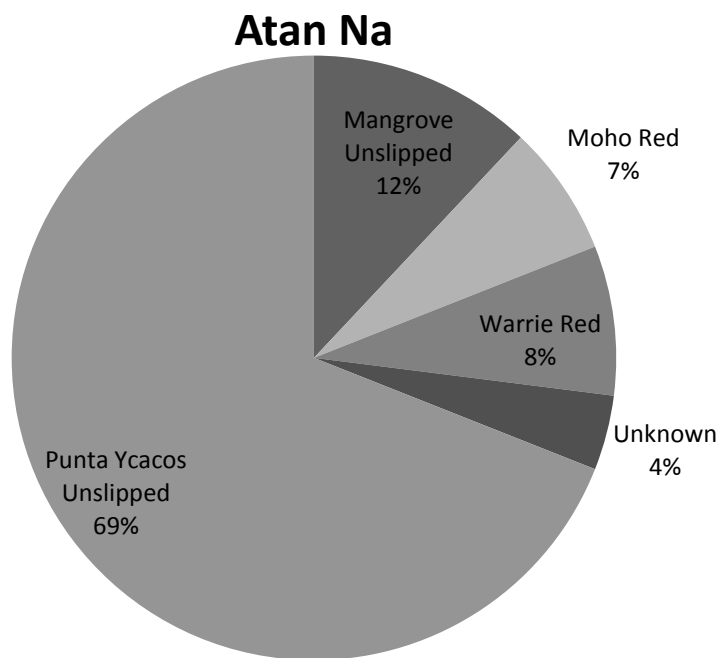
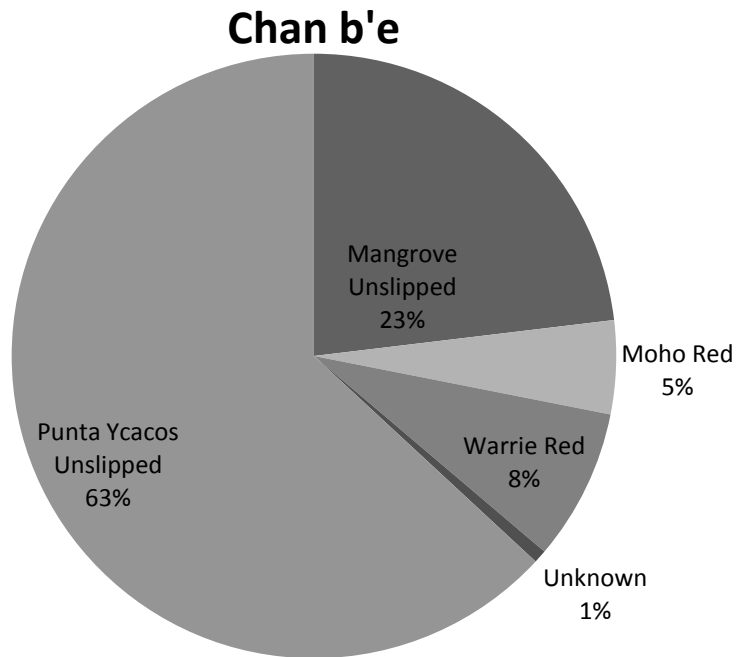


Figure 18. Pie charts showing pottery sherds by type as a measure of evenness of the ceramic assemblages by site.

the assemblage whereas Atz'aam Na only yielded one measurable sherd. However, both of the salt works yielded measurable cylinders. Comparison of the average median variation of Punta Ycacos jar rims from Chan B'i and cylinders from both sites with the average median variation of four previously studied salt works (McKillop 2002) show that the pots and supports used for salt making were standardized (Table 1). The average median variation (AMV) was used for interpretation instead of the coefficient of variation because the median is less skewed by outliers than the mean. The AMV is better for samples that depart from a normal curve. There is lower variability in the data set of Punta Ycacos jars and cylinders from Chan B'i than what is reported for jars at the other Late Classic salt works. However, the cylinders from Atz'aam Na have the same variability as what is reported from the four Late Classic salt works in Paynes Creek (McKillop 2002).

Table 1. Standardization of Punta Ycacos Jars and Cylinders from Chan B'i and Atz'aam Na compared with other Paynes Creek salt works from McKillop (2002: Tables 4.1 and 4.3); SD = Standard Deviation; CV = Coefficient of Variation; AMV = Average Median Variation.

Sample	N	Diameter of Vessel Orifices (cm)					
		Mean	SD	Median	Range	CV	AMV
Site 24 Punta Ycacos Jars	12	21.17	1.80	21.50	18-25	8.51	6.00
Other Salt Works Punta Ycacos Jars	132	21.90	3.40	22.00	14-38	15.60	9.50
Site 24 Punta Ycacos Cylinders	87	3.81	0.38	3.80	2.10-2.8	9.96	7.77
Site 35 Punta Ycacos Cylinders	14	3.64	0.51	3.60	2.7-4.5	14.03	10.32
Other Salt Works Punta Ycacos Cylinders	155	3.52	0.55	3.50	1.9-5.1	15.70	11.90

There are no burials typical of ancient Maya houses and no evidence of food consumption. There are no patio groups at the site indicating that the salt works were designed differently than households or workshops attached to houses. The structures do not resemble the rubble platforms most noted for the ancient Maya. The buildings do not have the typical assemblages found at ancient Maya houses. The sites are a place of production that diverge from what is recorded at attached workshops connected to plazuela groups or a domicile. Instead, the

ceramics and associated artifacts indicate that the sole purpose of these wooden structures was for workshop production of a basic commodity, salt.

There is no evidence of salt making activities centered around the palmetto palm posts. The absence of artifacts is as interesting as the presence of artifacts within the structure. The absence of artifacts indicates that most likely no fires or salt making was occurring in this area. Instead, the palmetto palm post lines were more likely landscape modifications to the mangrove peat environment (Sills and McKillop 2010; Somers 2007). Palmetto palms are used today to retain land—such as along the water’s edge by the landing strip at Placencia—and similar wooden posts are found in the Yucatan by Andrews (1983) forming retaining walls or forming a canal as described by Williams (1999).

## **Conclusion**

Wooden architecture and briquetage are preserved in a peat bog on the sea floor in Paynes Creek National Park. These perishable structures yield the only remaining wooden architecture in the Maya area and complement what is known from the stone foundations most commonly excavated. Systematic flotation survey of the Classic period sites recovered 51 hardwood wooden posts and 45 palmetto palm wooden posts. However, these posts are not associated with domiciles but instead form the infrastructure to a substantial Classic Maya salt industry along the coast of southern Belize. Underwater excavations at two salt works indicate the salt works were geared for the production of one consumer good, salt and not involved in multicrafting with only a limited amount of the assemblage associated with salt ritual. Specialization of pottery used in the salt evaporation process and the lack of diversity within the overall assemblages indicate that salt production in Paynes Creek began in the Early Classic and continued until the end of the Late Classic period when the sites were abandoned.

The excavations at an Early Classic and a Late Classic salt works refine our understanding of the place of production and offers an opportunity to examine activity areas at the place of production. The comparative study of the two salt works will further our understanding of the relationship of craft production to the wider Maya economy. The Paynes Creek salt works are different from the household workshops at Colha in northern Belize where stone tools were mass produced and distinct from the workshops connected to urban centers, such as Aguateca, where Maya attached workshops produced goods for the royal elite (Aoyama 2007; Emery and Aoyama 2007; Emery 2009; Inomata 2001; Shafer and Hester 1983). The research reported here demonstrates the importance of coastal environments that can preserve architectural features such as the wooden architecture at Paynes Creek salt works. Despite the intensive research at these two salt works, more work remains to further refine the chronology at the two sites and to develop more vertical stratigraphy.

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## **Chapter 4**

### **Chemical Signature of Ancient Activities at Chan B'i – A Submerged Maya Salt Works, Belize**

Elizabeth C. Sills, Heather McKillop, and Christian Wells

#### **Introduction**

Chan B'i is an Early Classic salt work that was submerged by sea-level rise in Punta Ycacos Lagoon in Paynes Creek National Park, Belize (Figure 19). Wooden architecture and ceramics are preserved underwater in a peat bog at the ancient Maya salt works. Previous research identified the salt works from the large quantities of briquetage—pottery used to evaporate brine over fires to make salt (McKillop 2005a, 2007; Sills and McKillop 2010). The results of transect excavations and type-variety ceramic analysis indicate salt making was the primary production occurring at the salt works (Sills and McKillop n.d.). The excavated material remains left no evidence of habitation such as animal bones and human burials at the salt works. Instead, study of the artifacts implies that the salt makers traveled to the salt works to produce salt and lived elsewhere. Chemical analyses of marine sediment was undertaken to discover evidence of human settlement—specifically organic waste including animal bones, shells, and also burials—that would not have preserved in the acidic matrix of the peat that spectacularly preserved the wooden architecture.

Transect excavations were carried out at Chan B'i in June, 2010 to evaluate the spatial patterning of artifacts and their relationship to wooden architecture. Two transects were placed across the site intersecting at right angles. Each transect was divided into one meter units. All material was excavated and water screened. The transects were placed to extend across the site—as defined by the surface distribution of artifacts and wooden architecture—and to include inside and outside areas of buildings. There are one or two hardwood post structures and two lines of palmetto palm posts (Figure 20). The palmetto palm posts are positioned to the south of

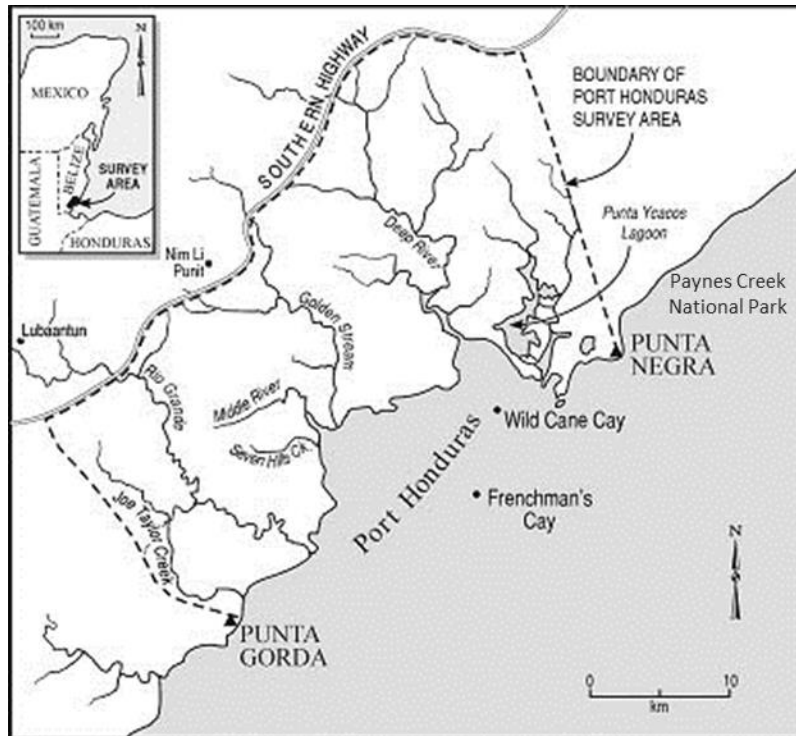


Figure 19. Location map of southern Belize showing Chan B'i within Paynes Creek National Park. Modified by Mary Lee Eggart from H. McKillop (2005b: Figure 10.6).

the hardwood posts and curve outward from the structure. Briquetage accounts for the majority of the ceramic assemblage along with large amounts of charcoal. There is no artifactual evidence that people were acquiring or processing food such as fishing weights found at nearby Wild Cane Cay (McKillop 2005b) or New River Lagoon (Valdez and Mock 1991). Other evidence of habitation such as bones from meals, spindle whorls, serving dishes, shell, botanical remains, and stone tools also is absent.

This study extends chemical testing on terrestrial soils to submerged marine sediment at an underwater site. Chemical testing of marine sediment at the Chan B'i salt work follows successful soil analyses carried out to detect ancient activities at other Maya sites, including Aguateca, Cerén, Chunchucmil, and Coyote (Hutson and Terry 2006; Parnell et al. 2002; Terry et al. 2004; Wells 2004). At the Classic Maya site of Aguateca and at the Maya site of Cerén,

high values of phosphorous were interpreted as areas for food preparation, disposal, and consumption (Parnell et al. 2002; Terry et al. 2004). Heavy metals including copper, iron, mercury, manganese, lead, and zinc can be associated with activities areas such as where pigments were produced used at Cerén (Parnell et al. 2002), painted urban houses at Piedras Negras (Wells et al. 2000), and midden deposits at Coyote (Wells 2004). High values of phosphorus obtained from plaster floors at structures from Chunchucmil indicate that debris was swept to the corners and edges of buildings (Hutson and Terry 2006). By way of contrast, high values of phosphorus from the main plaza at Coyote are interpreted as areas for the preparation and consumption of food and beverages (Wells 2004).

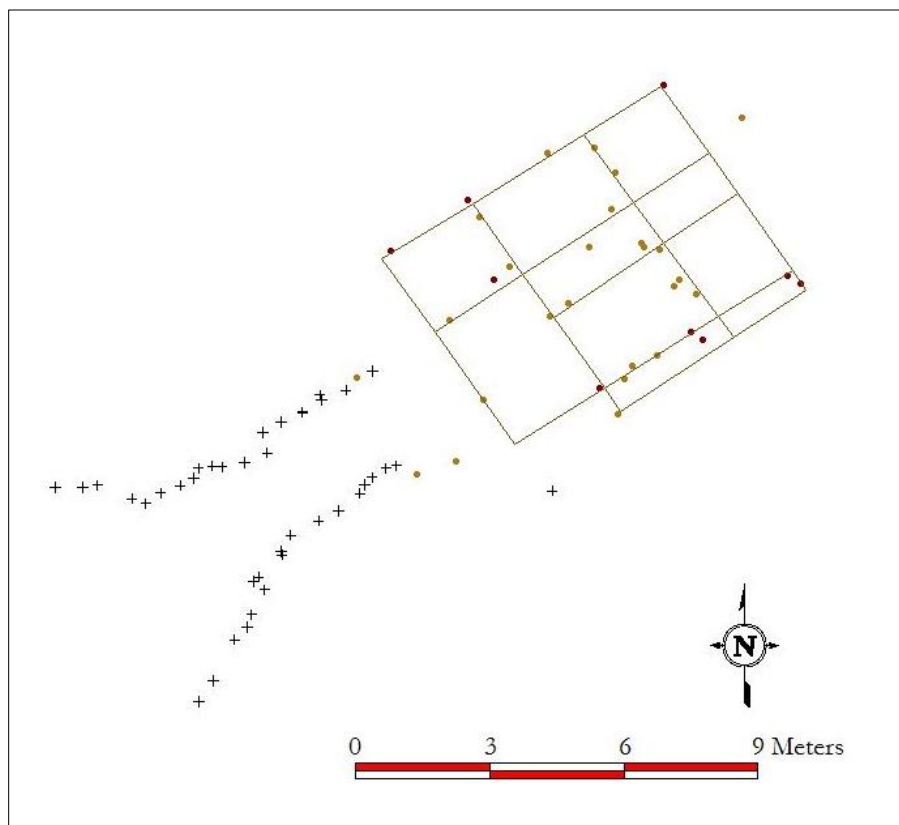


Figure 20. Map of Chan B'i wooden architecture with room divisions (GIS map by H. McKillop). The circles represent hardwood posts and the crosses represent palmetto palm posts.

Beyond the Maya area, soil chemistry detects evidence of human settlement through high concentrations of phosphates from the deposition of organic waste (Lippi 1988). Organic refuse deposits show higher phosphate values than areas where these activities do not occur (Middleton and Price 1996; Terry et al. 2004). Chemical sediment analysis can indicate activity areas not seen on the surface, such as refuse from meals, ash from fires, and human waste (Holliday and Gartner 2007; Hutson and Terry 2006; Lippi 1988; Middleton and Price 1996; Middleton 2004; Terry et al. 2000, 2004; Wells et al. 2000; Wells 2004, 2010). Chemical elements such as calcium show areas that were enclosed spaces (Middleton and Price 1996).

Ancient Mesoamericans frequently kept the floors of their homes and workshops clean by sweeping or removing debris to disposal areas. Archaeological sites that experienced rapid abandonment, such as, Aguateca and Cerén, are the exception to this rule (Aoyama 2007; Emery and Aoyama 2007; Inomata 2001; Parnell et al. 2002; Sheets 2002). Defining activity areas and loci in areas that were kept clean can be difficult due to the low amounts of artifacts. However, earthen or plastered floors inside buildings can hold chemical signature over time (Wells 2004).

### **Activities Associated with Salt Production in Mesoamerica**

There are two methods of evaporating brine to prepare salt that are documented for the ancient Maya. Salt was produced by solar evaporation on the north coast of the Yucatan (Andrews 1983; Andrews and Mock 2002) and by heating brine in pots over fires along the coast of Belize (MacKinnon and Kepecs 1991; McKillop 1995, 2002) and at inland locations (Reina and Monaghan 1981). Solar evaporation uses warm air and the sun to evaporate the water in shallow holding pans until only salt remains. Once the water is evaporated, the salt is removed from the pan. The Paynes Creek salt makers evaporate brine by heating it in pots over fires. In order to enrich the brine, salty water likely was leached through salt-saturated soil, which is

typical elsewhere (and which reduces fuel needs for evaporation by heating over fires). The acquired soil is put into a filtering apparatus where water is repeatedly poured over the soil. The brine filters through the soil to collect in a container. The salt-enriched brine is then evaporated in pots over fires. The leached soil is removed and placed into heaps, forming mounds (Andrews 1983; Good 1995; MacKinnon and Kepecs 1989; McKillop 2002). Both methods are documented in Mesoamerica, for modern and historic salt production as well as in the archaeological record, exhibiting variability regarding site layout and composition (Andrews 1983; Dillon et. al 1988; McKillop 2002: Killer Bee; Nance 1992; Parsons 2001; Reina and Monaghan 1981; Williams 1999, 2004).

Activity areas at salt making sites in Mesoamerica documented during historic and modern times vary according to the location of the salt works from the salt makers' domicile and if the salt is procured through solar or fire evaporation. The modern-day saltmakers from Costa Chica in Guerrero, Mexico, harvest salt-laden soil during the dry season (Good 1995). Salty soil is harvested and placed into a tapeite, a rectangular wooden container. The tapeites are constructed by placing eight forked posts into the ground. Wooden slats are placed on top of the forked posts to form a platform which is then covered with palm leaves or thick hearty grass as a filter. The palm leaves are then covered in a salt-enriched soil that is further saturated when brackish water is poured over the soil (Good 1995: Figures 4 and 5). The enriched water drains into holding pans placed below the tapeites which are emptied into large solar evaporation pans. The leached earth that remains is placed in a heap beside the tapeite that can be two meters or more in height (Good 1995:2). After the water is evaporated from the salt pans, the remaining salt is raked forming mounds.

Eduardo Williams (1999) investigated the continuity between modern and archaeological salt making sites near the Cuitzeo Lake Basin in Michoacán, Mexico. The salt makers use funnel shaped wooden structures, called estiladeras, to leach the salt from the soil and large wooden canoes to dry the salty soil. At the modern salt making sites, the tools associates with salt making are similar to those used for agricultural and house construction, such as shovels, hoes, and picks. In the past, the tools included jute fiber to carry soil and ceramic vessels to carry water (Williams 2004).

The salt makers at Nexquipayac use similar methods of evaporating and leaching the soil that are found at other modern salt works (Parsons 2001). In Nexquipayac, activity areas include locations to leach the soil, dispose of the leached soil, store brine, and storage containers for water and brine, as well as processing facilities including boiling huts and tools for excavating soil. The floors of the boiling huts are frequently swept of debris during the process of mixing and making salt (Parsons 2001).

At the modern day village of Sacapulas in northwestern Guatemala, soil is constantly enriched with salt at playas from a salt spring where the soil is continually saturated (Reina and Monaghan 1981). The salty soil is put into a wooden box for leaching. The brine is then placed into ceramic bowls and evaporated over a fire on a wooden platform inside a building. Items found inside the building include wood storage, clay vessels to hold the salt, and spent charcoal from previous evaporation episodes found along the edges and corners of the building. The floor of the building consists of salted soil (Reina and Monaghan 1981).

The continuity at salt-making sites from the past to the present within Mesoamerica shows changes in the economic infrastructure of sites and the updating of technology. At the site of El Salado, in Veracruz, Mexico, the people produced salt from a salt stream located at the site



during the Early Formative period (1,400 to 1,000 B.C.; Santley 2004). The salt makers returned to the site during the Late Classic period. Production increased from the Early Formative to the Late Classic. Salt was made year round inside small structures placed over brine evaporation areas. Evidence of salt making is found in the archaeological record from the ceramic remains of evaporation vessels and from charcoal from the fires. Excavations reveal a couple of low dams spanning a salt stream used to collect the water for boiling.

At Guzman Mound, located on a salt flat on the south coast of Guatemala, salt makers constructed artificial mounds in order to harvest salt using pottery vessels to evaporate brine over fires (Nance 1992). At Salinas de los Nueve Cerros in southern Guatemala, there is evidence of salt production using solar evaporation and evaporation over fires. The ancient Maya exploited the Tortugas stream, a salty spring supplied by an underground salt dome (Dillon et al. 1988). Excavations revealed that the salt makers harvested salt from the Late Preclassic until the Classic period. Salty water flowed year round and was evaporated over fires during the rainy season and by solar evaporation during the dry season. The spatial organization of the site included a rock dam to direct the salt-enriched water from the stream to the first terrace parallel to the stream. This dam enabled the producers to contain the salt-enriched water in a basin. At the first terrace, at the edge of the rock dam, a limestone wall forms a rectangle filled with charcoal debris interpreted as a fire pit. The salt makers removed the water from the basin and placed it into large ceramic vessels to be evaporated over the fire pit.

The only visible expressions of salt making at the Placencia Lagoon salt works in southern Belize are a series of mounds interpreted as slag heaps (MacKinnon and Kepecs 1989). They contained leached earth and salt making ceramics. Within Punta Ycacos Lagoon, the underwater site of Stingray Lagoon dating to the Late Classic was discovered approximately 1 m

below sea level (McKillop 1995, 2002). Artifacts associated with the site interpreted for salt production are clay cylinders, clay sockets, spacers, fired clay, and charcoal. Hearths for evaporating brine in ceramic vessels were recorded. Similar (but no cylinders or thick walled jars/bowls) artifacts are also found at the site of Marco Gonzalez on far north Ambergris Cay that dates from the Late Classic to the Terminal Classic (Graham and Pendergast 1989). The salt produced in Paynes Creek National Park used the technique of evaporating brine in pots over fires that results in leaching mounds for enriching the salinity of the brine were likely used but have been deflated by sea level rise. The Killer Bee site, located in a mangrove flat has an earthen mound interpreted as a leaching mound (McKillop 2002). Either salt water or fresh water was poured through salty soil to produce brine for evaporation over fires in pots. The enriched salt was placed in standardized vessels and heated over a fire.

## **Methods**

Sediment samples for chemical analysis were collected along the two excavated transects at Chan B'i approximately 44 cm depth below the water surface. The samples were collected from the peat matrix at 1 meter intervals along the two transects. A 2 to 3 cubic cm sediment sample was extracted from the sea floor using a clean stainless steel knife and placed separately into labeled whirl-pak bags (Figure 21). The collection of the marine sediment was arranged along the two excavated transects in order to compare the distribution of artifacts recovered from the excavations with the results of the chemical analysis of the marine sediment. A total of 18 samples were collected on Transect 1. Twenty-two samples were recovered from Transect 2. The two transects are perpendicular to each other.

The marine sediment was exported under permit from the Belize Fisheries Unit and housed in a refrigerator in the Coastal Archaeology Lab at Louisiana State University. Samples



Figure 21. Photograph of acquiring the marine sediment samples at Chan B'i using a stainless steel knife and placing the sediment into Whirl-pak bags (photo by H. McKillop).

were shipped to the University of South Florida for analysis, where they were dried in refractory porcelain crucibles in a laboratory oven at 100 °C for 2 hours to drive off extant moisture.

For this study, a 2.00 g portion was taken from each sample, pulverized with a Coors porcelain mortar, mixed with 10 ml of .60-molar hydrochloric acid (trace metal grade) with .16-molar nitric acid (trace metal grade) in a polyethylene scintillation vial, and shaken vigorously on an electronic shaker at 220 rpm for 30 minutes. For each sample, the solution was filtered using Whatman ashless filter paper and decanted into clean polyethylene vials. The extracts were then diluted with ultrapure deionized water (type I reagent grade 18 Megaohm\*cm-1 resistance) to bring the concentrations of the elements of interest into the optimal measurement range of the instrument.

All samples were analyzed using a Perkin Elmer Elan II DRC quadrupole inductively coupled plasma-mass spectrometer (with background correction techniques facilitated by the WinLab 32 software providing detection limits close to 1 ppb for most elements; reported

detection limits for the ICP-MS range from 0.1 ppt [0.1 ng/L] to 1 ppb [ug/L] for most elements) at the Center for Geochemical Analysis at the University of South Florida. For this analysis, each liquid sample was drawn into the ICP where a flow of argon gas converted it into a fine aerosol. A portion of the sample aerosol was then directed through the center of an argon plasma torch, where the temperature is near 10,000 °K. The energy of the plasma caused the sample ions to lose an electron and reach an “excited” state. As the excited ions relaxed to their base states, they gave off energy in the form of light. The spectrum of light frequencies emitted from each element is unique and can be used to identify the presence of that element in a sample. This emitted light was separated by wavelength using a mass spectrometer equipped with a solid-state detector, which identified each wavelength and its relative intensity. The intensity of the emitted light is analogous to the concentration of an element in the sample solution. This information was then compared to calibration data for quantification.

For calibration, known solution standards containing the elements of interest in concentrations bracketing the expected concentrations of the sample were run during the analysis. By running several standards of different concentrations, calibration “curves” were generated equilibrating instrument response with known concentration. The unknown data were then plotted on these curves and the amount of each element of interest was calculated. The calibrated concentrations of 20 elements were determined: barium (Ba), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), phosphorus (P), strontium (Sr), zinc (Zn), titanium (Ti), chromium (Cr), cobalt (Co), yttrium (Y), uranium (U), sodium (Na), magnesium (Mg), aluminum (Al), potassium (K), calcium (Ca), manganese (Mn), and iron (Fe). The results were reported in parts per million (ppm) of the element.

## Results

A total of 40 marine sediment samples were analyzed from Transects 1 and 2 at Chan B'i. The samples are from separate locations at one meter intervals at the site. Errors on the standards were generally better than 5% for high mass elements Ba through U and all replicates were good. Four elements, especially Na, Mg, K, and Ca, were extremely concentrated. Undiluted concentrations were in the upper ppm, consistent with expectations for samples derived from brackish water. These samples pushed the upper limits of the instrument at 10x dilution and, as a result, exhibited poor reproducibility on duplicates. All samples were reanalyzed as 100x dilution, yielding good reproducibility.

For each element, the data were analyzed for any discernible fluctuations in relation to the wooden architecture and artifact distributions. Out of the calibrated concentrations of 20 elements, 11 elements exhibited no variations (eg. Ba, Cu, Pb, Hg, Ni, Zn, Ti, Cr, Co, Y, and U) these elements include the heavy metals and rare earth elements which all have low concentrations. However, nine elements show variation in the data (eg. P, Sr, Na, Mg, Al, K, Ca, Mn, and Fe). The elements that contained variation in the data set were then compared to the wooden architecture and the artifact assemblage recovered from excavations.

The marine sediment samples from Chan B'i derive from the bottom of a salt water body and could contain concentrated organic matter. In fact, loss-on ignition indicates high organic matter accounting for approximately 60% of the sediment (McKillop et al. 2010a, 2010b; Rosado et al. n.d.). The concentrations of phosphorus, strontium, and manganese at Chan B'i are relatively low (<100 mg/kg) but these elements so show variation (peaks and lows) in relation to the wooden architecture and artifact assemblage. Strontium as well as barium can result from marine organisms and limestone substrate. However, limestone is not present in the coastal

marine setting of Punta Ycacos Lagoon. Freshwater drains from the pine savanna (not limestone) and the granite Maya mountains. Both sodium and calcium can be associated with calcareous sediments from brackish and saline contexts. As expected, the salinity of the water at Chan B'i resulted in high values of sodium throughout the data set. However, there are variations in the sodium and calcium concentrations. Magnesium, aluminum, potassium, and iron have constant values with discernible peaks and lows. These elements can be linked to the mineral chemistry of marine sediment including aluminum from clays and sands including broken and disintegrated pieces of pottery, potassium from water, and iron from gleyed soils. Within each elements data set, there are variations that are higher or lower than the majority of results, which warrant discussion.

### **Chemistry Associated with Wooden Architecture and Artifact Assemblage**

The variation in nine elemental signatures corroborates salt production activities associated with the wooden building and suggests other activities were occurring at Chan B'i. The wooden architecture at Chan B'i forms a rectangular building measuring 7.25 m by 5.75 m with 10 possible room divisions more or more room divisions (Sills and McKillop n.d.). There are two lines of palmetto palm posts (*Acceloracea wightii*) located to the southwest of the rectangular building. Chan B'i dates to the Early Classic period (A.D. 300-600). Excavations in 2010 revealed an abundance of briquetage—ceramic vessels used to evaporate brine over fires to make salt—located inside and directly surrounding the wooden building. Abundant charcoal that was mixed with the briquetage was found. Artifact density is diminished between the two lines of palmetto palm posts. The lines of palmetto palm posts found at the salt works in Paynes Creek have been interpreted as retaining walls (Sills and McKillop 2010). The areas inside and

directly surrounding the wooden building is approximately 15 cm higher in elevation than the area surrounding the palmetto palm posts.

The chemical signatures associated with the building at Chan B'i can be interpreted in terms of the modern Maya salt production at Sacapulas, Guatemala as described by Reina and Monaghan (1981). High values for phosphorus, strontium, magnesium, aluminum, potassium, and iron are recorded from the samples acquired within and directly surrounding the wooden building. Peaks for phosphorus, magnesium, and potassium occur together in the central area of the building and next to the wooden posts (Figures 22, 23, and 24). The values may indicate areas of refuse disposal from clearing or sweeping material to the walls and/or ash from fires used in the evaporation process to make salt. The excavations through the building yielded abundant briquetage inside and surrounding the building. For example, at Sacapulas, a dozen or more bowls are placed over a fire on a raised soil platform in the center of the salt building for the evaporation process (see Reina and Monaghan 1981:Figs 30-31). The ash and charcoal from the evaporation process is eventually swept and placed in discard piles along the edges of the interior of the building.

There is a high potassium value to the west of the wooden building where dense amounts of briquetage were recovered similar to the densities inside the building (Figure 24). This area is likely a continuation of the building activities. Briquetage includes all ceramics associated with salt evaporation and typical of the assemblage at the Paynes Creek salt works (McKillop 1995, 2002; Sills and McKillop 2010). Most of the vessels the majority of which are Punta Ycacos Unslipped jars and bowls that are attached to vessel supports called cylinders with spacers, sockets, and bases. The briquetage is friable with sand temper. Amorphous clay lumps are the fragmentary bits of ceramic that account for the majority of the briquetage.

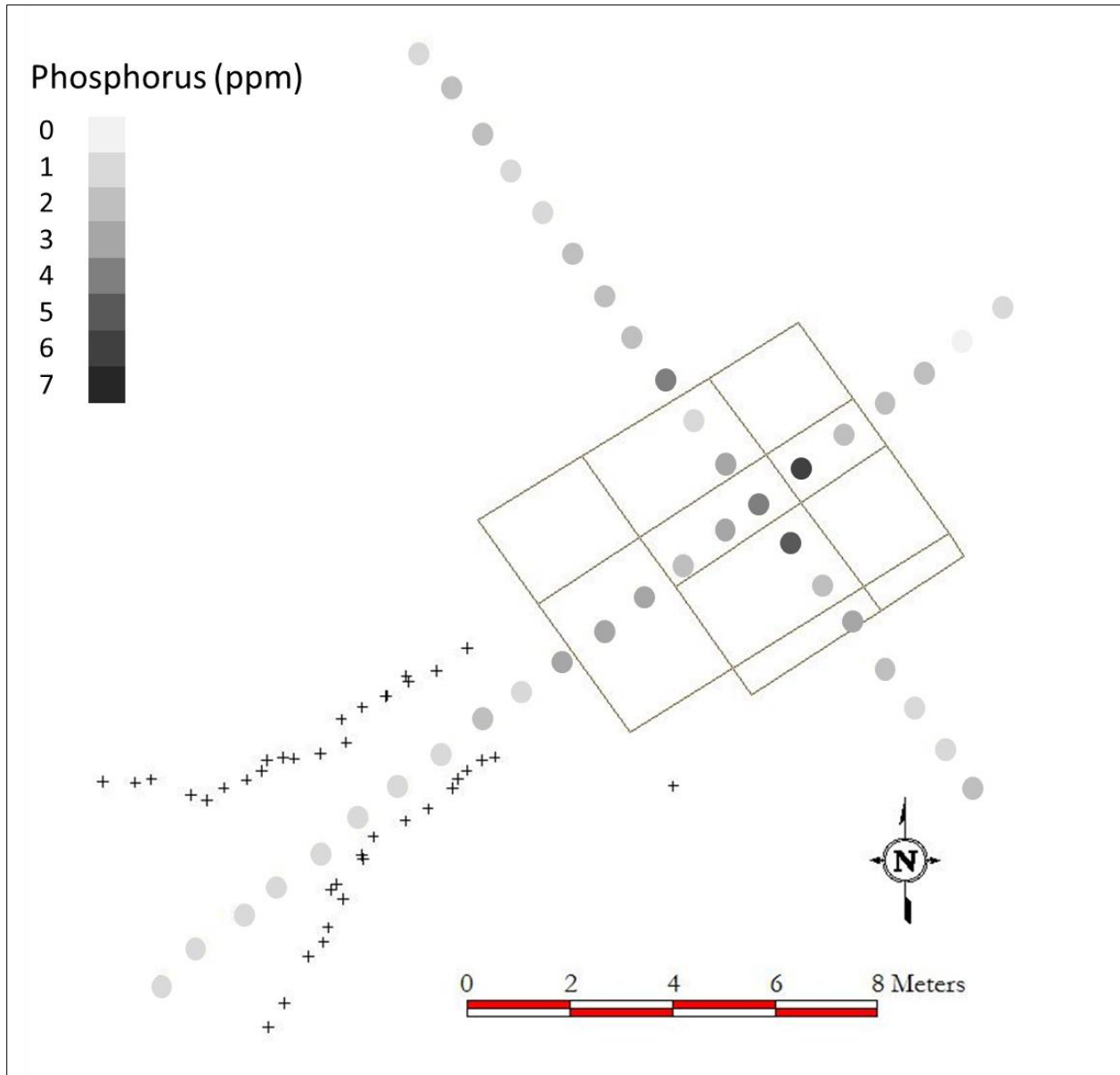


Figure 22. Map of Chan B'i showing the outline of wooden building including the lines of palmetto palm posts indicated by crosses. Fluctuations for phosphorus are shown along the two transects (GIS by H. McKillop and modified by C. Sills).



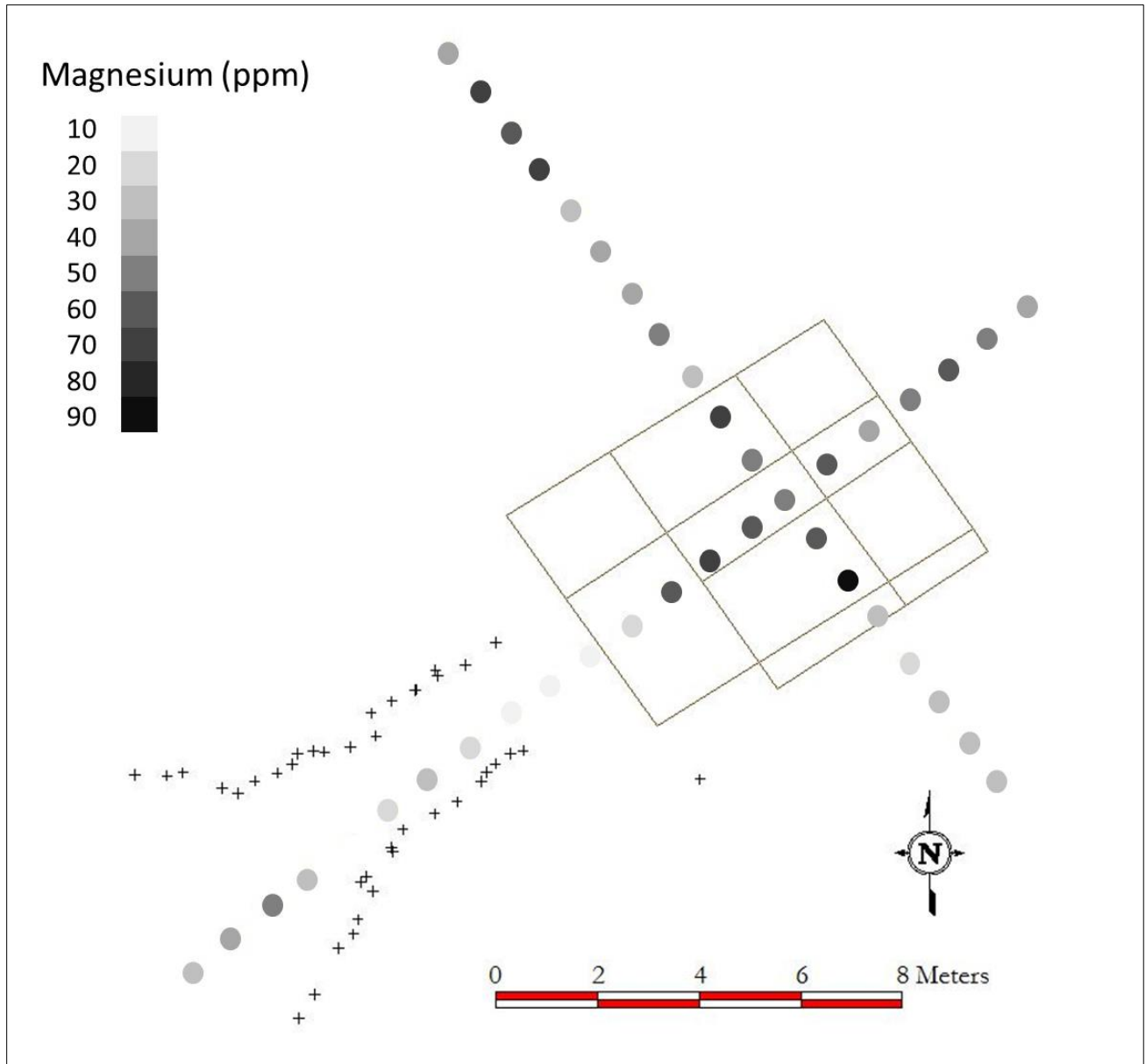


Figure 23. Map of Chan B'i showing the outline of wooden building including the lines of palmetto palm posts indicated by crosses. Fluctuations for magnesium are shown along the two transects (GIS by H. McKillop and modified by C. Sills).

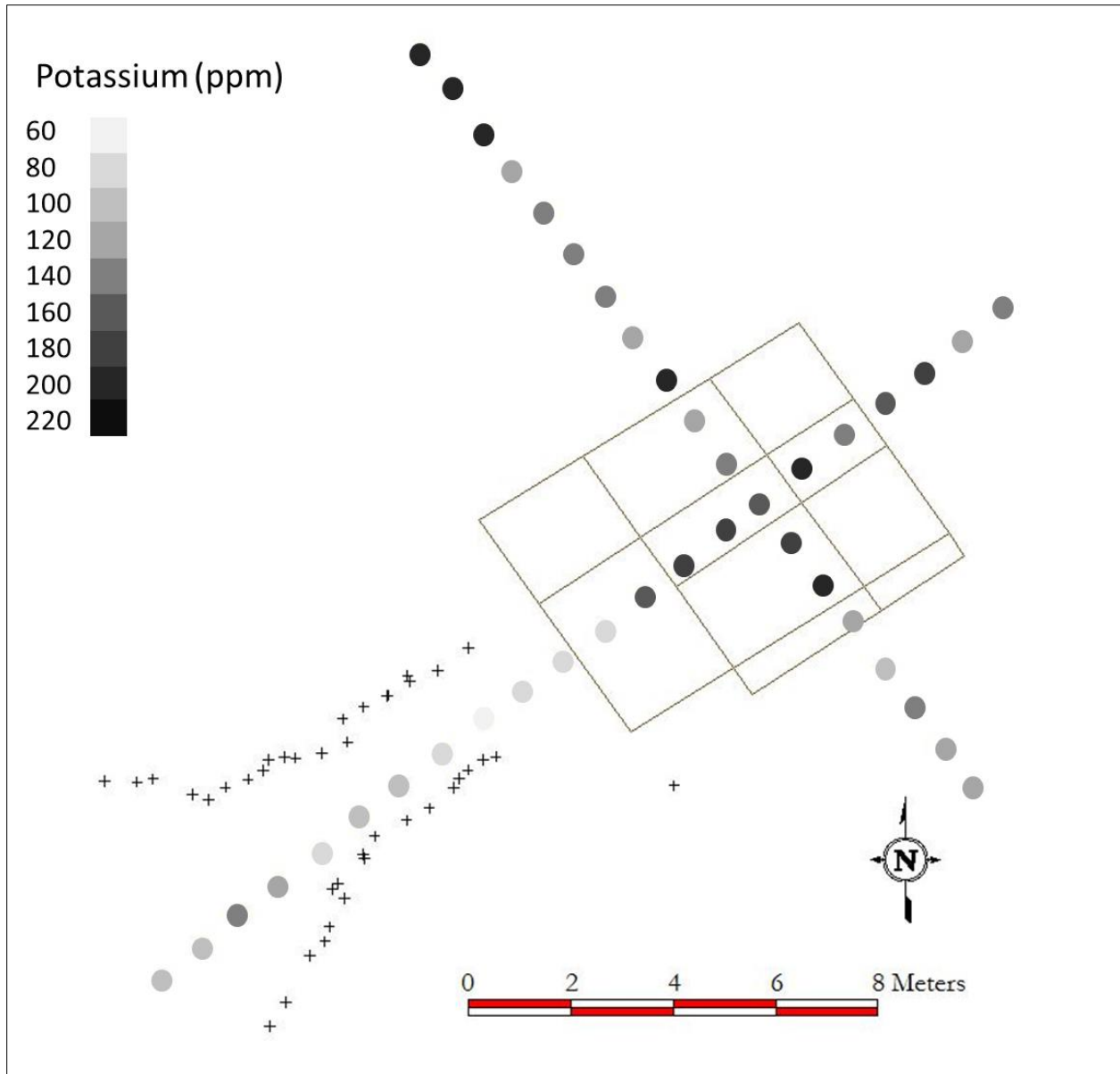


Figure 24. Map of Chan B'i showing the outline of wooden building including the lines of palmetto palm posts indicated by crosses. Fluctuations for potassium are shown along the two transects (GIS by H. McKillop and modified by C. Sills).

There is a peak in strontium and calcium outside of the wooden rectangular building, approximately 2 m east of the building near a living dwarf red mangrove stand (Figures 25 and 26). High values both strontium and calcium in this area are interpreted as a location for a shell midden or an area for fish processing due to the enrichment of calcium carbonate from shell and/or fish bones. However, the concentration of these two elements at one location might be associated with mangrove oysters that attach themselves to red mangrove prop roots. At the time of excavation and sediment collection no mangrove oysters were observed near Chan B'i or attached to the prop roots of the dwarf red mangrove.

The concentration of values between the two lines of palmetto palm posts shows a decrease in values for phosphorus, sodium, magnesium, aluminum, potassium, and iron compared to the interior of the wooden building and a high value for strontium and calcium. The lower values for phosphorus compared to the values inside and around the building suggest that the palmetto palm post area is not a locale of salt production or habitation. The area is bereft of briquetage and lower in elevation than the wooden building. The sea floor has thick silt—20 cm and greater in depth—that overlays the red mangrove peat. However, the area is demarcated by palmetto palm posts which suggest some function associated with the wooden architecture. Correspondingly, sodium values are lower than all the other tested marine sediment samples from Chan B'i (Figure 27). The sodium values are less than 1,000 ppm whereas the average values elsewhere at Chan B'i average 1,800 ppm.

One interpretation of the function of space between the lines of the palmetto palm posts is that the area is a sediment extraction locale where peat was excavated and used to filter salty water to increase the salt content for evaporation. The excavation of peat by the salt makers would result in lower elevation and the void would fill with the less salty silty sediment. Similar

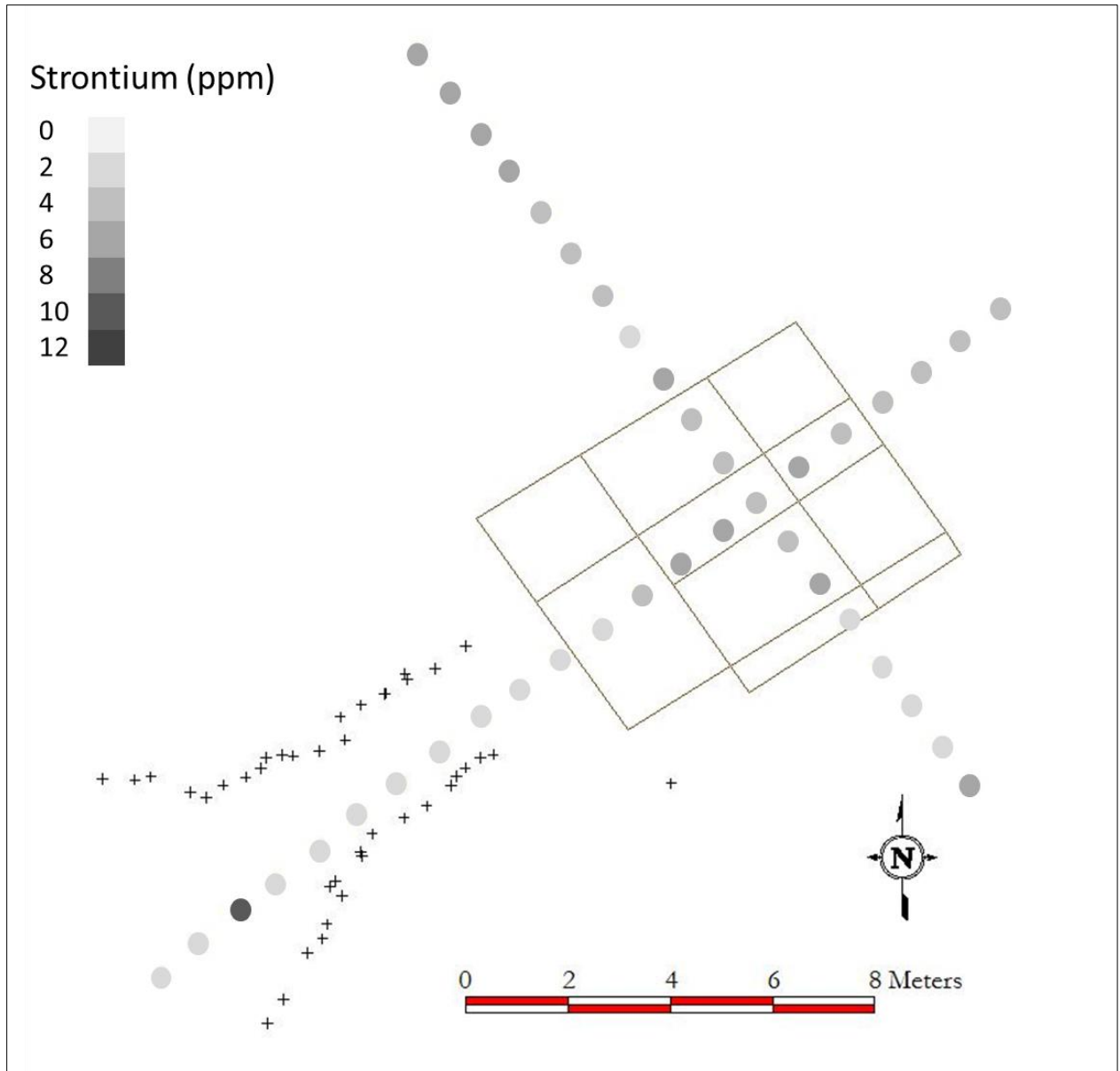


Figure 25. Map of Chan B'i showing the outline of wooden building including the lines of palmetto palm posts indicated by crosses. Fluctuations for strontium are shown along the two transects (GIS by H. McKillop and modified by C. Sills).

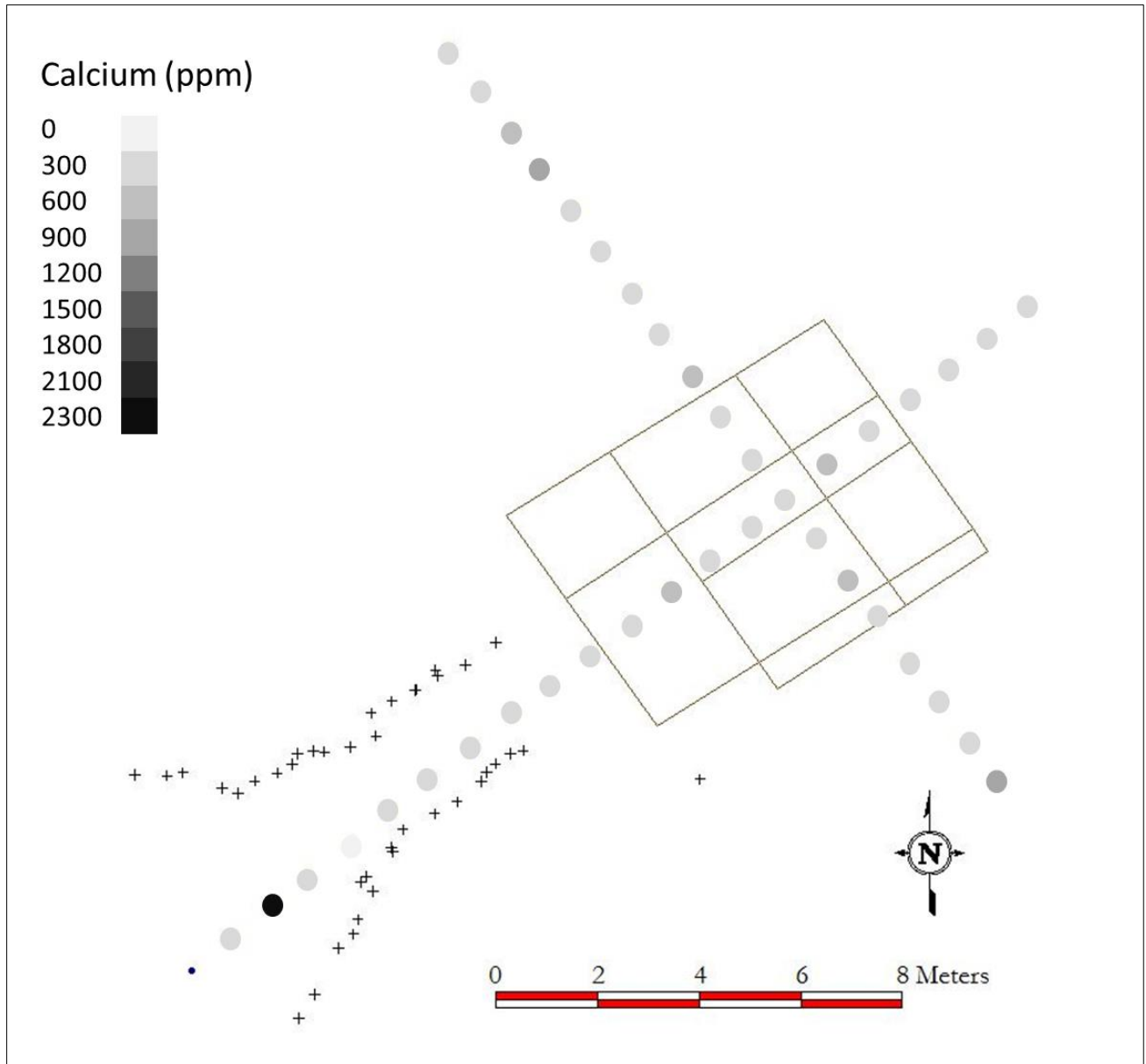


Figure 26. Map of Chan B'i showing the outline of wooden building including the lines of palmetto palm posts indicated by crosses. Fluctuations for calcium are shown along the two transects (GIS by H. McKillop and modified by C. Sills).

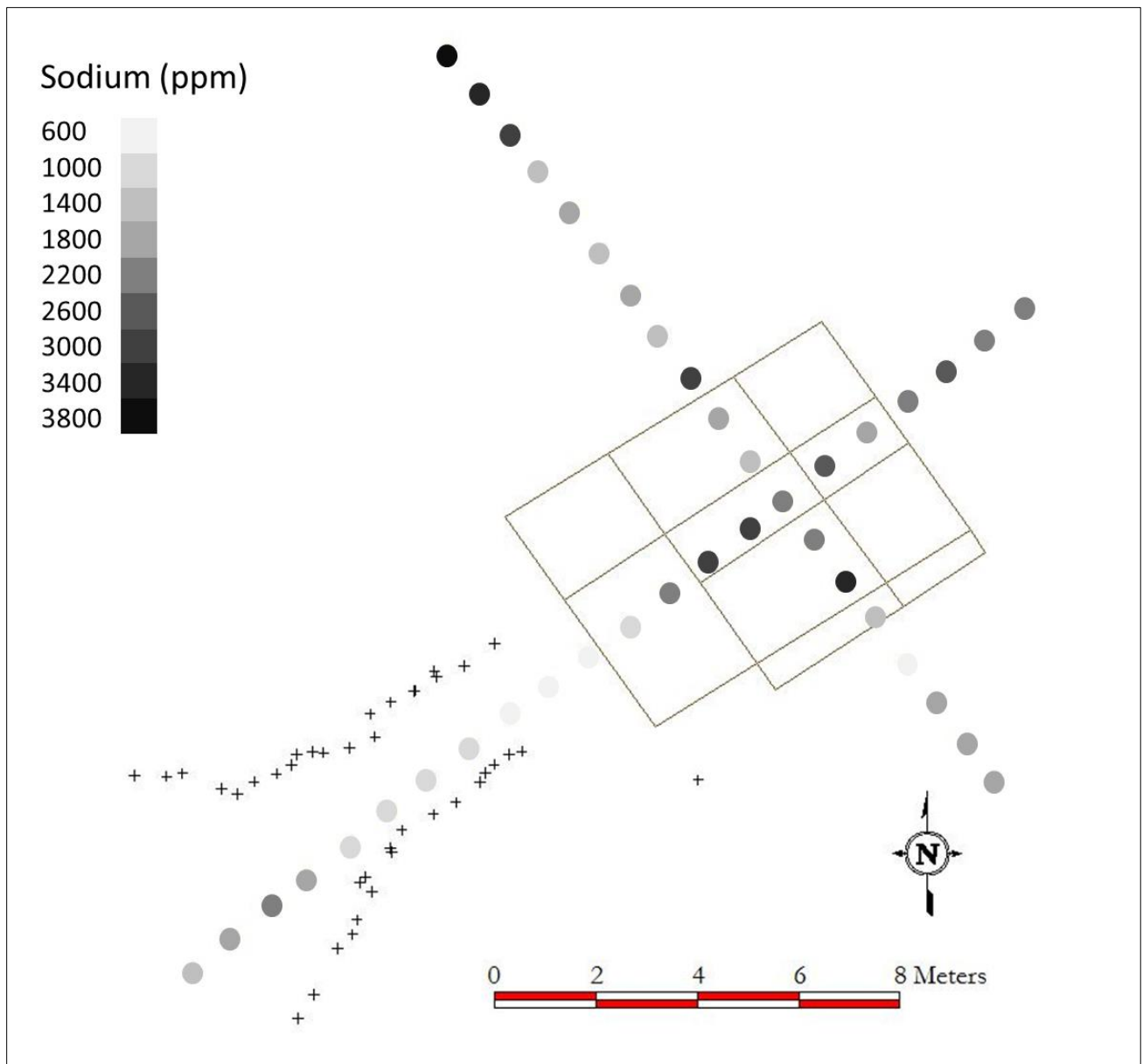


Figure 27. Map of Chan B'i showing the outline of wooden building including the lines of palmetto palm posts indicated by crosses. Fluctuations for sodium are shown along the two transects (GIS by H. McKillop and modified by C. Sills).

types of leaching processes have been documented throughout Mesoamerica (Andrews 1983; Good 1995; MacKinnon and Kepecs 1989; McKillop 2002; Parsons 2001; Reina and Monaghan 1981). An analogous leaching process at Chan B'i might account for the low sodium values recorded between the two lines of palmetto palm posts. The salty sediment for leaching was likely excavated in close proximity to the salt works demonstrated at the modern salt works at Nexquipayac and Sacapulas (Parsons 2001; Reina and Monaghan 1981). As with the high strontium and calcium value outside the eastern end of the building, there is the same signature between the palmetto palm posts. The high values of strontium and calcium may indicate an area of processing fish or shell, similar to the area outside of the eastern end of the building. Or, due to the sediment removal the area would be a good place to discard fish or shell.

## **Conclusion**

Chemical sediment analysis of terrestrial soils in the Maya area has been successful in determining and locating various activities not evident in the artifactual material alone. However, no known analyses of marine sediments from archaeological deposits using acid extraction to prospect for anthropogenic disturbances has been undertaken until this study. The organic artifacts—wood, botanicals, and charcoal—and ceramic materials are well preserved in a saline and mangrove peat environment. However, the mangrove peat sediment does not preserve the ash from fires or refuse such as bone from preparation and consumption activities. Chemical sediment analysis using ICP-OES and ICP-MS at Chan B'i an Early Classic Maya salt work was successful in defining activity areas associated with salt making along the southern coast of Belize.

The comparison of the chemical signatures and their association with the wooden architecture and artifact distribution show that the refuse from fires was swept to the corners of

the building and adds continuity between the past and the present. Comparable activities of leaching salty sediment, placing the brine into a container, and evaporating the brine over fires to make salt have been documented in the historic, ethnographic, and archaeological record in the Maya area and Mesoamerica. Moreover, chemical signatures suggest fish and shell processing as well as extraction of salty soil for leaching that were not deduced from the associated wooden architecture and artifact assemblage.

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**Chapter 5**  
**Chemical Analyses of Obsidian from Classic Maya Paynes Creek Salt Works, Belize**  
Elizabeth C. Sills and Heather McKillop

**Introduction**

Assigning Maya obsidian artifacts to their geological source locations by chemical and/or visual characterization has proved useful for reconstructing trade routes between the volcanic highland outcrops and lowland Maya consumers of obsidian (Andrews et al. 1989; Asaro et al. 1978; Braswell et al. 1994; Braswell et al. 2000; Clark et al. 1989; Dreiss et al. 1993; Guderjan et al. 1989; Hammond 1972; Healy et al. 1984; McKillop et al. 1988; McKillop 1995; Moholy-Nagy 1999; Moholy-Nagy and Nelson 1989; Nelson 1985; Rice et al. 1985; Sheets et al. 1990; Stross et al. 1978, 1983). The geospatial variability in obsidian source use over time within the Maya lowlands has suggested spheres of communication and trade (Driess and Brown 1989; Nelson 1985). During the Classic period, El Chayal obsidian was common at inland sites in the Maya lowlands whereas both Ixtepeque and El Chayal occur along the Caribbean coast (Hammond et al. 1984; McKillop et al. 1988). Commencing in the Terminal Classic through the Postclassic, Ixtepeque dominated obsidian trade, which was focused along the Caribbean coast of Belize and Mexico (McKillop et al. 1988).

Underwater survey in a shallow, salt water lagoon in Paynes Creek National Park, along the southern coast of Belize, revealed extensive ancient Maya salt works (McKillop 2005a). The earliest salt works date to the Early Classic, with expansion throughout the Late and Terminal Classic periods. The rise of the Paynes Creek salt industry mirrored the growth of population at inland communities in southern Belize, where salt—a basic biological necessity—was scarce. Shared decorative motifs on “unit-stamped” pottery from Paynes Creek to inland sites in southern Belize and adjacent Guatemala suggest inland consumers of coastal salt (McKillop

2002). In contrast to the recovery of abundant briquetage—pots used for the salt making process—a small quantity of obsidian was recovered from underwater survey.

The inland biological demand for salt produced at the Paynes Creek salt works, as well as shell, fish, and other marine resources underscores the coastal to inland movement of resources. Identifying the source locations of Paynes Creek obsidian is important for reconstructing patterns of coastal-inland trade and communication at the salt works. A predominance of El Chayal obsidian would align the Paynes Creek salt works with inland communities in southern Belize where El Chayal is was found to dominate at Lubaantun (Stross et al. 1983) and Uxbenka (Nasaroff et al. 2010). An alignment of the Paynes Creek salt works with the nearby coastal trading port of Wild Cane Cay would be supported by a predominance of Ixtepeque obsidian, found in quantities at Wild Cane Cay (McKillop 1987, 1989, 2005b).

Obsidian from the volcanic regions of Mesoamerica has been used to study trade and exchange routes. Obsidian can be sourced to its original location due to the variance in trace elements such as rubidium, zirconium, and strontium. Source studies are used to find the obsidian origins and establish trade routes. Analysis such as X-ray fluorescence (XRF), abbreviated neutron activation analysis, and full neutron activation analysis (NAA) have been used to identify sources and reconstructing their diachronic and synchronic uses (Andrews et al. 1989; Asaro et al. 1978; Braswell et al. 1994; Dreiss et al. 1993; Guderjan et al. 1989; Hammond 1972; Healy et al. 1984; McKillop et al. 1988; Moholy-Nagy 1999; Moholy-Nagy and Nelson 1989; Nelson 1985; Rice et al. 1985; Sheets et al. 1990; Stross et al. 1978, 1983).

Portable X-Ray Fluorescence (PXRF) can accurately and quickly chemically characterize obsidian samples, giving rise to the increasing use by archaeologists. PXRF studies have been incorporated into research for Peru (Craig et al. 2007; Craig et al. 2010), China (Jia 2010), New

Zealand (Sheppard et al. 2011), the Near East (Forster and Grave 2012; Frahm 2013a), Polynesia (Burley et al. 2011), central Mexico (Millhauser et al. 2011), Guatemala (Cecil et al. 2007), and Belize (Drake et al. 2009; Nasaroff et al. 2010). In this study, PXRf was useful to quickly and accurately assay a sample of obsidian from the ancient Maya Paynes Creek salt works. PXRf is well suited for identifying the geochemical sources of obsidian, which varies among outcrops in trace elements. Shackley (2010) has pointed out that increasing feasibility of PXRf does not equate to accuracy. Instead, Shackley cautions archaeologists to seek training and produce comparison studies. Therefore, the results of the Paynes Creek obsidian using PXRf will be presented along with their sourced designations.

We report the results of assaying 40 obsidian artifacts from the Paynes Creek salt works using an AXS Tracer-III portable wide range elemental analyzer. The coastal setting of the salt works provides an opportunity to examine the interplay between coastal-inland trade by sourcing the obsidian. Are the Paynes Creek salt makers predominately using El Chayal, Ixtepeque, or both?

### **The Paynes Creek Salt Works**

The obsidian was collected from 18 salt works in Paynes Creek during systematic flotation survey between 2005 and 2008. The field crew lined up parallel to each other, shoulder to shoulder, on research flotation devices, moving systematically across a site searching for wooden posts, artifacts, and other cultural material. The obsidian was assigned to the Classic period based on the presence of Classic period ceramics and radiocarbon dates obtained from the preserved wooden architecture.

The Paynes Creek sites are Classic Maya salt works located on the coast in southern Belize (Figure 28). They are submerged in mangrove peat in a shallow salt water lagoon. The

mangrove peat provides an anaerobic environment that has preserved wooden architecture. Relative sea-level rise occurred sometime after the Late Classic abandonment and inundated the salt works (McKillop et al. 2010a, 2010b). The wooden architecture discovered in Paynes Creek forms rectangular buildings and other ancillary apparatuses associated with salt making (McKillop 2005a; Sills and McKillop 2010). Due to the lack of disturbance, commonly found at terrestrial sites, large pieces of pottery are abundantly dispersed across the salt works. The large fragments of pottery are part of the briquetage assemblage—broken pieces of pottery used to evaporate brine over fires to make salt.



Figure 28. Map of the Maya area showing location of the Paynes Creek salt works (map by C. Sills).

The current research in the lagoon is a continuation of previous projects conducted along the coast and cays in southern Belize to investigate the role of settlements and workshops in the

ancient Maya economy (McKillop 1987, 1995, 2002, 2005a, 2005b; McKillop and Healy 1989; Sills and McKillop 2010). Salt, a biological necessity, was produced at the Paynes Creek salt works for distribution to inland southern cities such as Lubaantun, Nim li Punit, and Uxbenka where salt was scarce (McKillop 1995, 2002, 2005a; Sills and McKillop 2010). Trade routes have been documented for salt from ethnohistoric accounts and archaeological evidence throughout the Maya area (Andrews 1983). A mural on the exterior of a temple at Calakmul depicts a salt glyph accompanied by a depiction of a man with a basket and spoon (Vargas et al. 2009). The epigraphic evidence from Calakmul indicates that salt was an important trade good.

The nearest settlement to the Paynes Creek salt works—approximately 4 km—is Wild Cane Cay, a Classic to Postclassic trading port (McKillop 1996, 2005b). The community at Wild Cane Cay was a major trading port integrated into inland and coastal trade and thrived with a rich obsidian trade (McKillop 1989). However, with the decline of the southern inland sites such as Lubaantun, Wild Cane Cay reoriented its maritime trade to the northern Maya lowlands (McKillop 1987, 1989, 1996, 2005b). Chemical characterization at the Lawrence Berkley Lab of a sample of 105 obsidian artifacts identified six different obsidian sources were used by the Wild Cane Cay Maya (McKillop et al. 1988).

## **Materials and Methods**

The sample consisted of all obsidian recovered from the 2005 to 2008 systematic underwater survey. The material was exported under permit from the Belize government Institute of Archaeology to Louisiana State University for study. The sample includes obsidian blades and blade fragments from 18 different sites dating to the Late Classic (A.D. 600-900). The sample size of 40 is adequate to include the variability of obsidian sources used by the Classic Maya. A previous study of sites with less than 10 obsidian items sourced per time period



show less variability in source use compared to sites with 10 or more obsidian items per time period that show greater representation of minor sources (McKillop 2005b). The results were statistically significant.

We assayed 40 obsidian artifacts with an AXS Tracer-III portable wide range elemental analyzer from Bruker Elemental. The PXRF was supplied with a rhodium tube as the excitation source, and a peltier cooled, silicon PIN diode detector. Analyses of the obsidian artifacts were conducted at 40keV, 17 ua, with a filter composed of .006” Cu, .001” Ti, and .012 Al. to optimize the Tracer for particular elemental groups found in obsidian such as rubidium, zirconium, strontium, yttrium, and niobium. The obsidian was in contact with the X-ray path for 180 live time seconds as suggested by Bruker and demonstrated as an efficient time for excitation of the x-ray path for obsidian (Jia et al. 2010; Sheppard et al. 2011). Each obsidian artifact was x-rayed once, with the thickest and flattest part of the artifact placed over the detector window to insure consistency in readings from the instrument (Figure 29).

The Tracer 3-V analyzer was attached to a laptop using S1PXRF software developed by Bruker. As an obsidian artifact was assayed, the spectrum reading was recorded on a laptop and displayed as a graph showing the peaks of different heights for each element selected (Figure 30). The S1PXRF software is a qualitative tool that allows the user to compare and contrast different chemical elements of an obsidian artifact by visually overlaying spectra from known geochemical sources.

In order to carry out statistical analysis of our data for sourcing and to make our data comparable with published archaeological data, the data were converted to parts per million (ppm). To obtain parts per million for each obsidian artifact, the sum area under the peaks was calculated using the KTIS1CalProcess calibration process developed by Bruker. The conversion



Figure 29. Roberto Rosado arraying an obsidian blade in the Coastal Archaeology Lab with the Bruker Tracer 3-V (photo by H. McKillop).

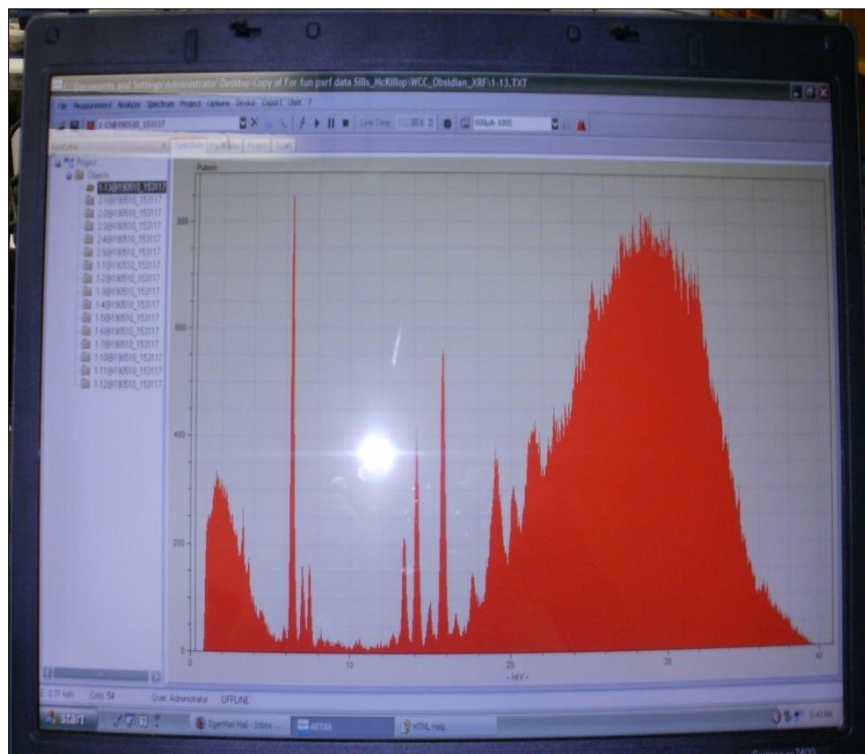


Figure 30. The elements identified by the X-ray are shown on the computer attached to the PXRF machine (photo by H. McKillop).

file was developed from obsidian of known geochemical sources in Mesoamerica (Bruce Kaiser, personal communication, 2010). The results of the conversion process were entered into a MS Excel spreadsheet. The ppm data for five variables (Rb, Sr, Y, Zr, and Nb) were statistically grouped using descriptive statistics and data reduction. Factor Analysis and Principal Component Analysis (PCA) were performed in the statistical program SPSS 15© for Windows to evaluate the geochemical source for each obsidian artifact. The results of the PCA, known as factor scores, were graphed along a linear regression line with 95% confidence.

## **Results**

Forty obsidian blade and blade fragments were assayed, with the values converted to ppm (Table 2). Groups were identified using PCA and graphed along a linear regression line to obtain a pattern of correlation within the data (Figure 31). PCA was conducted to find geochemical patterns from 40 obsidian artifacts in the data set. The values of five elements (Nb, Y, Sr, Rb, and Zr) were compared. Principal component analysis with a varimax rotation was computed to determine patterning. PCA of the ppm's from the 40 obsidian artifacts resulted in two components explaining 80% of the total variance within the dataset. The first component (=50%) consists of Rb and Y and the second component (=30%) consisted of Sr and Zr. Commonalities represent the proportion of the variance in the original variable that is accounted for by the factor solution. In this data set, all of the communalities were high (above .5); except for Niobium that was less than .5. The low commonality score for Nb indicates that this variable does not account for a significant variance within the dataset.

## **Trade at the Paynes Creek Salt Works**

The dominant obsidian source used at the Paynes Creek salt works is Ixtepeque (n=23) followed by El Chayal (n=15). The Ixtepeque source has been documented as the main source

Table 2. Concentrations of geochemical elemental data of Paynes Creek obsidian with assigned source. Ppm concentrations acquired from PXRF of rubidium (Rb), strontium (Sr), yttrium (Y), zirconium (Zr), and niobium (Nb).

<b>Sample No.</b>	<b>Rb</b>	<b>Sr</b>	<b>Y</b>	<b>Zr</b>	<b>Nb</b>	<b>Source</b>
1	136.31	237.20	22.36	234.84	9.15	Ixtepeque
2	196.19	207.70	30.88	145.56	8.63	El Chayal
3	156.04	259.64	27.16	247.01	8.81	Ixtepeque
4	130.49	229.45	24.18	234.91	9.18	Ixtepeque
5	126.50	233.15	25.19	216.30	7.84	Ixtepeque
6	131.74	230.54	25.66	234.17	7.70	Ixtepeque
7	139.27	235.51	25.72	236.58	6.68	Ixtepeque
8	119.95	211.04	26.97	221.77	9.30	Ixtepeque
9	113.45	182.96	23.18	201.11	6.43	Ixtepeque
10	137.60	239.95	25.38	238.52	9.45	Ixtepeque
11	137.41	225.88	24.15	228.64	9.43	Ixtepeque
12	136.11	238.22	25.68	239.32	7.78	Ixtepeque
13	206.47	233.30	31.13	157.37	10.42	El Chayal
14	135.31	238.19	27.25	241.63	11.15	Ixtepeque
15	189.78	209.48	31.90	139.97	7.59	El Chayal
16	90.42	115.40	19.94	182.87	12.94	Unknown
17	94.66	146.67	21.48	192.82	10.75	Unknown
18	192.43	213.78	32.34	144.38	8.86	El Chayal
19	129.73	229.71	27.28	237.40	8.73	Ixtepeque
20	138.49	253.62	27.20	236.28	8.61	Ixtepeque
21	132.81	232.64	24.78	233.92	6.98	Ixtepeque
22	132.43	246.38	25.96	239.39	9.05	Ixtepeque
23	200.93	236.52	28.42	155.04	10.13	El Chayal
24	131.35	226.39	27.75	238.77	9.65	Ixtepeque
25	182.44	197.28	30.87	136.97	6.90	El Chayal
26	196.23	233.43	31.22	153.48	9.04	El Chayal
27	197.91	226.18	31.91	148.62	9.33	El Chayal
28	199.38	200.65	26.70	152.56	10.02	El Chayal
29	126.18	221.98	25.38	232.94	8.01	Ixtepeque
30	192.31	203.12	32.25	142.99	8.25	El Chayal
31	205.03	222.76	25.16	145.30	10.17	El Chayal
32	193.53	221.52	32.47	153.07	10.22	El Chayal
33	192.79	212.27	28.68	142.79	6.81	El Chayal
34	130.41	223.26	25.45	219.59	6.60	Ixtepeque
35	128.81	224.50	23.37	235.40	7.55	Ixtepeque
36	105.72	187.68	22.81	203.40	8.40	Ixtepeque
37	127.83	231.78	26.32	228.96	7.64	Ixtepeque
38	182.19	200.38	30.54	141.36	9.87	El Chayal
39	131.78	228.88	25.11	222.76	7.65	Ixtepeque
40	204.19	215.75	30.14	155.93	12.07	El Chayal

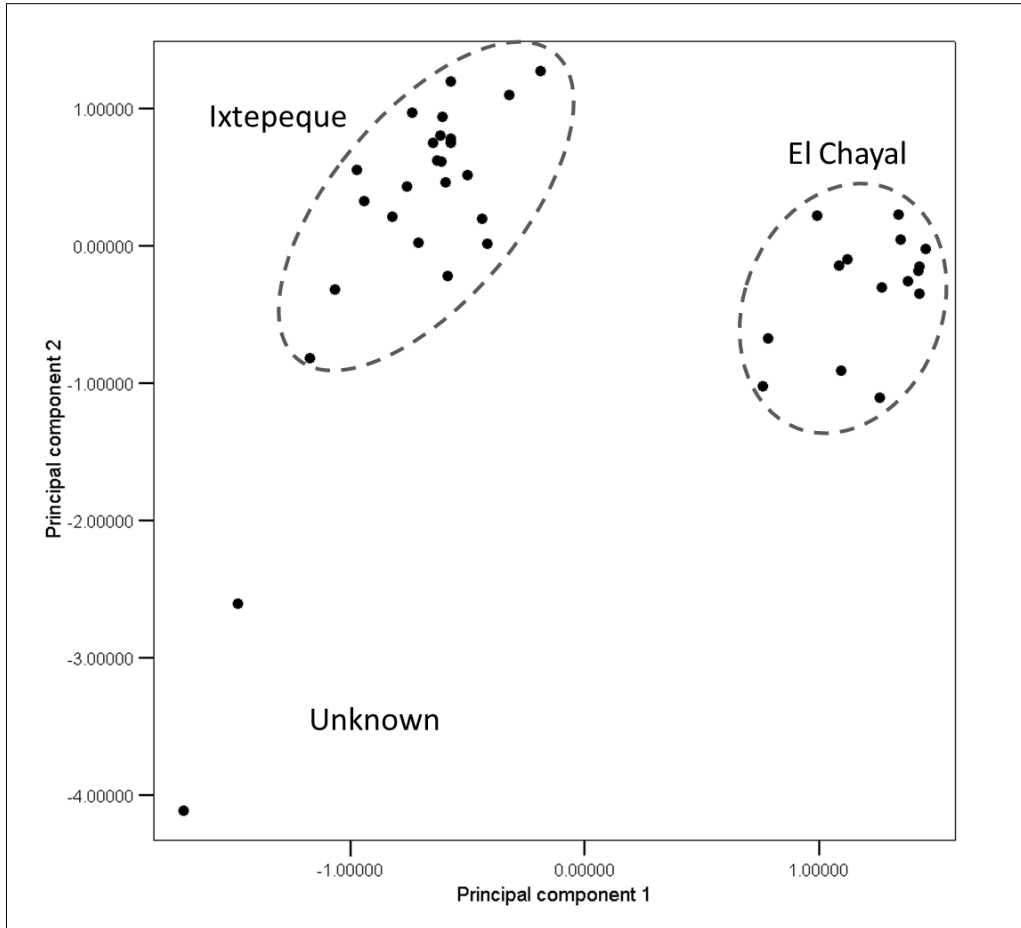


Figure 31. Plot of the geochemistry of the geological sources against the principal components. The regression of the PCA confidence level is 95%.

for the Late Classic at Wild Cane Cay whereas El Chayal is the dominant source at the inland sites of Lubaantun and Uxbenka in southern Belize (Stross et al. 1978; Nassaroff et al. 2010). The PXRf analysis of obsidian blades from the Paynes Creek salt works indicates the salt makers were using the two main Classic period source sites probably using both inland trade such as at Uxbenka and coastal trade with Wild Cane Cay. Two of the obsidian artifacts could not be sourced to either El Chayal or Ixtepeque. The unknown obsidian source (n=2) is likely from a minor source.

## Conclusion

The portable XRF was successful in generating concentrations of elements that could be grouped together using PCA. Sourcing was accomplished using a dataset of obsidian that was previously geochemically characterized by the LBL (McKillop et al. 1988). However, PXRF has limitations in sourcing minor sources such as the two obsidian blades that are unidentifiable. These limitations are due to a lack of access to a database of results not readily available in the literature.

We are publishing the results showing the main trace elements ppm's (rubidium, zirconium, strontium, yttrium, and niobium) as well as the source assignment. By publishing the results from our study we hope to begin a methodological practice for comparison of PXRF results. The accessibility of PXRF machines over more traditional laboratory XRF—both in cost and amount of obsidian analyzed—has led to increased use. However, the increase in use has not lead to an increase in the accessibility for comparative data. The ability to compare and contrast the results using various PXRF instruments will add to the growing body of literature concerning the reliability and validity of using PXRF (Frahm 2013a, 2013b; Speakman and Shackley 2013).

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## Chapter 6 Summary

In my dissertation I bring together analytical techniques for studying ancient Maya activities at Chan B'i and Atz'aam Na. The two salt works were evaluated to study the artifacts and their relationship to wooden architecture in order to (1), identify salt production and/or other activities; (2) identify if the sites were dedicated to the single activity of salt making, were household workshops, or were used in “multi-crafting”. The preservation of wooden architecture, not typical of the Maya area, at salt works in Paynes Creek offered an opportunity to examine activity areas at the place of production.

Transect excavations conducted at both sites establish that the wooden architecture forms buildings where salt was produced to meet the demand of a massive salt industry for inland cities during the Classic Maya, where salt was scarce. Excavations revealed an abundance of briquetage—ceramic vessels used to evaporate brine over fires to make salt—indicating the function of the wooden architecture is for workshop production of salt. The evaluation of the spatial distribution of briquetage in relation to the interior and exterior of buildings and lines of palmetto palm posts supports an interpretation that salt production was occurring inside the buildings at the Paynes Creek salt works. The wealth of briquetage and charcoal and the scarcity of domestic artifacts indicate that the sites were specialized salt works and not physically attached to households. The salt pots were standardized in contrast to other ceramic vessels from nearby Wild Cane Cay.

The peat has preserved wood, botanical remains, and large ceramic vessels, but not bone. However, the results from inductively couple plasma-mass spectroscopy (ICP-OES) and inductively coupled plasma-mass spectroscopy (ICP-MS) chemical analysis at Chan B'i detected evidence not found by examining the artifact assemblage. There are chemical patterns located

inside and outside of the wooden architecture. Examination of artifact densities and chemical signature from the interior of the building at Chan B'i indicates that the refuse from fires was swept to the corners of the building as with the modern day salt works at Sacapulas in Guatemala. The chemical signature values between the lines of palmetto palm posts suggest they were possibly posts for land retention where salty sediment was excavated for leaching. Other activities not represented in the artifact assemblage include chemical signatures suggesting fish and/or shell processing.

Portable X-ray fluorescence was successful in assigning obsidian to El Chayal and Ixtepeque—the two main obsidian sources. The results of the obsidian source study suggest the salt works were utilizing both inland and coastal trade. The obsidian along with 'unit stamped' stamped pottery support an interpretation that the Paynes Creek salt makers interacted with the inland Maya at sites such as Lubaantun as well as the Maya living on Wild Cane Cay.

## Vita

Elizabeth Cory Sills was born February 22 in Louisville, Kentucky. Her curiosity for understanding and interpreting culture began at the age of 14 when she participated in archaeological excavations in Belize directed by her step-father Dr. J. Jeff MacKinnon. She attended the University of Texas at Austin with a focus in Maya archaeology. She participated in the field school Programme for Belize Archaeological project in the Rio Bravo area under direction of Sr. Fred Valdez. In 1999, she earned a Bachelor of Arts degree in anthropology with a minor in sociology from the University of Texas at Austin. After completing her degree, she worked with a cultural resource management firm in Dallas, Texas where she developed methodological skills and specialized in Section 106 of the National Historic Preservation Act. She was in charge of many field projects surveying and excavating a diverse array of archaeological sites, mainly in Texas. In 2005, realizing she wanted to pursue a long-term career in archaeology she applied and was accepted into the Anthropology graduate program at Louisiana State University in Baton Rouge, Louisiana. While pursuing a graduate degree, Cory participated in the Mapping Ancient Maya Wooden Architecture field project in 2006 and 2007. She also worked as a student worker for the State of Louisiana, Office of Cultural Development, Division of Archaeology, learning the regulatory agencies policies regarding Section 106. She completed her master's thesis *The Architecture of Ancient Maya Saltmaking; Distribution and Analysis of Preserved Wooden Posts at the John Spang Site in Paynes Creek National Park, Belize* in August of 2007. She was accepted in the Geography doctoral program at Louisiana State University where she has since invested in completion of the requirements for the Geography doctorate with a Concentration in Anthropology. While pursuing her doctoral degree, Cory has participated in six field seasons on the Underwater Maya Archaeology project

and held a graduate assistantship through the NSF funded Ancient Maya Wooden Architecture and the Salt Industry. She is manager of the Digital Imaging and Visualization in Archaeology Lab where she instructs students and reconstructs ancient artifacts by 3D scanning and 3D printing. Cory was successful in applying and obtaining an NSF Dissertation Improvement Grant for analysis for her dissertation. As well as research, Cory has taught numerous undergraduate courses in Anthropology and Geography at Louisiana State University. During her graduate career at Louisiana State University, she participated in an initiative of the Geography and Anthropology (Graduate Student) Society to protect the LSU Indian mounds, the oldest earthen archaeological mounds in North America. Cory's future goals include obtaining a tenure-track Assistant Professor position at a University and continuing her research on the ancient Maya salt industry.