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Analysis of Marine Sediment of Prehispanic Maya Saltworks 24 and 35 in Paynes Creek National Park, Southern Belize

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ANALYSIS OF MARINE SEDIMENT OF PREHISPANIC MAYA SALTWORKS 24
AND 35 IN PAYNES CREEK NATIONAL PARK, SOUTHERN BELIZE

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ABSTRACT

Through the study of four marine sediment columns taken at two different underwater Classic Maya sites identified as saltworks facilities in southern Belize, this research had the objective of provide some insights on the occupation of these sites and the formation of their archaeological record. The marine sediment studied in this research was composed of partially decomposed plant matter, inorganic minerals, and water in different proportions, with mangrove roots composing the major organic component of the mangrove peat. This research included macroscopic descriptions of the marine sediment, loss-on ignition of 32 samples uniformly distributed throughout the sediment columns to determine the percentage of organic content, and microscopic characterizations of samples throughout the column samples. The results obtained through loss-on ignition suggest clear patterns of organic content distribution throughout the marine sediment columns that, along with macroscopic and microscopic characterizations of the marine sediment, suggest the effects of human activities in the areas where the sediment was collected. Occupation levels at these sites were tentatively identified at 35 cm to 55 cm depth from the modern sea floor at Site 24, and 45 cm to 60 cm at Site 35. Since archaeological artifacts are found at the modern sea floor in these sites, bioturbation was likely an important element in the formation of the archaeological record at both underwater sites.

INTRODUCTION

This thesis research focuses on the study of marine sediment from two Classic Maya (A.D. 300-900) underwater sites at Paynes Creek National Park, Belize, in order to know more about the occupation and chronology of the sites, the environment of the area in prehispanic times, and the formation of the archaeological record after their abandonment. This thesis project is part of the ongoing research "Ancient Maya Wooden Architecture and the Salt Industry", directed by my advisor, Dr. Heather McKillop. The prehispanic sites were flooded by sea-level rise and are underwater in Punta Ycacos Lagoon, Paynes Creek National Park, southern Belize. The accumulation of mangrove peat covering the archaeological sites secured good preservation of their archaeological record, with wooden architecture and other organic materials, as well as artifacts used on salt production activities (McKillop 2005a, 2007). The objective of this research is to compare and contrast the prehispanic occupation of Early Classic Site 24 and Late Classic Site 35 through the analysis of marine sediment cores extracted from each site.

The research questions guiding this research are: Is it possible to identify the occupation level at the sites under study through the analysis of mangrove peat? What is the origin of the sediment deposited over the occupation layer on Sites 24 and 35? Is there continuity or change in the environment in relation to the occupation of the sites? What inferences can be drawn from the results of sediment analysis obtained from both sites under study, and the sediment column already analyzed at Site 14 (McKillop et al. 2010a and 2010b)? What was the function of the lines of palmetto palm posts at Sites 24 and 35? What inferences can be drawn about site formation processes through the analysis of marine sediment?

The hypotheses that guided this study are the following: The occupation level is possible to identify in the sediment recovered at the sites under study, and is expected that this level would be recognizable through the identification of changes in the organic and inorganic composition of the sediment in comparison with other levels. These changes would indicate human impact on the natural environment. Other types of evidence of occupation would accompany these changes in the composition of the mangrove, including the presence of artifacts, charcoal, and other distinct organic materials not associated with mangrove peat.

Following the abandonment of the sites, mangroves re-colonized the area; in consequence, mangrove peat covered the occupation level at the sites under study. Since it has been proposed by previous paleoecological studies (see Cameron and Palmer 1995) that the region under study yields a record of 7000 years of mangrove peat accumulation, we would expect to identify the same sediment composition when the sites were abandoned as before the occupation of the sites.

The sedimentation will be different depending on the location of the columns under study. We can expect some variation in composition between column samples from the same site depending on their location in relation to the site (inside vs. outside). Because of the proximity and the general similarities in the area where the sites are located, we can expect some similarities between the results from Site 24 and 35, and the results previously obtained from Site 14.

The palmetto palm posts lines were used to limit specific activity areas (working areas vs. exterior), in this case areas related to salt production. The post lines may have served as a barrier to slow the effects of sea level rise in the working areas. We would expect to find a different sedimentation depending on the location of the sediment columns studied. The areas where human activities were performed relatively

frequently would reflect more changes in the natural environment, as opposed to the areas with less human intervention, with a more regular, and natural patterned sedimentation.

Since mangrove peat has the ability to preserve materials due to its anaerobic nature, the level of occupation will have an array of in situ artifacts and organic materials covered by mangrove peat. We would expect to find artifacts at the occupation level of the sites covered by mangrove peat.

This project studied four sediment columns of 60 cm depth from the sea floor taken from two different underwater sites (Site 24 and Site 35). The methods included field recovery and lab analysis of the sediment. In the field, the sediment was recovered following the same methodology employed in a previous sediment study in the area (see McKillop et al. 2010a and 2010b). Laboratory research included visual description of the sediment from each level, sampling for loss-on ignition for each level to identify percent of organic matter, and microscopic sorting of organic material to identify species composition. Some general observations that I made during a brief field visit on recently abandoned saltworks in the North coast of Yucatan provided additional information to understand the abandonment processes at these particular salt production contexts.

This research project has the potential to contribute to our knowledge of prehispanic social processes in the Maya area related with salt production, and to provide information on site abandonment and site formation processes. The effects that the natural environment has over human settlements, in this particular case the repercussions of sea level rise over coastal sites, should be taken into account for archaeological research in coastal areas.

BACKGROUND INFORMATION

Previous Archaeological Research in the Area

Paynes Creek National Park is located in Toledo District, southern Belize (Figure 1). Southern Belize has been identified as an archaeological area defined geographically, culturally, and temporally as a region (Leventhal 1990: 137). The internal homogeneity of southern Belize started around AD 395, with a predominantly Late Classic occupation in the inland major centers of Pusilha, Lubaantun, and Nim Li Punit, and ended with the collapse of these major centers around AD 900 (Leventhal 1992: 145-151). With the Classic Maya collapse, many centers in the southern Maya lowlands were affected by political instability and population decline or even total abandonment (Houston and Inomata 2009: 304). Geographically, the area presents numerous rivers running from the Maya Mountains into the Caribbean (Wright et al. 1959).

Archaeological research in the coast of southern Belize started with the characterization of the prehispanic Maya trading port of Wild Cane Cay (McKillop 1987, 2005b), and continued with the study of long-distance trade and the coastal economy of southern Belize by regional survey and excavations (McKillop 1994, 2002: 26). The research at Wild Cane Cay documented an increase in sea trade during the Postclassic period (AD 900-1500) in comparison to the Classic period, with evidence suggesting that Wild Cane Cay functioned as a place of trade and also as a refuge for long distance traders (McKillop 2005a). The study of the economy and trade networks in the southern Belize region revealed settlement beginning in the Late Preclassic and Early Classic, with an increase in coastal trade during the Late Classic period among offshore islands, coastal, and riverine sites (McKillop 1994: 117).

Figure 1. Map of the Maya Area showing the sites mentioned in the text and other selected Maya sites (map by H. McKillop).

The discovery of Late Classic inundated saltworks in Paynes Creek National Park allowed further study of the prehispanic economy and trade in the southern Belize region (McKillop 1995, 2002). Previous models of salt production and trade centered the importance of this industry in the *sal solar* obtained in the north coast of the Yucatan peninsula (Andrews 1983). Archaeological research at Punta Ycacos provides evidence of extensive salt production during the Late Classic period that could have supplied the regional demand of this natural resource (McKillop 2005a). Instead of the *sal solar* method, whereby salt is collected after the evaporation of sea water in salt beds, artifacts found in the sea floor suggest that the *sal cocida* method was employed in the Paynes Creek region (McKillop 2002: 15). *Sal cocida* is produced by boiling salt-enriched brine in ceramic containers over fires (McKillop 2002: 51). This method of salt production is indicated by the presence of *briquetage*, a relatively uniform assemblage of ceramic sherds, clay cylinders, sockets, and spacers, along with evidence of fire hearths found at the sea floor in these sites (McKillop 1995).

Wooden architecture was preserved in many underwater sites in Paynes Creek National Park due to the mangrove peat that surrounded and covered the archaeological contexts. The presence of the ceramic assemblage previously described suggests that the wooden architecture in these sites is associated with the infrastructure for salt production and distribution (McKillop 2005a,b; Sills 2007: viii). In general, hardwood posts and palmetto palm posts compose the wooden architecture discovered at the sites (McKillop 2007).

Previous studies have suggested that the abandonment of the saltworks in the area could be explained due either sea-level rise or because of cultural changes at the end of the Classic period associated with the Classic Maya collapse (McKillop 2002:137). Marine sediment studies in the Paynes Creek National Park (see below) were able to

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determine that the saltworks in the area were abandoned at the end of the Classic period and later inundated by sea level rise (McKillop et al. 2010b: 206) The abandonment of these saltworks can be explained if we consider that with the collapse of the southern Maya lowlands and the abandonment of inland cities in southern Belize, the demand for the salt obtained in the Paynes Creek National Park saltworks ceased (McKillop 2002: 173).

Sediment Studies in the Maya Area

The technique of coring in archaeological sites has been applied to reconstruct the environment surrounding sites, to collect samples from subsurface deposits, and to help in the location of buried archaeological sites (Stein 1986: 505). In the Maya area, the analysis of sediment cores taken from the bottom of lakes and reservoirs has been used to investigate such topics as human-environment interactions, regional climate histories, and the ancient environment of specific regions (Dunning et al. 1998; Johnston et al. 2001; Hodell et al. 2001). Analysis of the pollen record in sediment samples has also been used to detect the practice of agriculture in some areas. Palynological analysis has identified the presence of domesticated species such as corn and manioc in northern Belize by 3000 B.C., contributing to our understanding of the origins of agriculture in that area (Pohl et al. 1996). The identification of domesticated plant pollen has also helped identify the occupation of certain areas that were previously thought to have been abandoned after the Classic Maya collapse, like the Laguna Las Pozas basin in Guatemala (Johnston et al. 2001). Analysis of the change of sedimentation rates has also been used to propose various practices for controlling soil erosion in agriculture fields (Dunning et al. 1998).

In some regions of the Maya area, sediment analysis has been used to reconstruct histories of climate change. Studies of lake-sediment cores help to reconstruct the

climate history of the Maya lowlands over the past 2600 years, identifying a recurrent

pattern of drought episodes (Hodell et al. 2001). The identification of a Terminal Classic

(AD 800-1000) drought in the northern Maya Lowlands was inferred from multiple

sediment cores taken in the Lake Chichancanab, in Quintana Roo, Mexico (Hodell et al.

2005). This climatic event has been proposed by some researchers as the main cause of

the Maya collapse at the end of the Classic period (Gill et al. 2007).

Environmental characterizations of certain regions in prehispanic times have

been proposed by the study of sediment cores. Pollen studies have identified

deforestation in the area surrounding Copan and indicate over exploitation in the

environment (Abrams and Rue 1988).

Previous sediment coring at the *K'ak' Naab'* site in Paynes Creek National Park

(McKillop et al. 2010) followed research on mangrove sediment coring by mangrove

ecologists in Belize and elsewhere, most notably the work of project ecologist Karen

McKee (McKee et al. 2007; McKee and Faulkner 2000). The *K'ak' Naab'* sediment core

was collected just off-site at Site 14 and was composed primarily of mangrove peat

deposited before, during and after the use of the *K'ak' Naab'* saltworks (McKillop et al.

2010a). Results of loss-on ignition analysis, microscopic identification of plants, and

radiocarbon dating suggest that the saltworks in the area were on dry land at the time

of salt production which was later inundated by sea-level rise. Site abandonment was

related to the abandonment of inland cities rather than sea-level rise (McKillop et al.

2010b).

Mangrove Peat

Mangrove peat is composed of partially decayed plant matter, inorganic

minerals, and water in different proportions, mangrove roots being the major organic

component, along with leaves and wood (Cameron and Palmer 1995: 4; Middleton and

McKee 2001: 818). Generally, mangrove peat occurs in mangrove swamps of salty or brackish water in tropical and subtropical coastal areas (Cameron and Palmer 1995: 3-4; Middleton and McKee 2001: 818). Mangrove roots play a critical role in soil formation, vertical accretion, and stability in coastal areas, through the deposition of organic matter (McKee and Faulkner 2000: 48). Root production and decomposition are two important processes in mangrove peat formation.

The differential movement of fine and coarse mangrove roots in the peat is key to understanding the accumulation of mangrove peat. Small fine mangrove roots accumulate at the ground surface and have minimal vertical movement in the peat, as opposed to the larger coarse roots which have a greater range of vertical movement and can grow across stratigraphic levels of the peat (McKee and Faulkner 2000; McKillop et al. 2010b). Mangrove roots (especially fine roots) generally remain where they are produced and decompose extremely slowly due the anaerobic environment present in the peat (McKee and Faulkner 2000).

There is a close relationship between mangrove peat accumulation and sea level rise. Mangroves keep pace with rising sea level conditions, primarily through the accumulation of peat (McKee and Faulkner 2000: 55). Therefore, in settings where considerable mangrove peat deposits are found, a record of mangrove development, succession, and deterioration in relation to sea-level variations is available for study (McKee and Faulkner 2000: 48). Through root production and its later decomposition mangroves respond to sea-level rise scenarios.

Studies of mangrove peat deposits in the offshore mangrove islands of Belize provide information relevant to this study. Peat deposits in coastal Belize predominantly consist of root material. The peat consists of 50% to 90% organic matter (Middleton and McKee 2001). In the Tobacco Range islands of central Belize, there is a

record of at least 10 m of mangrove peat deposits that comprise an accumulation during the last 7000 years (Cameron and Palmer 1995). A previous study in Paynes Creek National Park area indicates that the mangrove peat extended to a depth of more than 4.3 m, yielding a record of natural conditions and vegetation changes for the past 4000 years (McKillop 2005).

MATERIALS AND METHODS

This research focuses on the analysis of marine sediment cores from underwater Sites 24 and 35, located in Paynes Creek National Park, southern Belize, radiocarbon dated to the Early and Late Classic periods respectively (Heather McKillop, personal communication 2010). The methods include field recovery and lab analysis of the sediment.

The field recovery was conducted as part of the "Ancient Maya Wood Architecture and the Salt Industry" project in June 2010. The field techniques followed the previous *K'ak' Naab'* coring, in which a hole is excavated in the sea floor, to expose a clean vertical face to the desired core depth. Blocks of sediment are then cut with a knife in 10 centimeter levels, wrapped in cling wrap and exported to Louisiana State University for study (McKillop et al. 2010a).

Laboratory research included visual description of the sediment from each 10-centimeter level, sampling for loss-on ignition for each level to identify percent of organic matter, and macroscopic sorting of organic material to identify species composition. The lab work was carried out in the Archaeology Lab and the Coastal Geomorphology Lab at Louisiana State University. I worked together with undergraduate student Jessica Harrison, who studied a second sediment core from the *K'ak' Naab'* site (Site 14) in the same area. Student workers assisted with microscopic sorting of organic material. This research project was supervised by Dr. Heather McKillop and Ph.D. candidate Cory Sills.

The sites were visited during the 2010 field season and the wooden posts at each site were relocated in the field and marked with plastic flags. Sediment column locations were selected in relationship to the palmetto palm post walls identified at each site. At Site 24, we took five sediment columns, but only two of them (column samples 1

and 3) were analyzed for this research (Figure 2). The first sediment core, column

sample 1, was taken 1.50 m at the northeast of the north palmetto palm wall, outside the

corridor formed by palmetto palm posts. The sea floor was at a depth of 54 cm below

sea level. The location was marked by plastic flags that were registered in the map of

the site with a Total Station.

Figure 2. Map of Site 24 showing location of column samples (drawing by Mary Lee Eggart from GIS map by H. McKillop).

A block of mangrove peat of 55 cm long, 40 cm wide and 60 cm deep was cut

from the sea floor, in order to expose a wall in the mangrove peat where the samples

would be taken. Using a stainless steel knife blocks of 10 cm of length and wide, and 10

cm depth each one were cut from the sea floor measured with a plastic tape (Figure 3).

For each marine sediment column, six samples measuring 10 cm in depth were taken,

for a maximum depth of 60 cm from the sea floor. Each block sample was wrapped in

cling wrap, which was labeled to indicate the top and the exterior side of each block (Figure 4). The wrapped samples were then placed in sealed bags marked with provenance information. This procedure was followed to take all the samples for this research.

Figure 3. Taking marine sediment samples from Site 35. Photo by H. McKillop.

Marine sediment column 3 from Site 24 was taken at the opening of a corridor formed by palmetto palm posts, located at 1.50 cm from the north wall, in the southwest of the site. The sea floor was at a depth of 45 cm below sea level.

The samples taken from Site 35 (columns 1 and 2) were located on either side of a palmetto palm post wall (Figure 5). The sea floor was located at a depth of 47 cm below the water level approximately. Both sediment columns from Site 35 extended to a depth of 60 cm below the sea floor.
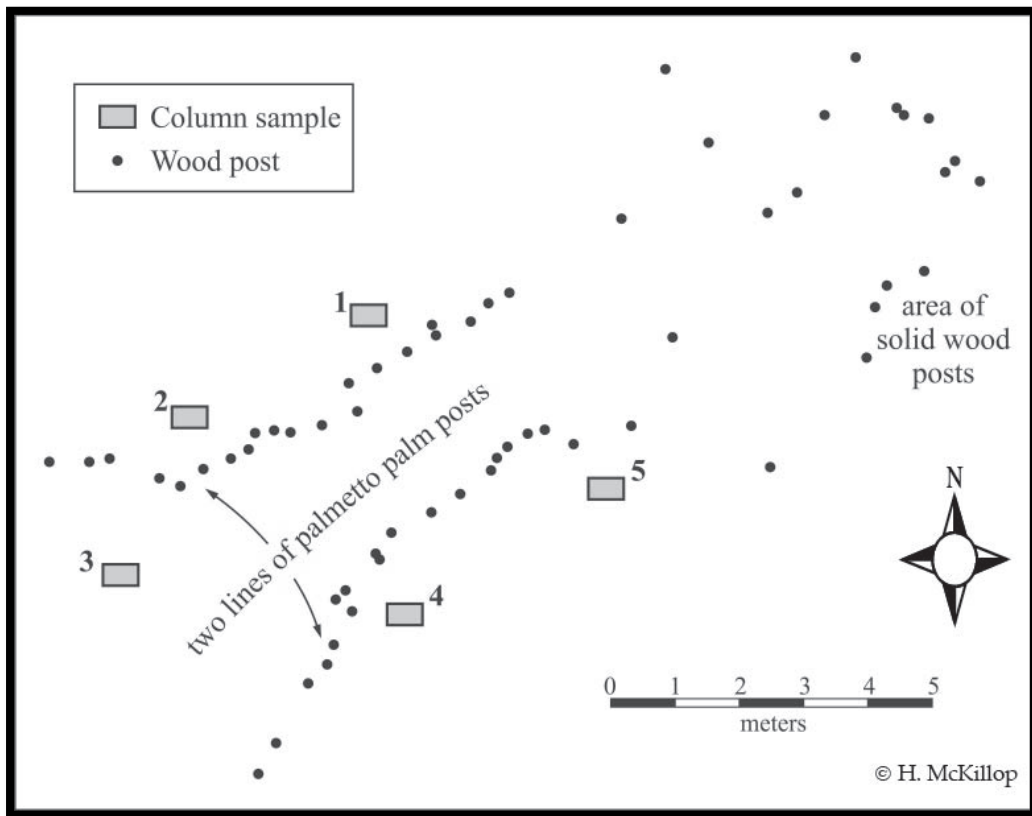
Figure 4. Site 24, column sample 3, 20 to 30 cm marine sediment sample.
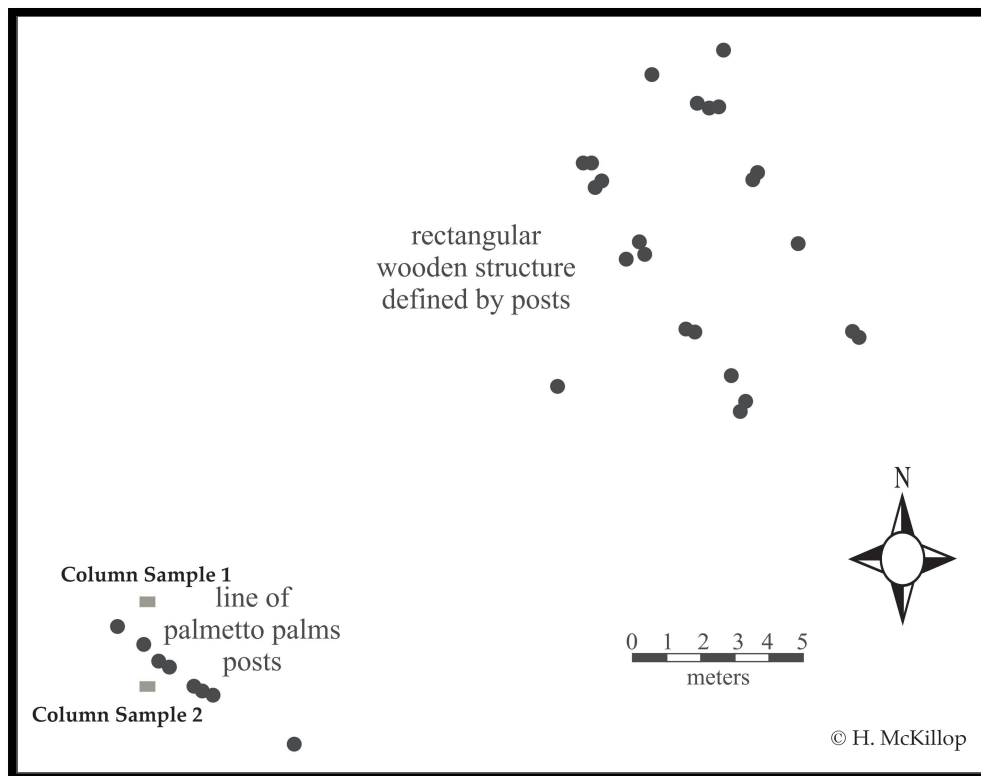
Figure 5. Map of site 35 showing location of column samples (drawing by Mary Lee Eggart from GIS map by H. McKillop).

The marine sediment samples were packed in a plastic container in the field

laboratory and exported to the Louisiana State University Archaeology Lab under the

permit from the Belize government - Institute of Archaeology to Dr. Heather McKillop.

In the Archaeology Lab at Louisiana State University the samples were unpacked and

sorted by site, location, and level.

Loss-on ignition and microscopic analyses followed the same methodology

performed in a previous study of marine sediment in a Paynes Creek National Park salt

work (McKillop et al. 2010a and 2010b). Loss-on ignition studies help to determine the

composition of sediment samples, by reporting the percentage of organic matter lost

during combustion and the mineral content remaining after this process (USDA 2004:

368). As previously demonstrated, the loss-on ignition procedure provides a fast and

inexpensive means of determining carbonate and organic contents of clay-poor

calcareous sediments with precision and accuracy, as long as standardized

methodologies are followed (Heiri et al. 2001). We followed the protocol previously

established by Karen McKee to set up the Coastal Geomorphology lab for loss-on

ignition (McKillop et al. 2010a and 2010b). Samples of marine sediment were taken from

the middle of each level of the four sediment cores studied. Samples were also taken

from the top of each column (modern sea floor) and bottom of each column to

complement the data for each sediment column sample. The total amount of sediment

that composed each sample was around 13 grams. In total, 32 samples were analyzed

using this procedure. Each sample was placed in an aluminum container and dried for

24 hours in a 60° Celsius oven (Figure 6), then ground in a ceramic mortar (Figure 7).

The sediment was then put back in the oven at 60° Celsius overnight to eliminate

humidity and ensure accuracy when weighing the sample. A ceramic crucible

containing at least one gram of sediment from each sample was then put in the oven for 4 hours at 105° Celsius and then weighed. The samples were then burned in a muffle furnace for 8 hours at 550° Celsius and the final weight was recorded (Figure 8). An extra 4-hour burning session was performed on the levels 1, 2 and 3 of the Site 24, column sample 1, and in the samples 1, 2, 3, 4, 5, and 6 of the Site 24, column sample 3 to verify that the 8-hour burning session was sufficient to combust the organic component on the samples. At the conclusion of this final step, all organic matter was burned and only the inorganic content of each sample remained in the crucibles. Percentages of organic matter for each sample were estimated by weighing the samples before and after burning them in the muffle furnace (Figures 9 and 10).

Figure 6. Samples from Site 35 drying in the oven.

Figure 7. Grinding dried samples.

Figure 8. Samples at 500° Celsius in the furnace. Photo by J. Harrison.

Figure 9. Weighing samples after the loss-on ignition procedure.

Figure 10. Inorganic content left after the loss-on ignition procedure.

Determining the composition of the marine sediment can help us to explain the sedimentation process in each site, reveal the ancient landscape in relation to the occupation of the sites under study, and propose assumptions on the formation of the archaeological context in the area.

Microscopic studies of the sorted sediment identified the species composition of the peat. Samples of 1 cm^3 taken from the top left corner of each level were rinsed through a 1 mm sieve and analyzed under a microscope in a Petrie dish with water. The organic content was then sorted in coarse roots, fine roots, leaves, wood, and other organic materials (charcoal, seeds, McKillop et al. 2010a: 248). The characterization of the organic and inorganic component for each sample was qualitative and using a microscope. This analysis helps to determine the composition of the marine sediment, refining the characterization of the organic component of each sample. We followed the directions provided by Karen McKee for microscopic analysis to identify coarse roots, fine roots, and leaves (McKillop personal communication 2010). After analysis, the marine sediment was packed in plastic bags labeled with provenance information and stored in a fridge in the Archaeology lab at Louisiana State University.

During the summer of 2010, I visited some areas where salt was obtained up to the 1970s in the northwest coast of Yucatan, and is still collected in the northeast coast of Yucatan. The observations I made during those visits helped to draw some comparisons with the sites under study for this research. More specifically, I was interested in the changes that occurred after the abandonment of those modern saltworks and the use of wooden posts in salt pans.

RESULTS

Description of Sediment Columns

Site 24, column sample 1: This sediment column measured 60 cm below the sea floor. The top 2 cm of the column, corresponding to the modern sea floor, had a Black-Yellow color (5Y 2.5/2), contrasting with the Black sediment (10YR/2/1) that composed the rest of the sample. The top layer also contained grains of quartz and sand. The sediment in this column had a fibrous and firm composition. A gradual change in color to a very dark brown color (10YR 3/2) was noticeable around 37 cm from the top of the column.

Site 24, column sample 3: This sediment column measured 60 cm below the sea floor. The sediment in the upper part of this column had a fibrous and firm composition, with a very dark brown color (10YR 2/2). There was a gradual change in color to very dark gray (10YR 3/1) around 25 cm from the top of the sample. In the bottom part of the column, the sediment changed from very dark gray to black (10YR 2/1) with a silty consistency.

Site 35, column sample 1: This sediment column measured 60 cm below the sea floor. The top 3.5 cm of the column had a grayish brown color (5Y 3/2), and the rest of the sediment in the column had a black color (10YR 2/1). The sediment in this sample had a fibrous and firm consistency.

Site 35, column sample 2: This sediment column measured 60 cm below the sea floor. The top 2 cm of the column sample had a dark brown color (10YR 3/3). The rest of the sediment was black (10YR 2/1). The composition of the sediment was firm and fibrous. At 47.5 cm, a change to very dark brown (10YR 2/2) was noted.

Loss on Ignition of Marine Sediment

The results obtained from the loss-on ignition procedure reveal the percentage of organic matter that composes the samples under study. A total of 32 samples from Sites 24 and 35 were analyzed using this method.

Column 1 from Site 24 has an average of 61.76% of organic matter (Figure 11). This result is similar to the results obtained in the analysis of the *K'ak' Naab'* sediment column, which had an average of 65% of organic matter for the entire sediment column (McKillop et al 2010b, 202). In contrast, the results from column 3 from Site 24 present significant differences, with an average of 37.93% of organic matter. For Site 24, the lowest percent of organic matter occurred at the top sample (sea floor) of column 1 and in the level 1 (0-10 cm) of column 3. The highest concentrations of organic matter were present in the lowest levels of both columns studied from Site 24.
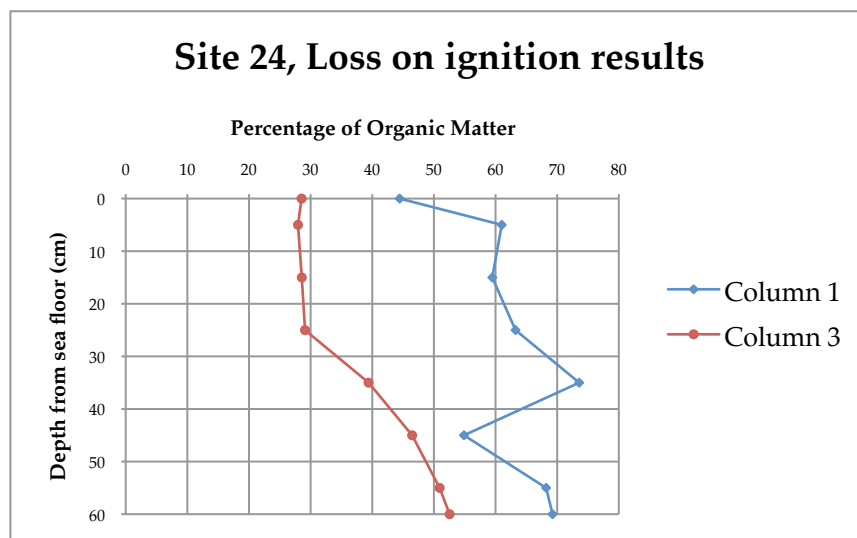
Figure 11. Loss-on ignition results, Site 24, column samples 1 and 3.

Sample 3 of Site 24 shows an increasing amount of organic matter from the sea floor to the deeper levels under study, having the first three samples in this column a minimum increase, but a more accelerated increment on the organic matter composition

in the three lower levels. The samples from column 1 of Site 24 have a more irregular

pattern for the content of organic content, making difficult to identify a pattern for the

presence of organic matter.

Site 35 column sample 1 presents an average of 49.35% of organic matter, a

concentration similar to the 52.96% obtained from column sample 2 at the same site

(Figure 12). The lowest concentration of organic matter corresponds to the sea floor in

both sediment columns; in contrast the highest concentration of organic matter was

located at the lowest part of both columns (the bottom layer at column 1 and the 40 to

50 cm sample at column 2).
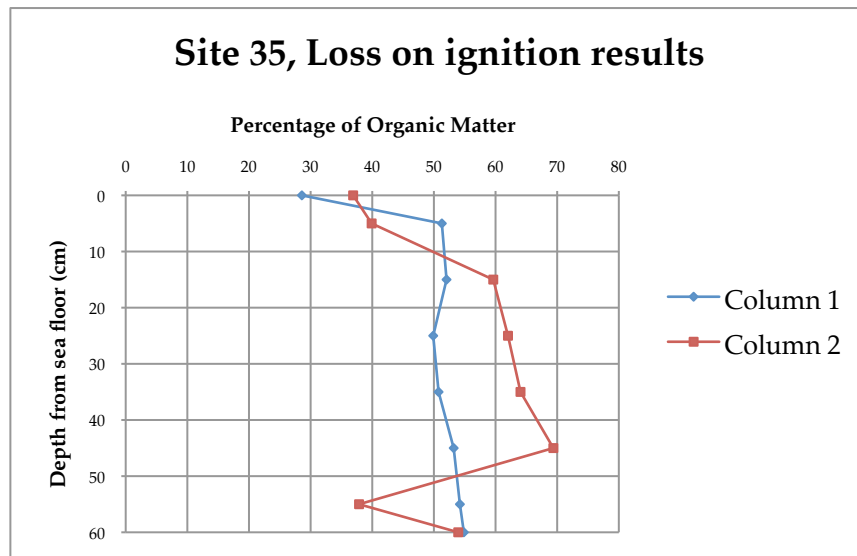
Figure 12. Loss on ignition results, Site 35, column samples 1 and 2.

Sorting of Marine Sediment

The general composition of the marine sediment under study consisted primarily

of fine mangrove roots, with a small amount of coarse mangrove roots, and a very low

frequency of leaves, seeds, and wood fragments. One particularly striking observation

relates to the fine roots that composed the mangrove peat. Fine roots are better

preserved at the top level of the columns and roots are more degraded as depth from

the sea floor increased. This characteristic is understandable if we take into account the fact that the organic material at the bottom of the columns was deposited first and the mangrove peat was built over previous layers.

Sand quartz grains were identified at the top level of Site 24 columns 1 and 3, on what is the modern sea floor. Sand quarts grains were also identified at level 5 (40 cm) in column 3 from Site 24.

More coarse roots than fine roots were identified at level 5 (40 cm) in column 1 from Site 24. This level was the only place where fine roots were not the main component of the sorted samples.

Observations on Modern Saltworks in the Yucatan Coast

During a visit to saltworks in Chuburna Puerto, in the northwest coast of Yucatan, some abandoned salt pans were observed (Figure 13). According to Andrews, salt works in this area were abandoned before the 1970s (Andrews 1983: 27-28). The salt pans were located in a coastal marshland zone on areas that are slightly raised due to accumulation of sand. Water depth at this location was generally less than 50 cm. Salt pans in this shallow lagoon are characterized by wooden posts arranged in oval or square enclosures, with grass and other vegetation growing inside of these areas. Within these enclosures, sand is held in place by the wooden posts, allowing the growth of dry land grass and other marshland vegetation.

A visit to the modern industrial salt-making center of Las Coloradas, in the northeast coast of Yucatan, further contributed to my observations about recently abandoned salt works. Since the procurement of salt in this area is highly mechanized, the site does not include salt pans surrounded by wooden posts. However, I observed some salt pans recently abandoned and the modifications since they are not subject to human intervention (Figure 14). Natural processes, including the flow of water and

wind, contribute to the accumulation of sand in certain areas that are slightly raised over the shallow water level. In these locations grass and other marshland vegetation grow, contributing to the accumulation of both inorganic materials, like sand and silt, and organic matter, resulting of the decomposed vegetation. The accumulation of organic and inorganic matter in abandoned salt works contributes to the deposition of sediment over the original activity level in these areas.

Figure 13. Abandoned salt pan at Chuburna Puerto, northwest coast of the Yucatan Peninsula.

Figure 14. Abandoned salt pan at Las Coloradas, northeast coast of the Yucatan Peninsula.

INTERPRETATIONS

Interpreting the Percentage of Organic and Inorganic Matter

The constant rate of organic matter throughout the levels in Site 24 column sample 3, and Site 35 column 1 suggests that mangrove peat formation in those areas was uniform, not subject to modifications of the environment such as clearing of the mangroves by human or natural activity. The high content of inorganic matter documented in Site 24 column sample 3, along with the peculiar arrangement of the palmetto posts which form an opening around the column sample location suggest that there was a constant washing of inorganic sediments that were deposited in the area where this column was located. The data from Site 35 column sample 1, show a relatively constant amount of organic matter, suggesting that the area immediately surrounding column sample 1 was not altered by human action or natural conditions.

The drastic changes in the proportion of organic and inorganic matter content at certain levels in the sediment columns under study could be used to propose the tentative location of the occupation level at the Sites 24 and 35 (see below).

Drawing Conclusions from the Results from the *K'ak' Naab'* Core to Sites 24 and 35

Following the idea that the sites under study are located in close proximity to Site 14 and that there are no visible changes in the topography of the area, we can propose that some of the results obtained from previous sediment analysis of Site 14 are applicable to Sites 24 and 35.

Five radiocarbon dates taken at different depths in the *K'ak' Naab'* sediment column provide a 4000 year record of sea level rise, demonstrating that sea level was rising before the Early Classic Maya settlement was established in the area, with an estimated rate of actual sea-level rise of 0.087 cm per year during the 660 year Maya settlement (McKillop et al. 2010a, 248). The analysis of mangrove peat production and

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accumulation at Site 14 suggests that the rate of sea-level rise fluctuated through time and that ground subsidence occurred (McKillop et al. 2010a, 248). Following this data from Site 14 we can assume that the same rate of sea-level rise affected both Sites 24 and 35 during the Classic period occupation, and that these sites were constructed on dry land that was subsequently inundated by sea-level rise. Archaeological evidence from Site 14 supports the conclusions that the site was located on dry land that became inundated after the salt work was abandoned (McKillop et al. 2010a, 250). We can suggest that the abandonment of the salt works in the Punta Ycacos Lagoon occurred sometime during the Late Classic period (ca. 800-900 AD) and the sites were subsequently covered by sea-level rise.

Occupation Levels Identified at Sites 24 and 35

The results of loss-on ignition procedure, along with macroscopic and microscopic observations of the sediment columns from Sites 24 and 35, provide a basis for tentatively identifying the Classic period occupation levels at both sites. Macroscopic observations identified a change in color at 37 cm in Site 24 column sample 1. Likewise, a change in color occurred at 47.5 cm in Site 35. These changes in sediment color match the characteristic vertical patterning of organic matter obtained through loss-on ignition studies. In Site 24 column 1, the highest percentage of organic content occurs at 35 cm from the sea floor, followed by a drastic drop in organic matter at 45 cm. In Site 35 column sample 2, the highest percentage of organic matter was documented at 45 cm, followed by an even more dramatic drop in organic content at 55 cm.

The pattern of an increase in organic matter following low percentages of organic content, which corresponds to a change in sediment color, is indicating a modification in the environment that could be attributed to human activity. Human occupation in an area where mangroves dominated the environment necessarily implies a clearing of

vegetation in order to establish permanent sites, in this case saltworks facilities. After the abandonment of these activity areas a recolonization by mangroves and other vegetation is expected since no human driven clearing was conducted. Activity areas imply a higher amount of inorganic content since a dry and firm surface is necessary to perform the activities associated with salt production.

Following these assumptions, we can suggest that the occupation level at Site 24 could be identified somewhere between 35 cm and 55 cm depth below the sea floor. In the same way, the occupation level at Site 35 could be proposed to be between 45 cm and 60 cm from the sea floor. Since we do not have more data below 60 cm for Site 35 it is possible that this pattern of increase and decrease in the content of organic matter could point to an occupation level situated deeper than 60 cm at this site.

A high percentage of organic matter in the sediment studied does not necessarily indicate a high presence of mangroves. Microscopic identification of mangrove peat can help to determine the nature of this high organic content. Sorting a sediment sample from 37 cm depth from the sea floor in Site 24 column sample 1 documented a relatively low content of fine mangrove roots and a high presence of coarse mangrove roots. Since fine mangrove roots are known to accumulate at the ground surface and have minimal vertical movement in mangrove peat, in contrast to the large coarse mangrove roots that can permeate deeper in the subsurface sediment (McKee and Faulkner 2000; McKillop et al. 2010, 248), we can suggest that the 37 cm depth from the sea floor in column 1 at Site 24 had less mangroves than other areas studied by sediment columns in the lagoon.

Since we did not have the opportunity to get radiocarbon dates for these tentatively identified occupation levels at Sites 24 and 35, we can draw some general ideas about site chronologies if we compare the data obtained from Site 14. The Classic period is represented at Site 14 by two radiocarbon dates located at 30.2 cm and 87.7 cm

depth from the sea floor. A sample of marine sediment recovered at 30.2 cm yielded a date of Cal. AD 1020-1200, and at 87.7cm a date of Cal. AD 410-590 (McKillop et al. 2010a, 249). Assuming that mangrove peat accumulation processes were similar in the area where these sites are located, we can expect that the tentatively identified occupation levels at Sites 24 and 35 correspond to the Classic period.

Formation of the Archaeological Context

If the occupation level was between 35 cm to 55 cm at Site 24, and 45 cm to 60 cm at Site 35, we can assume that the artifacts found in the sea floor at these sites were left at those levels during the abandonment of the area. So, why did we find artifacts at the modern sea floor at Sites 24 and 35?

We can suggest some general ideas for the formation of the archaeological record at these sites. Bioturbation, the movement of materials in deposits by plant roots and burrowing animals (Banning 2000: 245-246), could be considered as an important factor in site formation processes. The growth of mangroves and the alteration of the archaeological context by mangrove roots when the site was abandoned could represent a major factor in this issue, causing the artifacts to move vertically while mangrove peat accumulated. Accumulation of fine mangrove roots in horizontal levels, along with the movement of coarse mangrove roots across mangrove peat, are the main factors in the alteration of the archaeological record. We should also consider the action of waves and tide, and other natural phenomena like storms and hurricanes. Since the effects of bioturbation are better known in dry land areas than in underwater sites, is difficult to present a more complete characterization of this factor in the formation of the archaeological record.

The observations I made at recently abandoned saltworks on the Yucatan coast can help us to understand the processes occurring at these particular contexts after their

abandonment. The accumulation of both organic and inorganic material is facilitated by the presence of marshland vegetation and the action of aeolian processes and water movement. The accumulation of sediment at these particular activity areas comprises a major factor in the natural modifications happening at these archaeological contexts, along with mangrove root production, water movement and wind action.

Identifying Activity Areas Depending on the Location of the Sediment Columns

We can suggest a general pattern of differential human impact on the environment depending on the location of the sediment columns under study. A limited intervention of human activity in the area could be represented by a regular distribution of organic matter throughout the extent of the marine sediment columns studied. No drastic changes in the percentage of organic matter were identified in Site 24 column sample 3 and Site 35 column sample 1. The location of both sediment columns in relation to wooden architecture but outside of tentatively identified activity areas suggests that these areas were not constantly affected by human activity.

In contrast, in areas where human activity and occupation were more constant and significant, we can expect drastic changes in sedimentation processes before and after the area was occupied, due to clearing of vegetation, tampering, sedimentation of materials related with human occupation (trash). This scenario is suggested by the data obtained from Site 24 column 1 and Site 35 column 2, where occupation layers were tentatively identified by this study.

Ethnographic studies can help us to explain some of these patterns. For example, some activity areas, especially places where production is conducted are usually kept clean. In contrast, "inactive zones" do not present significant alterations (Kent 1984).

Important elements in these sites are the palmetto palm post lines. The palmetto palm posts identified at the saltwork sites in Paynes Creek National Park could have

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been used as a holding area for brackish water during the *sal cocida* method for salt production or pans for evaporate water using the *sal solar* method (Sills 2007: 70) or land retaining features (McKillop 2005a). Alternatively, we can suggest that these post lines could have functioned as fences to delimit dry areas, a common practice in modern coastal settlements in the Yucatan peninsula (Figure 15). Although we can recognize differences in sedimentation depending on the location of the columns studied in relation to these post lines, it is difficult to suggest further ideas about these features until we have taken more sediment columns from different locations within the sites, especially inside and outside of wooden structures.

Figure 15. Fence of palm posts in a modern household in Las Coloradas, northeast Yucatan coast.

CONCLUSIONS

This research performed analyses of marine sediment from two underwater sites in order to know more about their occupation, the environment of the area in prehispanic times, and to elucidate some general ideas about the formation of the archaeological record after their abandonment. Four sediment columns of 60 cm depth each from the sea floor were taken at two different underwater sites. Lab analyses included loss-on ignition and microscopic studies of 32 samples uniformly distributed among the sediment columns to determine the percentage of organic matter and the composition of each sample. The loss-on ignition procedure provided evidence to identify changes in mangrove peat formation in the area that we correlated with human occupation at both sites. Microscopic analyses helped us to determine that the marine sediment is highly organic and is primarily composed of mangrove roots. The tentative identification of occupation levels at 35 to 55 cm at Site 24 and 45 to 60 cm at Site 35 from the modern sea floor leads us to suggest that bioturbation represents an important factor in the formation of the archaeological record at these underwater sites. The movement of mangrove roots, along with the action of waves and tide, could be responsible for the vertical displacement of artifacts from the place where they were left after the abandonment of the sites. The observations made at recently abandoned saltworks in the northwest and northeast coasts of Yucatan helped to better characterize the natural factors involved in the formation of the archaeological context in the prehispanic saltworks studied by this research project.

Radiocarbon dating and pollen analysis could bring more information to present a more complete panorama of the underwater saltworks under study. Absolute dating techniques are important for determining whether the occupation levels proposed by this research fit in the previously proposed period of human occupation in prehispanic

times at the region. Pollen analysis could also help to identify human modification of the environment in the area and refine the occupation levels in the sediment at these underwater sites.

The study of other sediment columns at other locations in Sites 24 and 35 would be helpful to test and enrich the interpretations proposed in this research, especially the contrast that sediment columns taken inside the sites can offer with sediment taken in areas outside the sites. Analyses of sediment columns from other underwater sites in the Paynes Creek National Park area could also provide information to know more about the salt production activities carried out in the area during prehispanic times.

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VITA

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Roberto was lab manager of the DIVA lab (Digital Imaging and Visualization in Archaeology) under McKillop's direction. He was a co-author on a poster presentation on 3D imaging at the 2010 American Anthropological Association conference in New Orleans, Louisiana, and at a Technology session at the 2011 Society of Historical Archaeology meeting in Austin, Texas.