23 SEA-LEVEL RISE AND INUNDATION OF THE CLASSIC MAYA PAYNES CREEK SALT WORKS: EVIDENCE FROM MARINE SEDIMENT

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A column of sediment was recovered and studied from below the seafloor adjacent to the K'ak' Naab' salt works, in Paynes Creek National Park, in order to evaluate if the site's buildings were elevated above the water or if they were on dry land that subsequently became inundated. Actual sea-level rise and subsidence of the land were considered. The sediment was recovered in 10 cubic cm samples and subjected to loss-on ignition, which indicated high organic matter. Identification of the organic matter under a microscope indicated the organic matter was R. mangle, which forms under conditions of actual sea-level rise. Cracks in the K'ak' Naab' canoe paddle from alternating dry and wet conditions in antiquity, along with other archaeological evidence and the sea-level data support the interpretation that K'ak' Naab' was dry land during the Classic period when the salt works were constructed.

Introduction

A mangrove peat bog below the sea floor in a large salt-water lagoon system in Paynes Creek National Park, Belize provided excellent preservation of Classic Maya wooden architecture (McKillop 2005a; Figure 1). Underwater survey conducted between 2004 and 2008 resulted in 4000 mapped building posts at a total of 103 underwater sites (McKillop 2006, 2007a, 2007b, 2008, 2009; Sills 2007; Somers 2007). The buildings were part of a massive salt industry that supplied salt to nearby inland cities where this basic biological necessity was in short supply (McKillop 2002). Were the buildings elevated above the water on platforms as is common in some coastal areas? Alternatively, were the sites on land that was submerged by sea-level rise or subsidence, a common occurrence in low-lying coastal areas worldwide? If the sites were inundated, was submergence a rapid event from tectonic activity or was there a slow process of sea-level rise and subsidence over hundreds or thousands of years? Is there any evidence that the ancient coastal Maya impacted the physical landscape? In order to evaluate the ancient natural landscape of the Paynes Creek underwater sites, we report the recovery and analysis of marine sediment from below the seafloor associated with the Classic Maya wooden architecture near the K'ak' Naab' site, an underwater Maya site where an ancient canoe paddle was discovered (McKillop 2005a). Our findings provide new insights on the Late Classic landscape of the Paynes Creek salt works.

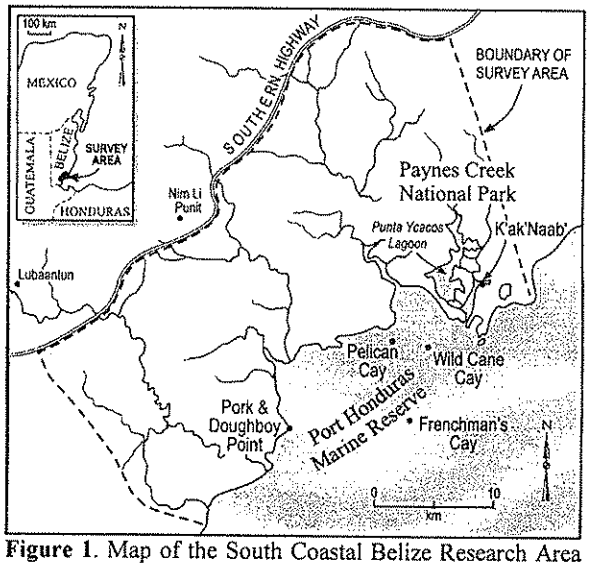

Figure 1. Map of the South Coastal Belize Research Area Showing Sites Mentioned in the Text. (Drawing by Mary Lee Eggart, Louisiana State University).

Previous Underwater Archaeology in the Maya Area

Underwater sites are common in the Maya area (Andrews and Coreletta 1996), although most underwater archaeology focuses on cenotes and shipwrecks (Leshikar-Denton and Luna Erreguerena 2008) instead of inundated land sites (McKillop 2002; Somers and McKillop 2005). Excavations commonly are abandoned when the water table is reached at coastal sites in Belize and the Yucatan of Mexico (McKillop 2002: 136-137). Research in the coastal region of southern Belize underscores the benefits of archaeological research at inundated sites.

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Previous archaeological research in Port Honduras Marine Reserve (Figure 1) documented Classic Maya sites on the offshore cays and coastline partially or fully below sea level (McKillop 1995, 2002, 2005b; McKillop et al. 2004; McKillop and Winemiller 2004). At the trading port of Wild Cane Cay, the Classic period midden deposits are below the water table (McKillop 2002, 2005b). A significant part of the Classic period site is offshore and buried below the seafloor, as demonstrated by a program of offshore shovel tests (McKillop 2002: Figure 5.3). Excavations were carried out in 20 cm levels to a maximum depth of one meter below the seafloor. The excavations indicated the Classic Maya site of Wild Cane Cay was approximately 10 acres in size, which was reduced by sea-level rise and shoreline erosion to its modern size of 3 ½ acres (McKillop 2002: Figure 5.4). Radiocarbon dating indicates sea-level rise of at least one meter since the end of the Classic period in the region (McKillop 2002: Figure 5.9).

Settlement on Wild Cane Cay increased with the expansion of circum-Yucatan canoe trade after the Classic Maya collapse in the southern Maya lowlands (McKillop 1995, 1996, 2002, 2005b). Midden accumulation and construction of coral architecture kept pace with rising seas. Although the Early Postclassic midden deposits at Wild Cane Cay were submerged during the rainy season, most of the coral architecture remained above the water table. The clearing of mangroves on Wild Cane Cay associated with historic settlement beginning in the late nineteenth century further contributed to shoreline erosion. Following the abandonment of the historic settlement, mangroves took hold offshore and protected the shoreline from further erosion. In the absence of continued midden accumulation, sea-level rise will eventually submerge the remaining dry land of Wild Cane Cay, as a natural process of mangrove island formation (McKillop 2002: Figure 5.9).

In contrast to the scenario at Wild Cane Cay where anthropogenic factors of midden accumulation and coral architectural construction ameliorated the deleterious effects of rising seas on the island, the nearby community on Pelican Cay was abandoned at the end of the Classic period (McKillop 2002: 156-159, Figure 5.6). With the lack of midden accumulation in the Postclassic, the sea reclaimed the island. Red mangroves (*Rhizophora mangle*) encroached on the site, accumulating mangrove peat among the roots. The Classic period site on Pelican Cay is buried below 40 cm of mangrove peat and covered by living mangroves. The entire island is slightly below sea level, with no surface evidence of an ancient Maya settlement, which was only discovered by shovel testing (McKillop 2002; Figure 5.5). The scenario at Pelican Cay underscores the likelihood that Classic Maya settlement lies buried below mangroves elsewhere on the low-lying mangrove coastline and offshore cays in Belize.

Underwater Sites in Paynes Creek National Park

Regional survey on the coast and cays of the Port Honduras Marine Reserve indicated that Late Classic Maya sites were up to 1.5 meters below modern sea-level, both on land and in offshore areas of sites, such as at Pork and Doughboy Point (McKillop 2002: 160, Figures 5.7, 5.9), Wild Cane Cay (McKillop 2002: 147-154), and Frenchman's Cay (McKillop 2002: 154-156; McKillop and Winemiller 2004). Sea-level rise also is documented from excavation of burials below the water table on land and offshore below the seafloor at the Classic Maya trading port of Moho Cay, located farther north along the coast in the mouth of the Belize River (McKillop 2004).

With this knowledge, survey was extended to shallow water where there was no land, on the assumption that we mightfind sites if sea level was lower in the Late Classic. Systematic boat survey traversing Punta Ycacos Lagoon in Paynes Creek National Park led to the discovery of three underwater sites: Stingray Lagoon, David Westby, and Orlando's Jewfish sites, which were underwater with no dry land area (McKillop 1995, 2002: 29-50). Comprehensive underwater survey in 2004 led to the discovery of underwater sites with wooden posts protruding from the seafloor, as well as a canoe paddle at the K'ak' Naab' site (McKillop 2005a). Site maps revealed the

Figure 2. Briquetage on the Seafloor, Paynes Creek National Park. (Photo by Heather McKillop).

footprint of buildings defined by the pattern of vertical posts extruding from the seafloor. In some cases, the rectangular shapes of buildings of various sizes were clear (McKillop 2009). The seafloor at the underwater sites was littered with "briquetage"- broken pots from boiling brine in vessels over fires to make salt (McKillop 2002: 51-72, Figures 3.2-3.21; Figure 2).

Environmental History from Marine Sediment

The underwater setting of the Late Classic architecture and associated briquetage remains perplexing. The wooden building posts that protruded from the seafloor were preserved in a peat bog, but information was lacking on the formation of the peat bog in relation to the sites, the species composition of the peat and its depth, and the location of land at the time of occupation of the sites. A test probe carried out between sites 14 (K'ak' Naab') and 15 in 2004 revealed that peat extended from the seafloor to the 4.3 m maximum depth of the probe (McKillop 2005a). This depth of peat was not surprising since other researchers have found a Holocene record of as much as 9 m of peat on the limestone bedrock in the southern barrier reef lagoon (Macintyre et al. 1995; McKee and Faulkner 2000; Woodroffe 1995).

In order to begin answering questions about the sediment history in relation to the underwater sites, we excavated a column of sediment from beside, K'ak' Naab,' near the 2004 test probe (Figure 3). Named the K'ak' Naab' core, the sediment column was cut from the peat in 10 cm levels. The maximum depth was 1.5 m below the seafloor. The marine sediment was packed in cling wrap and Ziploc bags by 10 cm levels (with arrows indicating orientation) and exported to Louisiana State University for study. We report loss-on ignition, sediment analysis, radiocarbon dating, and study of artifact contexts. Other analyses, including analysis of the abundant pollen and wood, are in progress.

Loss-on Ignition of K'ak' Naab' Sediment

Loss-on ignition was conducted to determine the amount of organic matter in the K'ak' Naab' sediment. Loss-on ignition was run for every sample collected, for a total of 15 samples. Overall, the organic content of the sediment from the K'ak' Naab' column is high, with an average of 65% (Figure 4). The lowest level for organic material is level 1 (1-10 cm), which is 50% organic material. The organic content is high and consistent with other peat sediment deposits on the cays of Belize (McKee et al. 2007; McKee and Faulkner 2000).

Figure 3. View of Underwater K'ak' Naab Site. (Photo by Heather McKillop).

Microscopic Identification of Sediment

Organic material was sorted from the sediment under magnification to identify the species composition of the peat. Objectives included determining whether the sediment consisted of mangrove peat accumulated in a marine setting under pressure of rising seas. Alternatively, was there evidence of terrigenous

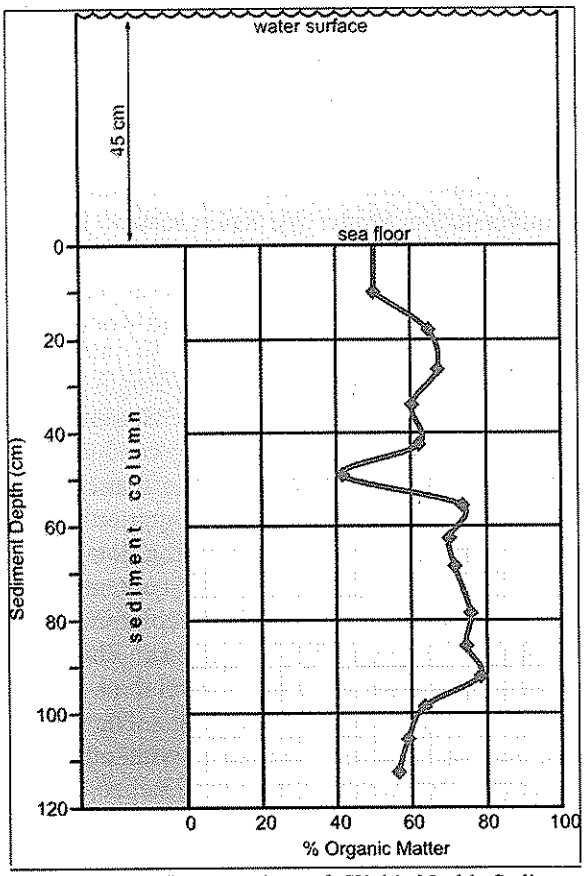

Figure 4. Profile Drawing of K'ak' Naab' Sediment Column Showing Percent Organic Matter of the Marine Sediment. (Drawing by Mary Lee Eggart).

soil indicating dry land in the area? One cubic cm of sediment was selected from levels 1, 2, 3, 4, 8, 11, and 12. The samples were rinsed through a 1 mm sieve and placed in a Petrie dish in water under a microscope. The sediment was examined and then sorted for coarse roots, small roots, leaves, and wood. Analysis of the morphology of the sediment examined under a microscope indicates that the peat is composed primarily of *R. mangle*_roots. This finding indicates the landscape in the immediate area of the Paynes Creek salt works was a mangrove swamp dominated by *R. mangle* throughout the entire sequence represented in the sediment core. Furthermore, the environmental setting of the Paynes Creek underwater sites was subject to actual sea-level rise, as evidenced by the solid record of mangrove peat, which is deposited as *R. mangle* keeps pace with rising seas (McKee and Faulkner 2000; Woodroffe 1995).

Sea-Level Rise and Inundation of the Salt Works

The depths of radiocarbon-dated sediment layers below sea level were used to evaluate the timing and rate of sea-level rise. Radiocarbon samples were submitted to date the top and bottom of the sediment as well as several intermediate layers of the sediment. The samples consisted of small *R. mangle* roots sorted under a microscope. Modern studies of mangrove ecology demonstrate that small mangrove roots accumulate at the ground surface and have minimal vertical movement in mangrove peat, in contrast to the large mangrove roots that can permeate deeper into the sub-surface sediment (McKee and Faulkner 2000).

The Paynes Creek sediment core shows a radiocarbon dated 4000-year record of vegetation changes mirroring the rise and fall of the Paynes Creek salt works (Table 1). A sample from 75.2cm below water surface dates to 920 ± 40 BP (Cal AD 1020-1200). Three other samples consisted of small *R. mangle* roots sorted from 10 cm levels. The deepest level, 149.4-159.4cm below water, dates to 4140 BC ± 40 BP. The uppermost sediment level, 45-55cm below water, dates to 850 ± 40 BP (Cal AD 1060-1080 or 1150-1270). This date overlaps witha date from 55-63 cm below water at 750 ± 40 BP.The depth of radiocarbon-dated deposits in the K'ak' Naab' sediment coremeasures a 4000-year record of actual sea-level rise (Table 1). Sea level was rising before the Early Classic Maya settlement, as indicated by the 26.6 cm of peat from the base of the core to the beginning of the Early Classic levels. The rate of sea-level rise must have slowed down, or even reversed, if dry land was available for construction of the Classic Maya buildings. The ground surface at the beginning of the Early Classic settlement was at least 132.7 cm below modern sea level, as indicated by the depth of radiocarbon-dated material below water surface (1580 ± 40 BP/ Cal AD 410-590; Table 1). If the structures were built on dry land and at least minimally above water, sea-level rise since the Early Classic period was likely greater[1] The end of Late Classic settlement is 75.2 cm below modern sea level. During the Classic period settlement, sea level raised a total of 57.7 cm. The continued deposition of mangrove peat after the

Radiocarbon age	Calibrated, 2 sigma C14 Date	Depth from seafloor	Depth from water surface
850 +/- 40 BP	Cal AD 1060-1080, Cal AD 1150-1270	0-10 cm	45-55cm
750 +/- 40 BP	Cal AD 1220-1300	10-18 cm	55-63cm
920 +/- 40 BP	Cal AD 1020-1200	30.2 cm	75.2cm
1580 +/- 40 BP	Cal AD 410-590	87.7 cm	132.7cm
4140 +/- 40 BP	Cal BC 2840-2820, Cal BC 2670-2470	104.4-114.4cm	149.4-159.4cm

Table 1. Depths and Dates for K'ak' Naab' Settlement Core.

Maya sites were abandoned marks an additional 30.2 cm increase in actual sea level.

Using mangrove peat to calculate the rate of sea-level rise (see Toscano and Macintyre 2003) reveals fluctuations in the rate over time and suggests that subsidence occurred. The rate of sea-level rise from 4140 BP to 1580 BP (2560 years) was 0.010 cm per annum, surprisingly low. The rate of actual sea-level rise during the 660 year Maya settlement was .087 cm per annum. The rate of sea-level rise in the 300 years of the Early Postclassic was .01 cm per annum, an increase in the rate compared to the Classic period. The 45 cm water depth to the top of the sea floor occurred some time after the Early Postclassic. Owing to the lack of peat deposits after the Early Postclassic, a working hypothesis is that rapid sea-level rise drowned mangroves in Late Postclassic and left the salt works underwater. Using the 45 cm water depth to the seafloor, the rate of sea-level rise from the end of the Early Postclassic to the present (A.D. 2000) is .06 cm per annum.

Archaeological Evidence of Ancient Landscape Changes

Archaeological evidence supports the interpretation that the Paynes Creek salt works were built on dry land that subsequently was inundated by sea-level rise. Piece plotting of 506 artifacts on the seafloor at the K'ak' Naab' site revealed that briquetage was widespread on the seafloor except inside the structures (McKillop 2007a). Evidently salt production was indoors and the work area was kept clean. The widespread presence of charcoal along with briquetage, including a large hearth at Stingray Lagoon (McKillop 1995, 2002:38), underscores the in-situ location of the ancient salt production. The absence of wooden floors, which would have been preserved in the peat bog, adds further evidence that the salt works were not elevated over the water, but instead were constructed on dry land that subsequently became inundated. The placement of lines of palmetto palm posts at the periphery of many sites may have been carried out to keep out rising seas, in an effort to reclaim land - an effort that ultimately was unsuccessful.

Examination of the K'ak' Naab' paddle following conservation[2] revealed the paddle was in a context of alternating wet and dry conditions in antiquity. The paddle was recovered at the edge of the site in a matrix of peat, with a portion of the blade protruding from the peat into the silt formed a lens between 10 and 20 cm on the sea floor. Curvilinear incisions from worms eating the wood along the edge of the paddle blade indicate where the blade had protruded from the sea floor (Figure 5). Cracking on the shaft and blade of the paddle is visible macroscopically as short, vertical incisions (Figure 5). The cracking occurred in antiquity as a result of alternating wet and dry conditions. Made from Sapodilla wood, which sinks, the paddle may have sunk in intertidal water or on land at the edge of the site. Following abandonment of the K'ak' Naab' salt works, the paddle was in shallow water covered by *R. mangle*, which buried the paddle with mangrove peat. This interpretation is supported by the radiocarbon-dated peat deposits from the K'ak' Naab' sediment column that indicate actual sea-level rise in the Early Postclassic

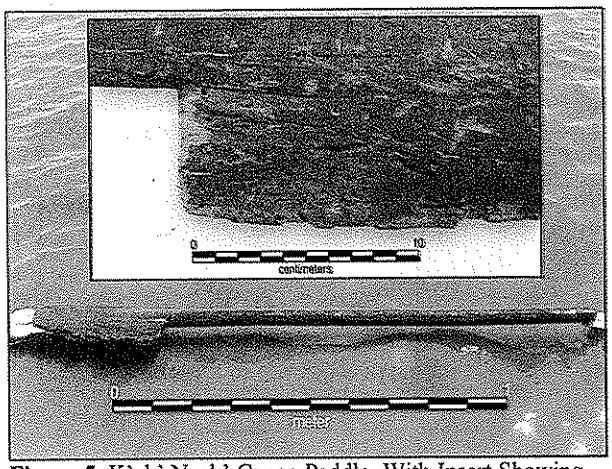

Figure 5. K'ak' Naab' Canoe Paddle, With Insert Showing Ancient Cracks. (Photos by Heather McKillop).

(Figure 4, Table 1). Rapid sea-level rise in the Late Postclassic drowned the R. mangle and
flooded the site, an interpretation supported by the cessation of peat development in the K'ak' Naab' sediment column after the Early Postclassic (Figure 4, Table 1).

Discussion and Conclusions

Study of a sediment column from beside the K'ak' Naab' underwater Maya salt works in Paynes Creek National Park was carried out to evaluate if the salt works were elevated on platforms above the water or if sea-level had risen and submerged salt works that were on dry land. A column of sediment was cut from the sea floor in 10 cm levels to 150 cm and transported to Louisiana State University for study. Radiocarbon dates on the top and bottom layers indicated the sediment included a 4,000-year environmental record. Three additional radiocarbon samples provided dates on intermediary sediment layers. Loss-on ignition of samples from each level indicated high organic content of the sediment. Microscopic examination of the organic content under magnification revealed the organic content was roots and leaves of *R. mangle*, that forms under conditions of actual sea-level rise, when red mangroves keep pace with rising seas. There was no evidence of terrigenous soil, suggesting that the location of the sediment column - between K'ak' Naab' and site 15, was water.

The radiocarbon dated mangrove peat indicates K'ak' Naab' and other nearby salt works were constructed on land, which was subsequently inundated by actual sea-level rise. The seafloor by the K'ak' Naab sediment column was 45 cm below the water in 2007 when we recovered the sediment. The ground surface at the beginning of the Early Classic construction of the salt works was at least 132.7 cm below modern sea level. For the salt works to be on dry land, sea level must have been lower (to account for daily and monthly tidal variations of 50 cm and the fact that *R. mangle* grows on inundated land).

Archaeological evidence suggests that the nearby K'ak' Naab' site was land that became inundated after the salt work was abandoned. The widespread occurrence of submerged Classic period sites in nearby Port Honduras Marine Reserve support the view that the Paynes Creek salt works were on land as well. The Classic community on Pelican Cay was inundated and lies buried below *R. mangle* peat. The Classic community at Wild Cane Cay was inundated, but the Postclassic community fared better, with midden accumulation and construction of coral architecture keeping pace with sea-level rise, at least for the Postclassic.

If the Paynes Creek salt works had been elevated on platforms above the water, there would be wooden floors, which we did not find. Instead, we found wooden posts marking the outlines of buildings. The cracking on the K'ak' Naab' canoe paddle indicates it was in an alternating wet and dry environment in antiquity. The paddle was recovered at the edge of the K'ak' Naab' salt work sites. The paddle may have been in an intertidal zone, subject to alternating wet and dry conditions, where *R. mangle* subsequently took hold, building peat, and burying the paddle. The findings from the K'ak' Naab' sediment column analyses supports the interpretation that actual sea level rose about 60 cm during the Classic period (Figure 4, Table 1). After the abandonment of the salt works at the end of the Classic period, sea level rose an additional 75 cm. The deposition of 30 cm of mangrove peat demonstrates there was actual sea-level rise (as opposed to subsidence) during the Early Postclassic. Subsequent flooding of the salt works may have been rapid sea-level rise that drowned the *R. mangle* and/or subsidence.

Additional sediment columns or cores are needed both at sites and between them to clarify the location of land and water during the Classic period use of the Paynes Creek salt works.

[1] The area is subject to micro-tidal variation of about 50 cm, which also needs to be factored into estimates of sea-level rise.

[2]The paddle was conserved by C. Wayne Smith and Helen Devereux at the Conservation Lab, Dept of Anthropology, Texas A & M University, using the polymer process (Smith 2003).

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