Modeling the Relationship between Climate Change and Landscape Modification at the Crystal River Site (8CI1), Florida

Sean Patrick Norman
University of South Florida, spn@mail.usf.edu

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Modeling the Relationship between Climate Change and Landscape Modification at the
Crystal River Site (8CI1), Florida

by

Sean Patrick Norman

A thesis submitted in partial fulfillment of the requirements for the degree of Masters of Arts Department of Anthropology with a concentration in Cultural Resource Management College of Arts and Sciences University of South Florida

Major Professor: Thomas J. Pluckhahn, Ph.D.
E. Christian Wells, Ph.D.
Brent R. Weisman, Ph.D.

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Abstract

The Crystal River site (8CI1) is a Woodland-period (ca 1000 B.C. to A.D. 1050) mound complex located on the Gulf of Mexico in west-central Florida. Among the features at the site are four shell and sand platform mounds, two burial mounds, and an extensive shell midden. The proximity to the Gulf and the reliance on marine and brackish resources present an apparent, yet poorly understood interaction between the people of this area and their environment. I attempt to model the relationship of the occupation of Crystal River with sea level change. The analysis of 58 soil cores from across the site provided detailed stratigraphic information and AMS radiocarbon dates needed to examine anthropogenic site formation. I then compared the rates of midden deposition and monumental architecture construction with sea level and climatic periods. This research revealed that landscape modification occurred during periods of both high and low mean sea level suggesting that human-environmental interaction at Crystal River cannot be modeled by sea level alone. Further comparison showed that mound construction increased and midden deposition decreased during the Vandal Minimum indicating a possible sociopolitical transition concurrent with changing environmental conditions.
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Chapter 1

Introduction

Since the Archaic period (ca 8000 to 1000 B.C.), coastal inhabitants of Florida have continuously altered the landscape through the accumulation of shell middens, rings, mounds, and other works (Marquardt 2010; Russo 1994, 2004; Saunders and Russo 2011; Thompson and Worth 2010). Burial mounds along peninsular Florida provide evidence of early monumentality (Piatek 1994; Randall et al. 2014; Russo 1994). Discerning the function and potential monumentality of other early shellworks, especially rings, remains a highly debated issue (Marquardt 2010; Thompson and Worth 2010). Monumental architecture is even more apparent in the Woodland and Mississippian periods with the widespread construction of burial and platform mounds (Lindauer and Blitz 1997; Luer 2014; Pluckhahn and Thompson 2014; Wallis 2008; White 2014).

The Crystal River site (8CI1), located along the Gulf of Mexico in central Florida (Figure 1.1), contains a variety of shell and earthen features dating to the Woodland period. Within the site are a discrete burial mound, another burial mound complex composed of several features, three platform mounds, and one other mound-like feature, all of which are comprised at least partially of mollusk shell (Pluckhahn et al. 2009). In addition to the shell mounds, a large shell midden covers much of the southern half of the site. Previous investigations by Moore (1903, 1907, 1918) and Bullen (1951, 1953, 1999 [1965], 1966) primarily focused on the excavation of the burial features with little
attention to the other features. These early investigations resulted in the development of the culture history of the site through ceramic analysis (Bullen 1953, 1966; Willey 1948a, 1948b, 1949; Willey and Phillips 1944).

The early investigations provided a general context for the site albeit within a limited scope. Moore and Bullen worked in an era where environmental context was rarely considered. Additionally, the coarse sampling and notation methods used during these excavations yielded little environmental data regardless of intent. Therefore, the relationship between the people of Crystal River and their environment remains poorly understood. This research seeks to contextualize the occupation of the site within the broader environment.

Figure 1.1. Location of Crystal River.
Research Design

Throughout the coastal Southeast dramatic shifts in social organization have been associated with climate change and sea level transgression (e.g. Marquardt 2010, 2014; Marquardt and Walker 2013; Russo 2010; Thompson and Turck 2009; Walker 2000; Widmer 1988, 2004). In The Evolution of the Calusa, Widmer (1988) postulated that the permanent settlement of the coast of southwestern Florida did not occur before A.D. 280. The area was only occupied after sea level rose and stabilized forming the approximate modern coastline (Widmer 1988). The resulting estuarine ecosystems provided increased carrying capacity allowing for greater population growth (Widmer 1988). According to the model, socio-political reorganization accompanied the increased population and is manifested in the construction of monumental architecture (Widmer 1988, 2004).

More recent studies in the area have disproven and refined different aspects of the model. It is now known that people permanently occupied several islands in the area during the Late Archaic (Russo 1994, 2010; Schwadron 2010). Evidence from excavations at Pineland and neighboring sites indicates that changes in sea level further impacted occupants after A.D. 280 (Marquardt and Walker 2013; Walker 2000; Walker et al. 1995). Inhabitants temporarily abandoned many sites from A.D. 300 to 500 when sea level rose (Walker 2000; Walker et al. 1995). However, when sea level rise began again around A.D. 800 people increased landscape modification instead of abandoning the area (Walker 2000). Widmer's model is certainly an oversimplification of the occupational history of southwestern Florida, but it brought attention to the impacts of climate and sea level on the coastal dwellers of this region.
The Crystal River site may exhibit some of the same cultural responses given the cultural and environmental similarities. However, examining cultural responses to climate change or sea level requires more consideration to the adaptability, resiliency, and agency of coastal people (Van de Noort 2013). The intentional and unintentional impacts on the environment resulting from such adaptations must also be considered. These human-environmental interactions constantly modify and redefine cultural landscapes (Balée 1998; Crumley 2007; Egan and Howell 2001). Finally, the resiliency of people cannot be understated, especially when tied to a cultural landscape. Thompson and Turck (2009) describe widespread abandonment and resettlement of the Georgia Bight following sea level rise at the end of the Late Archaic. The resumption of year-round coastal settlement included a new cultural feature, the construction of burial mounds as landmarks of social memory (Thompson and Turck 2009). Cultural responses to changing climate and sea level at Crystal River may be reflected in multiple ways, but in each scenario people are active participants.

Since there are no previous investigations at Crystal River regarding climatic conditions or sea level change, I must first determine if there is any relationship between the occupation of Crystal River and environmental change. From that point, I can make interpretations of human-environmental interaction as exhibited through landscape modification. This may manifest itself in a variety of ways including terrain reconfiguration, the construction of monumental architecture, temporary departure, or the complete abandonment of the site. The key is to remember the agency within these adaptive strategies.

In this study, I propose a model of Crystal River’s development in the context of environmental change. What is the nature of the relationship between environmental conditions and the occupation of Crystal River? Do periods of more intensive settlement and mound
construction correspond with more stable or "favorable" conditions? Is the opposite also the case; that is, do periods of decreased settlement and reduced mound construction correlate with less stable conditions? I use sea level and climatic episodes to represent the environmental conditions. To represent the occupation of the site, I use landscape modification, specifically midden deposition and mound construction.

Radiocarbon dates from earlier investigations suggest that the site was initially occupied around the Middle Woodland period which coincides with the Roman Warm Period (350 B.C. to A.D. 500) and a high sea level stand (Pluckhahn et al. 2010). If the occupation of Crystal River is associated with warmer temperatures and higher sea level stands, then I would expect to see reduced midden deposition and no mound construction during the Vandal Minimum (A.D. 500 to 850). This could be followed by a reoccupation during the Medieval Warm Period (A.D. 850 to 1200).

The alternative scenario is that climatic and sea level change did not result in the abandonment of the site or noticeable social re-organization. In this case, midden deposition and mound construction would reflect no particular pattern associated with climatic episodes and sea level high and low stands.

Ecological instability resulting from rapid, short-term sea level changes must also be considered (Marquardt 2010; Sassaman et al. 2011). This model can be further refined by examining midden deposition and mound construction during the transitional periods between climatic episodes where sea level is rapidly rising or declining. A reduction in midden deposition and mound construction during these transitions would indicate that ecological instability greatly impacted the occupation of the site regardless of the conditions during the climatic episodes.
I am aware of the potential oversimplification, as well as, the problems of equifinality. Sassaman et al. (2011:138) state that "the relationships of global climate to local environment and human history are matters to be investigated, not assumed." With no ecological or environmental context already associated with Crystal River, the goal is to open such an investigation.

I describe the physical setting and previous archaeological investigations of the Crystal River site in Chapter 2. In Chapter 3, I provide an overview of the research of shellworks along the coastal southeastern United States with a particular emphasis on Florida. Included in that chapter is a more detailed account of Widmer's model. I also include a discussion of the relevant climatic episodes and sea level curves that I used to develop this model. Finally, Chapter 3 contains a brief description of the importance of considering human-environmental interaction using a historical ecology perspective. I provide the methods used with this research in Chapter 4. In Chapter 5, I provide the stratigraphic descriptions and the results of the geovisualizations. In Chapter 6, I combine the results with radiocarbon dates to discuss how the landscape transformed during the occupation and use of the site. This chapter is also where I compare the results to the questions to refine the model. Finally, in Chapter 7, I address the limitations of this research and suggestions for improving this model through further investigations throughout the Crystal River estuarine system and the surrounding region.
Chapter 2

Background

Environmental Setting

The Crystal River site is located on the Gulf Coast of Florida in Citrus County. The site's name derives from the waterway that forms the southern boundary of the site. The spring-fed river begins southeast of the site in Kings Bay and runs approximately 10 km to the Gulf of Mexico. Approximately 500 m west of the site, the Salt River splits from the Crystal River around Roberts Island. The two rivers combine with the saline water of the gulf to form a broad estuarine system. The rivers are lined with brackish marshes, swamps, and archaeological sites built on manmade "islands" constructed of mollusk shell accumulations atop marshland.

The Florida platform that defines the peninsula is composed of carbonate rock beneath siliclastic sediments (Scott 1992). The earliest geological signature of the area is the Ocala Limestone formation from the Eocene epoch (Pilny et al. 1988; Scott 1992). This formation consists of mostly pure limestones with some dolostone inclusions (USGS 2014). Miocene and later Pleistocene sediments overlay the Ocala Platform. In areas where water penetrates the sediments partial dissolution of the limestone occurs creating karst features resulting in undulating topography (Scott 1992).
The Crystal River site itself lies on a limestone shelf of the Palmico marine terrace associated with the Gulf Coastal Lowlands (FDEP 2008; Pilny et al. 1988). This overlying soil is sandy and clayey sand in texture (FDEP 2008; Scott 1992).

The site consists of three soil types. Quartzipsaments (0 to 5 percent slopes) characterized as relocated sandy soil commonly associated with urban development cover around 60 percent of the site (Pilny et al. 1988; USDA, NRCS 2012). The southeastern quadrant of the site is covered by Matlacha, limestone substratum-Urban land complex which is considered fill material related to development (Pilny et al. 1988; USDA, NRCS 2012). The northeastern portion of the site consisting of Mound H and the plaza is labeled Okeelanta-Lauderhill-Terra Ceia mucks (USDA, NRCS 2012). This soil is poorly drained swampy area with limestone substrate generally within 80 in (2.03 m) of the surface (Pilny et al. 1988). The poor drainage results from the construction of a road that leads into the state park (Ellis 2006). The swampy area immediately west of the site is Okeelanta muck (USDA, NRCS 2012). This area is a freshwater swamp created by a depression in the topography (Pilny et al. 1988).

The soils described by the Soil Conservation Service are not overly informative, but do reveal a few of the basic attributes of the site which are described in further detail later. The primary description of the site as modified points to the obvious anthropogenic manipulation of the landform both in prehistoric times and more recently. The southeastern area urban soil is a combination of prehistoric midden deposition and the development of a trailer park in the second half of the twentieth century. Finally, the mucky soils encompassing the site are noted, especially the evident depression adjacent to the raised landform of the site.
Previous Investigations

Including the current, ongoing project of which this study is a part (described below), field investigations at Crystal River have occurred in three main bursts of intensive archaeological study, with intermittent smaller-scale excavations and even more sporadic studies of the resulting artifact assemblages. F.L. Dancy produced the earliest known description of Crystal River referring to Mound A as a Gulf "lookout" consisting of "exclusively oyster shells and vegetable mould" (Brinton 1859:179). Dancy, however, appears to have conducted no field work at the site.

The first period of intensive archaeological work consists of the work of Clarence B. Moore in the early twentieth century. Moore mapped the site in 1903 (Figure 2.1), identifying all of the prominent earthen and shell features except Mounds J and K. Moore’s excavations of the Main Burial Complex in 1903, 1906, and 1917 resulted in the recovery of burials and associated material culture (Moore 1903, 1907, 1918). The ceramics recovered by Moore allowed Gordon Willey to associate the inhabitation of Crystal River with the Woodland period (1948a, 1948b, 1949; Willey and Phillips 1944).

After Moore's excavations, the site remained untouched for 34 years until Hale Smith and colleagues organized a surface collection and opened test units on Mound H and the Feature B midden (Smith 1951). Encouraged by Smith's testing, Ripley Bullen started the most intensive work seen at Crystal River (Bullen 1953; Weisman 1995). Between 1951 and 1965, Bullen at least briefly tested or collected material from all landscape features of the site except for Mound J and the plaza (1951, 1953, 1999 [1965]). This work was intended to identify the occupation components of the site (Weisman 1995:14). In addition to testing, Bullen mapped the site to
include an additional 200 feet of shell midden, Mounds J and K, two limestone boulders described as stelae, a shell walkway between Mounds G and H, and a recent fill area east of Mound A (Bullen 1966; Weisman 1995:50).

The time between Bullen's investigations and the most recent, joint endeavor by Pluckhahn, Thompson, and Weisman is spotted with limited assessments and mitigation projects.
In 1985, Weisman and Jeff Mitchem opened a test unit in the Feature B midden to further assess the nature of the deposition (Weisman 1995). In 1992, Weisman described stratigraphy and artifact recovery from auger holes along a fence line with an adjacent trailer park. A storm in 1993 prompted Weisman and Christine Newman (1993) to investigate damage to the site. Mitigation projects related to other storm damage allowed Gary Ellis of the Gulf Archaeological Research Institute (GARI) to examine exposed profiles along the river bank (2006).

The renewal of rigorous fieldwork at Crystal River began with remapping the site using a variety of methods. Lori Collins and Travis Doering (2009) digitally recorded the features of the site through laser scanning known as high definition digital documentation. In 2008, assisted by a joint University of South Florida (USF) and University of West Florida (UWF) field school, Pluckhahn and Thompson remapped the site using total stations (2009; Pluckhahn et al. 2009). During that same span of time, Thompson and Pluckhahn geophysically mapped much of the site using electrical resistance and ground penetrating radar (GPR) equipment (2009; Pluckhahn et al. 2009).

The summer of 2011 marked the first field season under the National Science Foundation-funded Crystal River Early Village Archaeological Project (CREVAP) under the principal investigators Pluckhahn, Thompson, and Weisman. Assisted by graduate and undergraduate students from USF and Ohio State University (OSU), Pluckhahn and Thompson simultaneously worked at Crystal River and the nearby Roberts Island Shell Mound Complex. Work at Crystal River included additional resistance, GPR, and total station mapping, surface collections, soil coring (Blankenship et al. 2011). In 2012, Pluckhahn and Thompson with students from USF and OSU completed the second of three seasons at Crystal River and Roberts Island. The second year consisted of further geophysical mapping and the excavation of two
trenches in the Feature B midden. USF students excavated two more units in 2013 and conducted limited shovel testing of nearby marsh islands.

Prehistoric Landscape Modification

Prehistoric and modern people have greatly altered the terrain of the site and surrounding area (Figure 2.2). Occupants of the site deposited a tremendous quantity of shell, sand, and other refuse forming several the features we observe today. The conspicuous absence of material in plaza exhibits a different form of intentional landscape manipulation.

Here I briefly recount the descriptions of these features over the past two and a half centuries. The more recent intrusions are discussed in the following section.

When one approaches the Crystal River site from the water, the 9 m-tall platform mound (Mound A) near the bank dominates the view. It was this sight that both Dancy and Moore first described about Crystal River (Brinton 1859). Later, the Crystal River gained notoriety for the exotic Hopewellian artifacts recovered from the burial earthworks. Today the landform, largely free of intrusive foliage, boasts an array of anthropogenic features from the still imposing remnants of Mound A to the flat, open plaza at the foot of Mound H.

Here I describe the features related to this research, including previous investigations of them. Since the Main Burial Complex and Mound G are not modeled in the conclusion due to a variety of limitations and complicating factors, I excluded from them this discussion.
Figure 2.2. Digital Elevation Model of the Crystal River Archaeological State Park.
**Feature B Midden**

Moore (1903:390) depicted the Feature B midden as a hook-shaped ridge, extending from Mound J at the north, south to Mound K, and from there southeast to the river bank. Bullen produced three maps of the site in 1951, 1960, and 1966. The 1951 version is basically Moore's map with the locations of the two test units and water west the Main Burial Complex and northeast of Mound A. In the 1960 version, Bullen altered his map to include an additional 200 feet (60 m) of midden extending northwest from Mound A across the western boundary of the site, replacing one of the areas previously marked as water (Weisman 1995) (Figure 2.3). The midden in Bullen's 1966 map appears the same shape as the previous version. A comparison of site maps showed that the midden varies the most among the features mapped by Bullen, Moore, and most recently by Pluckhahn and Thompson (2009).

Willey described the midden as at least 1000 ft (304.8 m) in length, over 100 ft (30.5 m) in width, and 2 to 3 ft (0.6 to 0.9 m) higher than the neighboring surface (Willey 1949; Pluckhahn and Thompson 2009). Today the better preserved western ridge rises above the marsh by 1.8 m, while the more heavily impacted eastern boundary of the midden is 0.6 m above the adjacent surface (Pluckhahn and Thompson 2009).

Until 2012, testing of Feature B has been limited to the western ridge north of Mound A and east of Mounds J and K. Smith (1951) noted the depth of the midden north of Mound A as 48 in (121.9 cm). Bullen excavated two units in the midden north of Mound A and east of Mound K in 1951 (Units I and II) and coarsely described their stratigraphy. Unit I contained approximately 70 percent shell in the top 4 ft (1.2 m) with an ash deposit between 2 and 4 ft (0.6 to 1.2 m) followed by a lower density of shell around 15 percent to a depth of 5 ft (1.5 m) (Bullen 1953). Unit II is described the same except that Bullen (1953) described crushed oyster...
shell between 7 and 8 ft (2.1 to 2.4 m). The density of the crushed shell stratum is not mentioned; presumably, the shells he encountered at higher depths were more often whole. In 1964, Bullen excavated two additional units in the midden, but the results of this work were never reported (Weisman 1995). Pluckhahn and colleagues (2009:27) mapped the approximate locations of
these units. One was placed southeast of Mound K and the other northwest of Mound A (Pluckhahn et al. 2009:27).

In 1985, Weisman and Mitchem probed the midden and subsequently excavated two units measuring 1 x 1 m and 2 x 2 m (Weisman 1995). Excavation was limited to a single level extending 20 cm below the surface and no stratigraphic descriptions were reported beyond the presence of shell (Weisman 1995).

More recently, a GPR grid northwest of Mound A revealed numerous near surface anomalies possibly representing previous test units (Pluckhahn et al. 2010). The geophysics survey also exhibited less reflectivity below 40 cm indicating variation of midden deposition possibly related to discrete isolated deposits instead of continuous fill (Pluckhahn et al. 2010; Thompson and Pluckhahn 2010). Three cores placed in this part of the midden confirm the changes in midden deposition patterns through time seen in the GPR data and alluded to by Bullen (Pluckhahn et al. 2010). Excavations from the 2013 revealed these deposits as shell-filled pits (Thomas Pluckhahn, personal communication 2013).

The investigations since 2009 have focused largely on the midden. The aforementioned GPR analysis provided a basis for limited coring/augering of the midden (Pluckhahn et al. 2009). A total of five cores were collected including the three mentioned above. The cores provided evidence of discrete shell deposits, the remnants of the Mound A ramp, and the disturbance associated with the trailer park (Pluckhahn et al. 2009). This heavily influenced the sampling strategy of the soil cores examined in this thesis.

In 2012 and 2013 four tests were excavated in Feature B. The units were placed east of Mounds J and K, along the central ridge, north of Mound A, and on the knoll where the park ranger's house stands on the eastern boundary of the park. The excavations provided Pluckhahn
and colleagues with stratigraphic evidence of how the midden formed and yielded a series of radiocarbon dates (Pluckhahn et al. 2014).

The stratigraphy of the midden deposits, as well as the artifacts and ecofacts associated with the strata, may hold the key to two persistent questions regarding Crystal River. The first issue concerns the chronology of occupation. Bullen's descriptions of artifact recovery at Crystal River by and large focus on ceramics. By examining the ceramic types, Bullen could identify distinct occupation periods (Weisman 1995). Bullen divided the occupation of the site into two periods Pre-Weeden Island and Weeden Island based on the presence or absence of Dunns Creek Red sherds. These red filmed ceramics appeared almost exclusively in the top 34 in (86 cm) of test units (Bullen 1953). Combined with analysis of lithic and shell tools, Bullen (1953) categorized the major periods of occupation as Santa Rosa-Swift Creek and Weeden Island. Citing earlier work by John Goggin, Bullen suggested that the site was occupied from A.D. 0 to 1600 (Bullen 1953; Goggin 1950).

Evidence indicates that the site was occupied during the Woodland period, but more precise dates are needed. Radiocarbon dating has been used at Crystal River. However, the contexts and accuracy of many of these dates remain questionable. Furthermore, no feature has been systematically sampled to provide a complete range of dates from beginning to end.

In his synthesis of work at Crystal River, Weisman (1995:39) summarized previously-obtained radiocarbon dates. More recently, Pluckhahn and colleagues (2010:174) provide an updated compendium that includes seven newly-obtained dates. A total of five dates are present in Feature B. The earliest sample came from unidentified material and has a 2-sigma calibrated date range from 350 B.C to A.D. 250. The latest date comes from deer bone from a depth of 24-30 in (61-76 cm) which has a 2-sigma calibrated date range from A.D. 540 to 660. This date
pertains to the early Weeden Island occupation identified by Bullen based on ceramic distribution. No dates are present from last of the midden deposits closest to the surface. Overall, the earliest midden date coincides with Bullen's loose timeframe, but the most recent date is much earlier than the postulation.

Bayesian modeling of radiocarbon dates on bone and soil-carbon from column samples excavated in the midden have greatly refined our temporal understanding of this feature and the site as a whole. Pluckhahn and colleagues (2014) define the site's formation in terms of four phases. The first phase has a starting two sigma date range of cal A.D. 65 to 224. The final phase ends from cal A.D. 890 to 1151, but this period is mostly associated with the nearby Roberts Island Mound Complex (8CI41). A vast majority of the midden accumulated between A.D. 65 and 543 during the first two phases in the region (Pluckhan et al. 2014). These phases and the methods used are discussed in greater detail in Chapter 6 as they are pertinent to my interpretation of landscape modification in the context of environmental and climatic conditions.

*Mound A*

Marking the southwestern corner of the site, Mound A looms over the marsh and the Crystal River. This mound was the first feature at the site described by Dancy, Moore, and Willey (Brinton 1859:178-179; Moore 1903; Willey 1949). In 1960, the approximately one-third of the eastern side of the mound was removed and used as fill in area east of the mound (Weisman 1995). While the mound no longer retains the initial shape, it was originally rectangular with the long side running northwest-southeast. A lengthy ramp reportedly extended east-northeast from the flattened summit of the mound to an open area just south of the midden.
ridge. Willey (1949:42) stated that the ramp was so well preserved that only the biggest mound
at Moundville was comparable.

Dancy estimated the summit of the mound to stand about 40 ft (12.2 m) tall and 30 ft (9.1
m) across (Brinton 1859:179). Moore (1903) measured the mound at 28 ft 8 in (8.7 m) in height,
182 ft (55.5 m) by 100 ft (30.5 m) at the base, and 107 ft (32.6 m) by 50 ft (15.2 m) on the
platform with a ramp 80 ft (24.4 m) long and between 14 and 21 ft (4.3 and 6.4 m) wide. Willey
(1949) estimated the mound's height as 25 to 35 ft (7.6 m to 10.7 m).

Pluckhahn and Thompson (2009) measured the remaining portion and found that the
shorter, northwestern side of the mound is 28 m at the base and 12 m on the platform. The height
of the mound is 9.39 m above mean sea level and rises 7.9 m and 8.2 m above the ground surface
to the north and east, respectively (Pluckhahn and Thompson 2009).

Beyond mapping and measuring, very little work has been done with Mound A. Smith
(1951) included the mound in the surface collection. Pluckhahn and colleagues (2010) collected
a core sample from the approximate location of the ramp and identified undisturbed midden
material extending to a depth of at least 120 cm below the surface. GPR data from this area
supports the possible integrity of the subsurface shell (Pluckhahn et al. 2010).

Bullen (1966) acquired a radiocarbon date from exposed charcoal 19 ft (5.8 m) below the
platform surface. The 2-sigma calibrated date ranges from A.D. 560 to 970 (Pluckhahn et al.
2010). The apparent inclusion of cultural refuse in the composition of the mound has led to
speculation that it was constructed from redeposited midden material (Weisman 1995:46).
**Mound H**

Located on the northeastern edge of the site, Mound H is a well preserved, rectangular, flat-topped construction of shell and sand. The summit of the mound runs northwest-southeast, and these is a ramp extending from the summit to the plaza to the southwest. Moore only briefly described this feature as "12 feet in maximum height, with a graded way" (1903:379). The mound is 73 m by 25 m at the base and 50 m by 8 m on the platform, which rises 3.7 m above the plaza surface (Pluckhahn and Thompson 2009). The ramp measures 31 m in length and 6 m wide (Pluckhahn and Thompson 2009). Bullen noted and mapped a shell causeway linking Mound G with Mound H (1999 [1965]; 1966:862).

Smith (1951) excavated a 2 ft by 2 ft unit on Mound H. However, the precise location of this excavation is unknown. No stratigraphic information was reported.

Bullen excavated two units on Mound H, one on the platform just beyond the ramp and a second on the ramp (Weisman 1995). The platform unit was excavated to a depth of 5 ft (1.5 m). No information is known about the ramp unit, but the unit appears approximately 5 x 5 ft based on a photograph (Weisman 1995).

A GPR survey revealed two highly reflective layers first at 45 to 50 cm and 90 cm below surface leading to interpretation that Mound H was constructed in at least three stages (Pluckhahn et al. 2010; Thompson and Pluckhahn 2010). A radiocarbon sample from a deer bone collected between 1 and 2 ft (0.3 and 0.6 m) in Bullen's first unit provided a 2-sigma calibrated date range of A.D. 420 to 600 (Pluckhahn et al. 2010).
Mound K

Apparently hidden by dense vegetation at the time of Moore’s visit, Mound K was first mapped in Bullen's 1960 sketch (Bullen 1966:862; Weisman 1995). This mound is generally rectangular in shape with rounded summit that could be an eroded platform. The base of the mound is 21 m by 19 m with the long side running north-south (Pluckhahn and Thompson 2009). The platform is approximately 12 m by 7 m and rises approximately 2.1 m above the ground surface north of the mound (Pluckhahn and Thompson 2009). In Bullen's 1966 map, he incorrectly labeled Mound K as “Mound J” and added a ramp extending northeast (1966:862). However, no evidence of this ramp is present today and there is speculation that the ramp was drawn to support the claims that structures that housed chiefs or priests rested upon Mounds J and K (Pluckhahn and Thompson 2009; Weisman 1995). However, resistance mapping identified possible structural features on Mounds J and K (Thompson and Pluckhahn 2010:42).

Bullen tested the mound with a single unit that reached a depth of 5 ft (1.5 m) (Weisman 1995). Unfortunately, the test was never properly reported. Based on GPR survey, Pluckhahn and colleagues (2010) suggest that the mound was constructed of dense shell in a single event covered by 40 to 50 cm of less dense soil that may be cultural or natural soil formation.

Mound J

Mound J was first mapped by Bullen along with Mound K and the western midden ridge (Weisman 1995). Although labeled as a chief's or priest's mound by Bullen (1999 [1965]), little is known about this feature. It is roughly rectangular, but irregular in shape. Pluckhahn and Thompson (2009:18) described the measurements of the mound as "approximately 27 m northeast-southwest by 12 m northwest-southeast" at the base and "roughly 12 by 4 m" on top.
The highest point of Mound J is 1.7 m above the ground surface and about 40 cm below Mound K (Pluckhahn and Thompson 2009). As noted in the discussion of Mound K, anomalies indicative of architectural features were identified on Mound J (Thompson and Pluckhahn 2010:42). The function and construction of this feature and its counterpart Mound K are among the multitude of questions at Crystal River.

**Plaza Area**

The plaza is a flat, open area southwest of Mound H, bounded by Mound G to the west, the shell causeway to the north, and the Main Burial Complex to the south. Bullen only labels the area in the 1960 site map and mentions it briefly as a place "to watch ceremonies conducted on top of Temple Mound H" (Bullen 1999 [1965]:225; Weisman 1995:45). Based on the previously mentioned boundaries, Pluckhahn and Thompson (2009) measured the plaza as 88 m north-south and 57 m east-west. While the plaza has not been previously excavated or cored, resistance surveying revealed no anomalies that would suggest midden deposits or structural remains further supporting the designed "cleanliness" of this area (Pluckhahn and Thompson 2009; Pluckhahn and Thompson 2010).

**Modern Landscape Modification**

Residential development and river-bank mitigation have dramatically altered the landscape of Crystal River and its surrounding area. As noted before, a large portion of largest platform mound was removed in 1960, before the property was acquired by the state. The property owners redeposited some of this material across the area east of Mound A and along the
river bank (Bullen 1966). This can be observed as the "recent fill" designation on Bullen's final site map (1966). Bullen (1953) previously described the filled area as a lagoonal depression and marked the area directly northeast of Mound A as water. Analysis of the midden along the river bank suggests that the Mound A material was used to level a previously undulating surface to better suit development (Ellis 2006). Owners of this portion of the site used the area as a trailer park. In 1993 storm damage resulted in the abandonment of the trailer park eventually leading to the incorporation of the property into the Crystal River Archaeological State Park in 1995 (Estabrook 2011).

In 1991 Weisman recorded the stratigraphy and artifact recovery from the post holes excavated during the installation of a fence between the state park and the trailer park. Weisman's report (1992) revealed varying depths of disturbed and modern fill strata. A single core placed in the fill zone encountered compacted material containing broken shell at 50 cm which could not be further penetrated (Pluckhahn et al. 2010). In addition to redeposited material, raised areas may have been impacted by construction. Thompson and Pluckhahn (2010) suggest that the modern discontinuous shape of Feature B is due to terrain modification related to the trailer park. The full impact of the disturbance and the extent of the original landscape are not well known.

A sea wall was installed along the river in the 1960s following the creation of the trailer park (Estabrook 2011). Storm damage necessitated the replacement of sea wall in 1998 (Estabrook 2011). Today the wall spans the entire southern edge of the site and rises approximately 2 m above current river level. GARI engaged in multiple mitigation projects starting in 1997 when portions of the seawall collapsed exposing midden soil (Ellis 2006). The updated report revealed that some culturally intact midden remains as well as possible pre-
occupation river bank soil, but the extent of alteration of the bank is unclear (Ellis 2006). Based on the stratigraphy 40 to 50 cm of fill is present, but it may extend deeper into lower areas (Ellis 2006).

Further landscape modification at Crystal River is related to the development of the site into a state park starting in 1962. The development of a raised platform on which the museum building rests, a parking lot and an access road all impact current conditions such as drainage at the site. Water flow and drainage north of Mound H is restricted by this construction impacting the current water table (Ellis 2006). The house where the managing park ranger dwells rests on the eastern edge of Feature B. Mapping shows that this area is 60 cm above the surrounding ground surface suggesting that the midden is at least partially intact. The extent of recent landscape modification at Crystal River complicates the interpretation of the archaeological features on the site.
Chapter 3
Cultural and Environmental Context

Shell Middens and Mounds of the Coastal Southeast

Since the Middle Archaic period (6000 B.C. to 4000 B.C.), the people of the rivers and coasts of southeastern North America have exploited freshwater and marine resources (Milanich 1998). The utilization of mollusks is evidenced by the accumulation of shell middens. These deposits are commonly viewed as simply the accumulation of discarded food remains. However, the inclusion of burials and the construction of middens of substantial size and elaborate shape suggests middens were conceived as more than simply refuse disposal (Claasen 1991; Russo 2004; Thompson 2010).

By the Late Archaic period (4000 B.C. to 1000 B.C.), shell features varied greatly in shape from small deposits to large shell rings and mounds. Shell rings formed in "C", "U", and "O" shapes are the most widespread monumental features of this time (Saunders and Russo 2011). These features are present along the coasts of South Carolina (e.g. DePratter 2010), Georgia (e.g. DePratter 2010; Thomas 2010; Thompson 2010), and Florida (e.g. Russo 2010; Saunders and Russo 2011; Schwadron 2010).

The Tomoka Mounds and Horr's Island sites, located in northeastern and southwestern Florida respectively, contain burial mounds composed of sand and shell providing more
supporting evidence of coastal monumental architecture during the Late Archaic (Piatek 1994; Russo 1994; Saunders and Russo 2011). Similar burial mounds are present on Fig Island in South Carolina (Saunders and Russo 2011).

The formation of shell features declined significantly across much of the southeast in at the end of the Late Archaic period (Russo 2010; Sanger 2010; Saunders and Russo 2011). The people of the Early Woodland period (1000 to 300 B.C.) are characterized as small community or family-based groups of mobile foragers (Anderson 2001; Thomas and Sanger 2010; Russo 2010). This phase of social reorganization is accompanied by less landscape modification (Anderson 2001; Russo 2010). A renewed tradition of increased earthen and shellwork construction began in the Middle Woodland period (300 B.C. to A.D. 500) (Anderson 2001).

Research regarding this transitional period has primarily concentrated on changes in climate and sea level (Kidder 2006, 2010; Marquardt 2010; Sanger 2010; Thompson and Turck 2009; Widmer 1988). Most commonly, these types of studies focus on shifts in settlement patterns resulting from reduced resource availability and tumultuous weather patterns. Thompson and Turck (2009) examined site occupation along the Georgia Bight and found that people moved away from the coastline as sea level dropped and returned during the more favorable conditions of the Middle Woodland. Although the resettlement of these areas reflects social memory, these people came with different social practices (Thompson and Turck 2009). A shift toward sand burial mounds and fewer shellworks may represent one of the traditions directly altered by reduced mollusk availability (Russo 2010; Thompson and Turck 2009).

The influence of sea level transgression on settlement patterns and monumental architecture is arguably more pivotal for southern Florida. Low-lying coastlines and the complex wetland ecosystem of the Everglades makes this area highly susceptible to both salt and fresh
water levels. Widmer (1988) suggested that coastal conditions restricted settlement until 700 B.C. Furthermore, permanent settlement along the shore did not proceed until A.D. 280 (Widmer 1988). This shift to year-round occupation is seen in conjunction with subsistence of almost entirely estuarine organisms (Widmer 1988). This model indicates that permanent settlement in southern Florida is tied to the availability of estuarine resources which are reliant on sea level stability.

Widmer (1988, 2004) suggests that sedentary lifestyles and abundant coastal food sources led to unmitigated population expansion which spurred socio-political evolution. The changes in social structure included the formation of new lineages that constructed mounds to exhibit power (Widmer 2004).

This model indicates that opportune climatic conditions, specifically high and stable sea levels, allow for the proliferation of population which in turn leads to the construction of monumental architecture as social structures evolve. Widmer (2004) attributes the abandonment of Archaic sites like Watson Brake and Horr's Island to the dissolution of social complexity resulting from the destabilization of ecosystems through broader climatic changes. However, the model for southern Florida in the first millennium A.D. is significantly different. Widmer (1988) argues that the population of southern Florida overwhelmed the regional carrying capacity by A.D. 800. Environmental circumscription led to the formation of chiefdoms (Widmer 1988).

More recent research suggests that settlement patterns and development of social complexity (as evidenced by monumental architecture) are more complex than modeled by Widmer. The aforementioned Horr's Island site, as well as, other sites such as Bonita Bay, Russell Key, House's Hammock, and Ten Thousand Islands all date to the Middle to Late Archaic periods (Russo 2010; Saunders and Russo 2011; Schwadron 2010). While it appears as
though a lot of sites were abandoned during the Late Archaic, shell bearing sites like Reed Shell Ring persisted into the Early Woodland period (Russo 2010). Furthermore, Everglades City, Dismal Key, and Sandfly Key all contain shell ridges that date to the beginning of the Early Woodland period showing continuity despite sea level transgression that dramatically altered settlement throughout the coasts of southeastern North America (Russo 2010; Schwadron 2010). The geomorphologic features of southwestern Florida may have facilitated the continued habitation of coastal dwellers despite declining sea level. Russo (2010) suggests that some estuarine systems would continue to function, while new estuaries formed despite a 2 m drop in sea level. The rapidity with which these ecosystems form and stabilize is a key point to consider here. While the specific ecological and environmental dynamics of sea level transgression are poorly understood, there is sufficient evidence to exhibit some degree of continuity from the Late Archaic to the Early Woodland (Russo 2010).

This continuity not only shows the persistent habitation of large settlements, but also the transition between shell rings and other more complicated shellworks. Located among the Ten Thousand Islands, Russell Key's earliest feature is a shell ring dating to the Early Woodland period (Schwadron 2010). Modification of the site continued with the formation of finger ridges, rounded mounds, and platform mounds. Mound construction at Russell Key dates to the Late Woodland period, while the most recent finger ridge continued into the Mississippian Period (A.D. 1000 to 1500) (Schwadron 2010). People throughout Florida and southeastern North America largely ceased shell ring construction in the Late Archaic period with the exception of southwestern Florida, where a clear transition from shell rings to shell mounds and other features is present (Saunders and Russo 2011).
Settlement trends in the Middle and Late Woodland periods also appear to be more complicated than described by Widmer. Both the quantity and size of coastal shell-bearing sites significantly increased (Widmer 1988). Some of the more studied post-Archaic shell midden and other shellwork sites include Wightman, Solana, Cash Mound, and the Pineland Site Complex. Walker and colleagues (1994, 1995) identified signs of episodic sea level change at these sites; specifically, they may have been inundated starting around A.D. 200 and continuing until 600 (Walker et al. 1994, 1995). During this span, sea level may have risen over 1 m above current conditions, causing the inhabitants to move inland (Walker 2000; Walker et al. 1995). The reoccupation of these sites coincided with a decline in sea level (Walker 2000; Walker et al. 1995). An increase in mound construction, rather than abandonment, accompanied the next rise in sea level around A.D. 800 (Walker 2000). Walker (2000) suggests that people intentionally increased the elevations of their settlements to deal with rising sea level. However, sea level modeling indicates that this later transgression was less severe than earlier increases (Balsillie and Donoghue 2004:14).

The central and northern Gulf coast of Florida reflect the same abandonment of coastal shell sites at the end of the Late Archaic period as seen on the Atlantic coast. (Russo 2010). The erosion and recent destruction of Late Archaic sites around the Tampa Bay has limited investigations in this area (Milanich 1994). The shell midden islands and other coastal sites north of Tampa Bay have not been thoroughly studied and are likewise in danger of being lost to natural and anthropogenic forces. This is one of the primary reasons for the renewed work at Crystal River and the surrounding area.

The post-Archaic sites of the Tampa Bay area are better known than their Archaic predecessors, but limited sample size remains a problem. Recently, Austin and colleagues (2014)
analyzed post-500 B.C. sites as part of a refinement of chronology in this area. They found that dates were most frequent from A.D. 1 to 600 and A.D. 800 to 1400 which coincide with periods of higher sea level (Austin et al. 2014). However, the impacts of sea level change and the responses of coastal occupants varied by location (Austin et al. 2014).

In 2009, faculty and students from the University of Florida began work on the Lower Suwannee Archaeological Survey to study coastal sites endangered by rising sea level. Thus far results are considered preliminary and dates are primarily based diagnostic artifact recovery with limited radiocarbon dating. These investigations have shown that many shell midden, shell mound, and possible shell ring sites exhibit repeated use (McFadden and Palmiotto 2012; Mones et al. 2013; Sassaman et al. 2011). However, these occupations primarily occur during the Middle and Late Woodland periods. Bird Island shows signs of early use as a cemetery as well as a later Woodland occupation, but non-cultural deposits may indicate a 2000 year hiatus starting around 2290 B.C. (McFadden and Palmiotto 2013). The earliest component of Deer Island dates to the Early Woodland with other components in the Middle and Late Woodland (Mones et al. 2013). This shows a rare example of a significant shell deposit dating to this period outside of South Florida. However, these dates still do not exhibit occupational continuity between the Late Archaic and Early Woodland periods. Furthermore, the role of shell deposits and monumental architecture has yet to be examined at these sites.

Changing hydrologic systems and severe weather are cited as reasons for a lack of permanent coastal settlement around the Choctawhatchee and Apalachicola Bays along the Panhandle of Florida (Donoghue and White 1995; Saunders 2010; White 2003). White (2003) speculates that coastal sites around the Apalachicola Delta remained purely seasonal due to persistent changes in the terrain. The settlement patterns and consequently the human-
environmental interactions in the Panhandle are remarkably different from the rest Florida. This divergent relationship with coastal environments similarly resulted in different manifestations of landscape modification.

*Modeling Sea Level in the Gulf of Mexico*

As the previous section shows, archaeologists have often discussed the relationship between sea level and cultural change in southeastern North America. The interest in sea level and climate change has significantly increased over the past 15 years, in association with growing concern over contemporary conditions (Walker 2013).

Models of sea level and climate change have problems with consistency in methods, with reliance on additional proxy data, and with local variability. A larger problem is the assumed relationship between sea level and climate change; while there is a general correlation between the two, the tempo and severity of change may be discordant. In this study, I primarily refer to the global climatic episodes defined by Marquardt (2010). However, I use the names given to sea level episodes as defined by Stapor and colleagues (1991) to discuss specific conditions for southwestern Florida when necessary.

Reconstructed sea level records have existed since the late 1600s, but only for isolated areas. The development of radiocarbon dating facilitated the study of past changes in areas where written records were not available (Balsillie and Donoghue 2004) (Figure 3.1). Since the 1950s, an extensive variety of methods have been employed to acquire proxy data from which past sea levels are measured. Unfortunately, the proliferation of such studies has led to a great
deal of inconsistency in method, and disagreement about the accuracy and utility of these records.

There are a multitude of sea level records available for various areas of the Gulf of Mexico and the Caribbean Sea, but Tanner's (1991, 1993) curves are most frequently applied to archaeological models along the Gulf Coast of Florida. This is largely due to the work of Walker and Marquardt who have most frequently applied sea level records to archaeological sites in Florida since Widmer's models from the 1980s.

Tanner's sea level reconstruction is based on analysis of sand grains from St. Vincent Island in the Florida Panhandle and the Jerup ridge in Denmark. Tanner (1991:584) found that "wave energy density in the surf is a function of 1/kurtosis." The curve is then created by inverting this correlation, showing sea level as a reflection of wave energy. However, this function does not work on some high energy and sharply-curved beaches (Tanner 1991). Another problem is that the time span of the curve is limited to the initial formation of the ridge. The existing beach ridges along the Gulf of Mexico formed within the last 3500 years (Tanner 1991). The Jerup curve, however, spans 8000 years. A comparison of the Gulf curve with the Jerup curve shows a similar pattern of peakedness (Tanner 1993:228). This congruity allows for the use of sea level data from Denmark for the Gulf of Mexico.

Marquardt (2010:257) used Tanner's raw data to create a smoothed curve that shows the climate episodes from 5600 B.C. to A.D. 1950. The occupation of Crystal River falls into the Roman Warm Period (350 B.C. to A.D. 500), the Vandal Minimum (A.D. 500 to 850), and possibly the Medieval Warm Period (A.D. 800 to 1200) (Figure 3.2). Other sources use slightly different names and dates (for example, "warm" is sometimes replaced with "optimum") (Walker 2013). However, I stick to the designations used by Marquardt (2010) and Walker (2013).
The terms for reconstructed sea level along the Gulf Coast of Florida are based on beach ridges on islands located in southwestern Florida. Stapor and colleagues (1991) examined and dated the depositional history of several barrier islands in Lee County, Florida. This 3000 year curve shows sea level episodes relative to current mean sea level (MSL) (Stapor et al. 1991:835). The curve noticeably lacks detail and generalizes sea level change. However, the MSL estimates are useful because Tanner's curve only shows the degree of sea level change and not the actual elevation. The Wulfert High, Buck Key Low, and La Costa High correspond well with the RWP, Vandal Minimum, and MWP respectively.

Figure 3.1. 7-point floating average sea level curves for the Gulf of Mexico (Balsillie and Donoghue 2004:14).
Figure 3.2. Sea level curve for the Gulf of Mexico based on Marquardt's (2010:257) plotting of Tanner's (1993:231) raw data. The graph depicts sea level rise and fall during the occupation of Crystal River.

The biggest area of contention is the decline in sea level that marks the transition from the Wulfert High to the Buck Key Low. Stapor and colleagues (1991) designate A.D. 450 as the dividing line. Additional environmental and archaeological proxy data supplement both Tanner's and Stapor's models.

According to Stapor's curve, sea level during the Wulfert High may have reached 180 cm above present before dropping to approximately 60 cm below present during the Buck Key Low (Stapor et al. 1991; Walker et al. 1995). At the Solana site, Widmer (1986) suggested that sea level was at least 60 cm above present. The presence of mollusks associated with structural
features suggests that the site was inhabited toward the end of the Wulfert High (Stapor et al. 1991; Widmer 1986).

The analysis of middens at several coastal sites in southwestern Florida further refined time spans and degree of sea level change during the Late Holocene. According to Walker and colleagues (1995), MSL was 60 cm below present prior to A.D. 100. Between A.D. 100 and 200 sea level approached the current point. Sites became inundated to various degrees during the Wulfert High. Sea level was at least 70 cm above present at the Wightman site and may have reached 150 cm above present at Pineland (Walker et al. 1995). Sea level rapidly declined to 50 cm below present by A.D. 600. A dramatic increase in the ratio of large gastropods to oysters indicates ecological destabilization resultant from a quick and steep drop in MSL (Walker 1992; Walker et al. 1994).

The archaeological and ecological proxy data are invaluable because of the support and refinement of the curves, as well as, revealing some noteworthy flaws of globally and regionally modeling sea level. Overall, these dates and MSL measurements match the pattern of both models. In Stapor's curve, the supplemental data improve date ranges for the sea level episodes to show that the Wulfert High started 200 to 300 years later and persisted for 200 years less than originally modeled (Walker et al. 1995:215). For Tanner's curve, the additional data provide actual magnitude measurements which are absent when using the inverse kurtosis method. The dates of Tanner's curve and the site inundations overlap, but suggest that the high stand episode started earlier and lasted longer in northwestern Florida (Walker et al 1995). This discrepancy could be seen as refinement as well as variation of sea level specific to local geological, hydrological, and environmental features. The difference in high stand levels observed at the Wightman site (70 cm above present) and Pineland (150 cm above present) shows how
dramatically different measurements can be using similar methods in a single estuarine system. These disparities are worsened further by the reliance on different types of proxy data.

Proxy data from the Suwannee Delta projects a lower magnitude impact of sea level during the RWP than seen in Stapor's Wulfert High. Wright and colleagues (2005) used systematic coring to show that sea level transgression decelerated in the Middle Holocene. The coastline stabilized and formed to roughly its current position as side channels of the Suwannee River refilled. This suggests that MSL never exceeded the present level during the RWP/Wulfert High. Archaeological investigations in the Suwannee Delta support the deceleration hypothesis. Midden from Little Bradford Island shows that sea level did not exceed present conditions A.D. 20 to 280 (Sassaman et al. 2011). Further excavations and more radiocarbon dates are needed to improve the understanding of climatic and environmental conditions in the Big Bend, but at the moment there is significant variation between the southern and northern Florida in terms of sea level transgression.

In the absence of sea level curves for every major hydrological and geological feature that derive from a consistent and comparable method, multiple models and types of proxy data must be applied with a consideration of the present limitations. Balsillie and Donoghue (2004) compiled and analyzed 23 reconstructed sea level datasets for the northern Gulf of Mexico. Following the removal of outlying data using a reference curve based on global sea level data, a series of smoothed seven point floating average curves were created.

A set of curves for the younger data sets (the last 6000 years) derived from onshore sampling are the most applicable for the occupation of Crystal River. These shoreline curves include beach ridge datasets from both Tanner's St. Vincent Island sand Stapor's southwestern Florida studies (Balsillie and Donoghue 2004:14). I use the onshore because they provide a
better comparison for sea level relative to the coastline instead of showing depth in the Gulf of Mexico like the offshore samples. The younger onshore curves are separated by the method of dating as either $^{14}$C or Absolute years BP. When calibrated as they are, there is little difference between the two curves over the last 2500 years. From this point forward I reference the younger onshore curves as Balsillie and Donoghue's curve unless it is necessary to discuss the relatively minute differences as they relate to landscape modification at Crystal River.

Balsillie and Donoghue's curve at least partially rectifies the discrepancies between Tanner's and Stapor's curves. The smoothing removes some of the oscillations displayed in Tanner's curve, but not to the extreme of Stapor's curve and Walker's contextual modeling. Rapid short-term changes associated with climate and sea level that affect ecological stability are important to the analysis of human-environmental interaction (Marquardt 2010; Sassaman et al. 2011).

Another potential problem with averaging multiple datasets is the loss of local specificity as the region of study is expanded. Datasets from Texas (Blum et al. 2002; Morton et al. 2000) are averaged alongside the St Vincent Island and southwestern Florida curves. Given the complicated issues associated with measuring reconstructed sea level records, there is a fine line between the acquisition of regional/global accuracy and accounting for local conditions. Unfortunately, useful contextual data, both archaeologically and geologically, are limited for the Crystal River area. This increases the reliance on proxy data from elsewhere in peninsular Florida to supplement the three sea level models and global climatic episodes.
Human-Environmental Interaction

Clearly coastal dwellers are impacted by their environment at a variety of scales from local ecosystems to global climatic shifts. Sea level transgression is by far the most apparent environmental influence on settlement of the shorelines around the world. However, the intentional and unintentional effects that human populations have on their environment cannot be discounted. Historical ecology refers to the dialectical interaction and influence between people and their environment over time (Balée 1998; Crumley 1994, 2003; Egan and Howell 2001; Kidder 1998; Marquardt 2010). This perspective allows an observer to examine both the ways people were influenced by their environment and how people responded to challenges imposed by environmental conditions. Emphasis is placed on landscapes as temporally and spatially dynamic scenes of interaction between people and the non-human environment. This interaction results in culturalized ecosystems, as well as consciously and unconsciously constructed environments (Balée 1998; Crumley 2007; Egan and Howell 2001). In other words, human behavior is constantly adjusting itself as it constantly adapts to, modifies, and constructs the natural and perceived world. This theory views these ecological and environmental alterations and modifications as a historical process rather than an evolutionary one, as proposed by other environmentally-based theories such as environmental determinism (Balée 1998).

Since the historical continuity of the human-environmental interaction is the key, the scales at which these exchanges are observed are worth consideration. Anderson (2001) examines scale in short, intermediate, and long terms. The intermediate term, which incorporates decadal to centurial spans, is best suited for examining both changes in climatic shifts and the smaller sea level fluctuations observed in the last 5000 years (Anderson 2001). For a site like
Crystal River that was occupied in the Middle and Late Woodland periods and dealt with sea
level fluctuations less than 2 m in magnitude, analysis at the intermediate scale fits. To account
for rapid or punctuated environmental change a high resolution of contextual records is
necessary (McFadden 2010; Sassaman et al. 2011). Unfortunately, the curves described above
and throughout the Gulf of Mexico lack such fine detail. Tanner’s (1993) Jerup ridge curve uses
intervals of about 50 years. Balsillie and Donoghue’s (2004) curve has a periodicity of 60 years.
Worst of all, Stapor and colleagues (1991) rely on radiocarbon dating of shell that results in a
resolution of 200 to 400 years.

While their resolution is far from ideal, these curves are still viable for measuring the
occupation and modification of the site through climatic episodes, sea level transgression, and to
a certain degree ecological stability. The results of this research, as well as other ongoing
research under CREVAP, should help refine this resolution locally. This is especially important
for examining the influence of humans on the environment in areas such as resource exploitation
and alteration of the local hydrology through the construction of anthropogenic landforms (see
Gilleland 2013).
Chapter 4

Methods

The examination of the natural and anthropogenic forces that shape site formation at an archaeological site such as Crystal River requires stratigraphic data. Soil cores provide the greatest access to this data across a large area with the least destructive impact and thus were the method of choice for this project. Here, I describe the methods that were employed in retrieving, processing, and interpreting stratigraphic core samples from Crystal River.

Stratigraphic Sampling

A total of 58 soil cores were systematically collected in the summer of 2011 (Figure 4.1). With the assistance of Dr. Glen Doran and Grayle Farr of Florida State University, 46 soils cores were acquired using a GeoProbe Model 54LT. This machine hammers a metal sleeve containing a plastic liner into the ground. Transported by ATV, truck, and radio control, cores were taken at 20 m intervals across the Feature B midden and the plaza. Single cores were collected from summits of Mounds A, H, J, and K. The Main Burial Complex and Mound G were intentionally avoided to avoid disturbing human remains. Core locations were established using a total station, with locations tied to the site-specific grid system established in 2008 (Pluckhahn et al. 2009). These grid locations were subsequently translated to the UTM grid system.
Figure 4.1. Map of GeoProbe core locations. Contours at 0.2 m intervals. Based on EROS LiDAR data processed by Thomas J. Pluckhahn.
Cores and core sections were numbered sequentially and documented on project-specific forms. A core section consists of a plastic tube measuring 116 cm in length and 4.5 cm in diameter. At Crystal River, each core contained between one and nine sections, depending on surface elevation and depth to limestone substrate. Following the extraction of each section, we measured the depth using a tape measure; this was performed to check the depth of the core, since sections were not always hammered to full depth (to facilitate extraction in compact soils). Each core section was immediately capped and labeled. The small amount of loose soil (slough) present at the bottom of the metal sleeve was bagged and labeled accordingly.

Twelve additional cores were collected from the marsh adjoining the site using a custom-built, pneumatic vibracoring device. Gary Ellis and Ken Nash of GARI provided the device and instruction. The same plastic tubes were used, but only a single section was recovered from each location. The areas sampled include: northwest of Mound A, west of Mound K, east of the plaza, and north of Mound H.

**Stratigraphic Description**

In the lab, each core section was cut lengthwise, dividing it in half and thus providing a profile. Upon opening a section, I described, recorded, and drew the stratigraphy on specialized forms (Figure 4.2). Strata were labeled sequentially using Roman numerals and measured in centimeters. Identification of strata derived from Munsell soil color, texture based on feel, and structural properties. Additional noted attributes include, but are not limited to: organics, plasticity, shell content, boundary clarity, and oxidation. I labeled some strata with horizon
designations, but depositional processes and stratum composition often made identification difficult. I primarily focused on identifying buried A horizons to locate breaks in deposition.

The profile of each section was hand drawn on graph paper and photographed. The data were later transferred to a Microsoft Excel spreadsheet. These spreadsheets were imported into Strater 2 (Golden Software, Inc.) to create visualizations of each section containing the stratigraphic data and photographs. I labeled strata using Roman numerals in the descriptions, but for simplicity used Arabic numbers in the Strater profiles.

Once described, the measurements of the strata were converted into depths below surface. The use of the GeoProbe presented multiple problems with calculating actual depth. First, the
limited diameter of the tube combined with the hammering technique either broke, crushed, or
displaced the oyster shell that is a primary constituent of the midden and many of the mounds,
leaving vacant areas in the tube. Indeed, some of the sections in shell-dense strata such as the
upper layers of Mound A were completely empty. Finally, upon extraction of a section, soil from
higher strata often fell to the bottom of the core creating “slough.” This fallback material was
identified by its disturbed, heavily mottled appearance, and loose unorganized structure.

To account for these issues, particularly compaction, a ratio-based calculation was
employed to approximate the depth and thickness of strata before compaction. For example, to
estimate the thickness of a particular stratum before compaction, I divided by the thickness of
this stratum in the core section by the total amount of soil in the tube, thus creating a ratio. Then
I multiplied the ratio with the depth of the core (i.e. the length of the tube), generally 116 cm, but
tubes were cut short in a few cases due to complications of the coring process. For example, if
Stratum II is 6 cm in thickness and a total of 42 cm of soil was recovered in a 116 cm tube then
the ratio is 6/42 or 0.14. The core length (116) is multiplied by the ratio (0.14) which produced
an estimate of 16.2 cm for the thickness of Stratum II prior to compaction.

The loose nature of slough indicates that minimal compaction is present and so this is
removed from the calculation. Limestone also compacts at a much different rate so is calculated
at a 1:1 ratio and that is factored into the rest of the calculation for the section. The compaction is
uneven among different soils and midden materials which must be considered, but overall this
formulation yields relatively accurate results, as indicate by comparing the results with soil
horizons of known depth. Similar calculations have been applied in shell middens in the Pacific
Northwest (see Cannon 2000). No corrections for compaction were applied to vibracore samples,
since the amount of compaction in a single section in the marsh is minimal.
Each section was sampled for texture, unless there was no soil present. Sampling for texture analysis consisted of 15 ml from each stratum. Thicker strata were sampled every 20 cm. Each sample was combined with 1 ml of dispersing reagent (sodium pyrophosphate solution) and 29 ml of water. After thoroughly mixing the components, the mixture was allowed to settle for thirty seconds. The fluid was poured into another test tube leaving behind the sand content. The material in the second tube rested for thirty minutes after which the fluid was again removed and poured into a third tube. The material remaining in the second tube is silt. The content of the sand and silt tubes were measured and converted into percentages by dividing by fifteen, the original volume of the soil sample. The clay content is determined by subtracting the volume of sand and silt from fifteen. I then applied the percentages to the texture triangle. The sand was collected and saved for analyzing grain size, roundedness, and frosting.

Following texture sampling, one cup of soil from each strata was collected for future testing, such as palynological analysis. The quantity of soil sampled is based on the guidelines provided by PaleoResearch Institute, Inc (Cummings 2007). All collection tools were cleansed between samples using distilled water to prevent contamination. These samples could also be used to perform methods excluded from this project due to budget constraints or inadequate equipment. This includes testing for phosphates, iron, magnetic susceptibility, soil organic matter, and carbonates.

Remaining soil from a stratum was then collected for screening. The volume and weight of sample were recorded prior to wet screening with 1/8" (0.32 cm) mesh. Artifacts and ecofacts were sorted and cataloged. Analysis of artifacts and ecofacts provides general information regarding cultural and temporal site occupation as well as ecological state. The volume and weight were used to calculate shell density within each stratum. In the profiles shell density
based on volume is labeled as abundant (> .75), common (.5 g to .75), occasional (.25 to .5), and rare (< .25).

Wood and charcoal were submitted to the University of Georgia for radiocarbon dating. Following the description and analysis of the stratigraphic data, specific strata were identified as related to discrete depositional events. Material suitable for dating recovered from these strata was then submitted for radiocarbon dating. Suitable material means that the wood and bone could be identified at the genus level or better. In the case of bone, samples were drawn from bone identified as terrestrial mammal, to avoid marine reservoir effects. Where no datable floral or faunal material was present, soil samples were used for radiocarbon dating.

Digital Elevation Models

The stratigraphic data provide a means of modeling landscape change. In order to visualize the transformation of the landscape through time a series of Digital Elevation Models (DEM) were created. Pluckhahn obtained LAS point files from the online database of the U.S. Geological Survey Earth Resources Observation and Science (EROS) Center (https://lta.cr.usgs.gov/LIDAR). According to the accompanying metadata, the LiDAR data for the Crystal River area were obtained by Woolpert, Inc., in 2006. Pluckhahn converted the LAS files to point features in ArcGIS and re-projected from the original state plane coordinate system to UTM (NAD83). Elevations (NAVD88) were converted from feet to meters. For manageability, the extent of the data was reduced to include the contemporary parameters of the Crystal River State Archaeological Park, some of the river, and a portion of the marsh west of the site, an area measuring about 500 m east-west and 750 m north-south. This area encompassed
roughly 500,000 bare-earth elevation points, but the coverage was uneven; Mound A, in particular, was poorly represented in the LiDAR coverage. Therefore, the LiDAR data were combined with about 18,000 elevation points collected with a total station (Pluckhahn et al. 2009; see Pluckhahn and Thompson 2012 for a summary of similar methodology applied elsewhere).

To model past land surfaces, I removed elevation points associated with the access road, the museum building, paved walking paths, and boat slip to more closely reflect the surface of the site prior modern disturbance. At this stage, I did not alter the elevations for the filled area east of Mound A; this surface is included in the modeling, as discussed in detail later.

This combination of data provides the basis from which all DEMs were constructed. The LiDAR and point data reflects the approximate surface of the site following the last of the prehistoric landscape modification. The LiDAR represents the terrain in great detail, but the file contains over 200,000 points making manual data input untenable for this project. Instead the 56 GeoProbe and GARI II cores represent the basis for interpolating the general stratigraphy. I used the LiDAR and total station point data to determine the surface elevations of the core points. Stratigraphic depths were then subtracted from the calibrated surface elevations.

The sampling design presents some problems with accurate interpolation. Coring was concentrated in the Feature B midden, the plaza, and the four potential platform mounds. The Main Burial Complex and Mound G were intentionally avoided thus creating a lack of stratigraphic knowledge of those areas beyond the rough descriptions established in previous excavations. Similarly, no stratigraphic data are present for the area covered by the museum. Finally, the limited quantity of cores skews the interpolation in some areas such as the marsh.
These issues were addressed through the creation of 68 "dummy points" based on estimated stratigraphic depths. These points were created to more accurately define the natural landforms of the extent. A majority of the points were created in the marsh to outline the change in elevation from the raised limestone outcrop on which the site rests to the surrounding, low-lying marsh. Similarly, I defined the riverbank by creating pairs of dummy elevations, one representing the land and the corresponding point marking the height of the water. The seawall report (Ellis 2006) shows that original bank extended beyond the current boundary, but that actual extent and slope to the water are unknown. Other dummy points were placed on the raised terrain of the site to smooth the interpolation and improve accuracy of the land form especially in the case of the area north and east of Mound A and the natural landform on which Mound H rests.

The process of creating an elevation for each point in the layer or strata of interest is a multi-stage process worked out in Microsoft Excel and ArcGIS 10. Each point is given an initial elevation in meters based on the elevation nearest to that point in the combined LiDAR and total station data. In some areas, I encountered an approximately 20 cm discrepancy between the surface elevations of the cores (as measured with the total station) and the elevation data, probably owing to issues with projection. To ensure continuity among manually created points, all initial elevations are based on the LiDAR values.

I defined several strata of interest to serve as references for modeling former land surfaces; these included the limestone substrate, the basal sand and clay soils, the stratum directly below the midden, and the surface of the final midden deposits. To illustrate the modeling process, consider the substrate, the geological limestone outcrop on which soil formed to create a an elevated landform fit for human occupation along the otherwise mostly low-lying
estuarine environment of the Crystal River. To model the surface of this substrate, I subtracted the depth to the limestone in our cores from the corresponding surface elevation. In cases where the cores did not reach limestone, I used the final depth of the core. In many cases, this depth is below sea level (in one case as much as 2.8 m below), resulting in a negative elevation value; to make modeling easier (i.e., to avoid having to interpolate negative values), I increased all the substrate elevations by 2.8 m so that the lowest point had a value of zero. Former marsh elevations were similarly calculated based on the maximum depth to the limestone for the soil series (Pilny et al. 1988).

*Calculating Midden and Mound Volume*

Determining the amount of material deposited in the midden and the non-burial mounds shows how much effort and resources were applied to these monumental features. Combining this information with radiocarbon dates facilitates a broad comparison of landscape modification and climatic conditions.

Pluckhahn and colleagues (2013, 2014) used the soil cores, excavation units, and radiocarbon dates to map the boundaries and thickness of the midden over time. Pluckhahn calculated the volume using ArcGIS to trace the feature's extent during four different occupational phases. The resulting area was multiplied by the average depth of deposits during each phase producing a volume measurement in cubic meters.

The volume of mound construction was calculated using the following formula for a truncated pyramid (Bronshtein et al. 2007):

\[
V = \frac{1}{3} \times h \times (B + \sqrt{B \times T + T}) = \frac{1}{3} \times h \times (a \times b + \sqrt{a \times b \times c \times d + c \times d})
\]
The basal and platform dimensions for each mound are based on the measurements described by Pluckhahn and Thompson (2009). The size of the platform is determined using the thickness of construction episodes and the current slope of the mound.

A few of the mounds required additional considerations for calculating the volume. Since Mound A is partially destroyed, I used Moore's (1903) measurement for the east-west side. The portions of Mounds J and K below the surface may be part of the greater midden or early mound building events as discussed in the following chapters. I included these areas as part of the mound volume. For these mounds I used the basal dimensions to calculate subsurface volumes. Applying the current slope of the mound to project the possible extent of subsurface dimensions was suspect. Mound J was particularly problematic because the long side measured over 55 m, which may overextend into the marsh. I chose the more conservative approach, but such considerations must be included for further investigations regarding the origins of these mounds.

The volumes from the midden and the mounds were used in conjunction with radiocarbon dates to plot the amount of material deposited over time. The resulting plot or curve was then compared to Marquardt's (2010:257) sea level curve based on Tanner's (1993:231) kurtosis values.

The volume for each construction or deposition episode was matched with the most compatible radiocarbon date. By this I mean that some radiocarbon dates fall into the middle of construction episodes, some dates are out sequence, and other episodes are undated. The time spans for these layers were estimated accordingly. In most cases the episodes spanned multiple centuries and so the corresponding volumes were divided appropriately. These estimates are reflected in the interpretation presented in Chapter 6.
Chapter 5

Results

I divided the following text into two majors sections, core descriptions and GIS modeling. The first part discusses the stratigraphy of the sampled features. In the subsections where we recovered multiple cores, representative examples are described with accompanying figures. I also include certain exceptions and anomalies from the general stratigraphy. All core profiles are available in Appendix 1. When describing specific cores, depths are provided in the adjusted measurement and the original section measurement. The latter is noted in parentheses. The second major section details the landscape recreations at key intervals in natural and anthropogenic site formation.

Results of Coring

The Plaza Area (Cores 23-29)

The seven cores from the plaza consist of only one or two sections. The cores taken from the northeastern and southern extents of the plaza each consist of two sections while the others are more shallow. In each location limestone is present within two meters of the surface. Shell is only present in only a single core (Core 28) which is on the southern edge of the sampled locations.

Core 24 is typical of the plaza area; Figure 5.1 illustrates the soil layers encountered in this core. The stratigraphy of the plaza area follows a general pattern of a thin, dark sandy loam
A horizon above a leached grayish sandy loam or loamy sand E horizon. The A horizon is black or very dark brown and reaches a depth from 7 to 21 cm below surface (cmbs). The leached soil incrementally ranges in color from dark gray/grayish brown to light gray/grayish brown and varies in depth from approximately 30 to 90 cmbs. In one case (Core 26) the A horizon is noticeably thinner (3 cm) and the gray soil is replaced by very pale brown 3 to 62 cmbs (78 to 95 cm in section 1). The pale brown soil is most likely recently imported fill soil used to level this area (Nick Robbins, personal communication, 2011).

The gray and grayish brown sand is underlain by a dark sandy clay loam horizon. This is followed by heavily mottled olive brown clay resting atop dissolving soft limestone that is white or pale yellow in color. The abrupt change in color to black or very dark brown, combined with a sudden increase in clay content to sandy clay loam, is consistent throughout the plaza cores. The surface of the limestone is present around 100 cmbs, but the constitution and rigidity fluctuate from solid crumbly rock to semi-fluid soft limestone mixed with clay.

There are two exceptions to this generalized description of stratigraphy in the plaza. The first exception is Core 25 (Figure 5.2), located in the approximate middle of the plaza. Here the soil consists of two separate black strata above white limestone. The second of the two black strata consists of loam which is uncommon compared to the sandy loam, sandy clay loam, and sandy clay observed across the plaza and throughout most of the site. This combination of color and texture may be indicative of a feature. This might be worth attention in future visits to the site.

Located on the southern end of the plaza, Core 28 is the only sample from this area containing shell. The shell bearing Strata II and III, which extend from 7-29 cmbs (51-64 cm in Section 1), are grayish brown sandy clay loam and dark gray sandy loam. While these layers
Figure 5.1. Profile of Core 24, Section 1.
Figure 5.2. Profile of Core 25, Section 1.

1: (A1) 10YR2/1 black mottled with gray particles, sand loam (56.7% sand, 26.7% silt, 16.7% clay)

2: (A2) 10YR2/1 black loam (50% sand, 33.3% silt, 16.7% clay)

3: (R) 10YR8/2 10YR8/2 white limestone mottled with 10YR2/1 black
contain shell, they do not match the midden strata present in Feature B. This may represent shell drift from the Main Burial Complex or Feature B.

The coring results support the identification of the area southwest of Mound H as a plaza (Bullen 1999 [1965]; 1966; Pluckhahn et al.2010). These types of features are most commonly bounded by mounds and other archaeological features, devoid of midden material, and sometimes bounded by waterways (Kidder 2004). The plaza at Crystal River is bounded to the northeast by Mound H, to the northwest by Mound G, and to the southeast by the Main Burial Complex. A ramp from Mound H leads directly to the plaza. The plaza is further bounded by the causeway connecting the two mounds (Bullen 1999 [1965]; 1966:862). Directly to the east of the plaza lies the edge of the site's landform and the neighboring swamp.

While these geographical characteristics were already known, the coring confirms that no midden material is present. The small quantities of shell were found in a single core on the southern edge of the sampling area. This likely marks the southern extent of the plaza, and may represent material displaced from excavations in the Main Burial Complex. The anomalous black loam located in the middle of the plaza is the only peculiarity identified in the cores. Kidder (2004) describes plazas as highly modified architectural features. Further assessment, such as soil chemistry studies, would be necessary to better interpret the types of activities that may have taken place on the plaza at Crystal River.

The Feature B Midden (Cores 4-11, 14-20, 30-31, 33-40, 45, 46)

As previously described, Feature B is a comma-shaped ridge extending from Mound J at the north, south to Mound A, and from there east for several hundred meters to the eastern edge of the park in the vicinity of the park ranger’s house. The western part of the ridge, between
Mounds A and J is higher and better preserved. Much of the ridge to the northeast of Mound A has been destroyed, but isolated prominences remain. On the eastern edge of the site, the park manager's house sites on top of another, larger isolated prominence.

The midden is commonly identifiable as a black or very dark brown sandy loam or sandy clay loam containing dense oyster shell fragments, similarly dense if less obvious fish and mammal bone, as well as some charcoal. Since non-mound coring was limited to three sections or less, and because the midden is about two meters elevation, most of the descriptions of the midden do not include limestone. The substrate is generally only observable along the boundary of the midden, most notably northeast of Mound K, near the low lying drainage area. Unlike the relative uniformity of the plaza, the midden stratigraphy varies considerably. My summary description here is structured according to three general areas with similar stratigraphy: the higher, western ridge; the isolated eastern extension of the midden in the area of the ranger’s house; and finally, the more poorly preserved area of midden between these other two areas.

Core 10 is typical of the stratigraphy on the western ridge (Figure 5.3). The western ridge of Feature B rises approximately 220 cm above modern sea level. A few centimeters of grass cover the A horizon, a very dark brown or black sandy loam that ranges from 60 to 110 cm below surface. The underlying E horizon is inconsistent in this area, typically appearing in various shades of gray and grayish brown sandy loam but white loamy sand is present in some cases. This slightly-leached soil layer extends to depths ranging from 70 to 120 cm below surface.

The gray E horizon abruptly changes to black midden soil. Scattered crushed shell fragments are present in the more recent A and E horizons, but the density is significantly higher in the midden strata.
Figure 5.3. Profiles of Core 10, Sections 1 (left), 2 (center), and 3 (right).
The total depth of the midden varies with undulations of the pre-occupation surface. The midden extends as far as 260 cm below surface and can exceed 150 cm in thickness. Throughout the midden several layers are present that differ in color value, shell density and size, and other faunal content. In Core 33, nearest to Mounds J and K, a layer of large fragments of oyster shell and minimal soil is the uppermost midden level. The base of the midden is defined by a change from rich black sandy loam to very dark gray sandy loam with the sudden absence of deposited shell.

Below the midden, the soil lightens in color from very dark gray to gray or even light gray before reaching mottled grayish brown sandy clay loam or sandy clay around 320 cmbs. This latter stratum is approximately 20 to 30 cm thick. White or light gray partially dissolved soft limestone underlies the sandy clay loam and sandy clay strata. Clay and limestone were observed around 200 to 220 cmbs in test units excavated in 2012 and 2013 (Thomas Pluckhahn, personal communication, 2014). This difference is most likely a product of the undulating terrain associated with a karst substrate.

The stratigraphy of the portion of the midden northeast of Mound A is considerably different from the western ridge. Figure 5.4 documents the stratigraphy of Core 40, which is typical of the area. Here the surface rises only about 1 m amsl. Light gray and light brownish gray sandy loam layers extend from the surface to between 20 and 40 cm. Below this, the organically-rich shell midden is present as black sandy loam or very dark gray sandy clay loam. The midden is around 40 to 50 cm thick, considerably thinner than the deposits of the western ridge. Excavation of a test unit in 2012 documented the fact that the midden in this area has been truncated by modern grading (Thomas Pluckhahn, personal communication 2014). Shell density is significantly lower on this portion of the midden, especially Core 40.
Figure 5.4. Profiles of Core 40, Sections 1 (left), 2 (center), and 3 (right).
Below the midden, leaching is present as the dark gray sandy clay loam gradually becomes light gray and white. The soil suddenly changes to brown sandy loam from 125 to 160 cmbs. This brown layer exhibits leaching, in one case fading to pale brown sandy loam before changing to light gray sandy clay loam at a little over 300 cmbs. The light gray soil extends to the bottom of the third section. In Core 40, which does not exhibit the leached stratum, light gray mottled with olive brown sandy clay loam marks the transition to clay soil around 190 cmbs. The layers then transition to grayish brown and gray sandy clay loam before reaching gray clay at 310 cmbs. Limestone is not present in any of the cores in this area, although the presence of clay suggests that limestone may be present within 4 m of the surface.

Contrary to these relatively thin midden deposits, the isolated high ground on which the park manager's house rests contains a thick midden layers that exhibits a high density of shell. Only one sample, Core 39, was collected from this area, at an elevation of approximately 150 cm amsl (Figure 5.5). Nearly all three sections are composed of shell midden soil. Below a 2 cm (49 to 51 cm in Section 1) layer of grass and organic material, the black sandy loam A horizon extends to 20 cmbs (51 to 61 cm in Section 1). Another black sandy loam layer, differentiated by its shell content, lies below the A horizon. A thin layer of very pale brown clay loam that contains no shell is present from 45 to 50 cmbs (75 to 78 cm in Section 1). Excavation of a test unit in this area in 2013 confirmed the presence of lenses of similar, lighter colored soils within midden in this area (Thomas Pluckhahn, personal communication, 2014).

Three distinct shell strata are below this unusual clay loam layer. Black sandy loam mottled with very pale brown extends to 80 cmbs (78 to 95 cm in Section 1). Black sandy loam without mottling is present until 127 cmbs (95 to 116 cm in Section 1 and 68 to 72 cm in Section 2). The final shell bearing stratum is very dark gray sandy clay loam that proceeds to 316 cmbs
Figure 5.5. Profiles of Core 39, Sections 1 (left), 2 (center), and 3 (right).
(72 to 116 cm in section 2 and 81 to 104 cm in Section 3). The upper part of this gray stratum could be an early leached midden deposit extending to about 231 cmbs. The lower part of the stratum appears less anthropogenic. This interpretation more closely supports the excavations by Pluckhahn and colleagues in 2013 where the midden was observed to a depth of about 200 cmbs. This suggests that at least two distinct midden deposition events occurred prior to the placement of the clayey soil, either as a capping mechanism or possibly historic disturbance during residential development. Below the midden is 26 cm (104 to 111 cm in section 3) layer of black sandy loam resembling a buried A horizon. The surface of the limestone is at 342 cmbs (111 cm in Section 3).

The Area of the Former Lagoon (East of Mound A) (Cores 1-3, 12, 41-44)

This area includes cores taken east of Mound A in what Bullen (1966:862) described as a filled lagoonal area. I anticipated highly mottled shell fill that would roughly correspond with the material observed in our core on the nearby mound. However, this was not the case. True to my expectations, each of the cores in this area contained some disturbed or recently-placed soils in the uppermost profile, but these soil layers did not clearly resemble the material we observed in Mound A. Instead of the sandy, shell-rich strata that predominated in Mound A, the disturbed soils here consisted mainly of yellowish sand and mottled gray soils with high clay content. The sand might be fill associated with the construction of the trailer park that stood in this area in the later twentieth century; a sandy overburden of this sort was observed in a test unit excavated in 2012 (Thomas Pluckhahn, personal communication 2014). Clay layers could be the result of inundation of this low-lying area during storm surges.
Below the recently disturbed strata is black midden soil that also has a suspiciously high clay content. This could represent intact deposits impacted by the movement of clay particles. Considering the presence of in situ midden along the river bank identified by GARI (Ellis 2006) midden in this area is not unexpected.

Core 12 is located in the center of eight cores taken from this area that definitely fall into the area described by Bullen (1966), and serves as a good example of the stratigraphy of the area (Figure 5.6). The top three strata are recently altered soils that include: light yellowish brown sand, mottled very dark grayish brown sandy clay loam, and very dark gray silt loam. Among these strata, shell is only present in the mottled second layer. These strata are clearly the result of modern disturbances.

Black midden underlies the disturbed strata, beginning at 60 cmbs and continuing to 230 cmbs. The top of the midden was certainly altered as a result of the landscape modification in the trailer park; the uppermost 40 cm contains a much higher silt content than is typical of the midden elsewhere, thus falling in the range of loam. These strata do not resemble material from Mound A.

A few scenarios may account for the presence of seemingly undisturbed midden. One possibility is that the lagoon was not always filled with water. During periods of lower sea level people may have deposited refuse material in this depression. Another conceivable explanation is that activities along the edge of the lagoon resulted in the deposition of organics, shell, and artifacts. The displacement of midden from Feature B could also account for these deposits.

The third and final section contains mostly light brownish gray sandy loam. Notably this core and Core 43 directly to the east do not have limestone in their lowermost sections. This is important because it exhibits a depression in the substrate located in the approximate area of
Figure 5.6. Profiles for Core 12, Sections 1 (left), 2 (center), 3 (right).
Bullen's lagoon (1966:862), a point I return to in the my description of the landscape reconstruction.

Cores taken west of the perceived depression exhibit a similar pattern. A thin horizon of recently deposited material is underlain by black shell filled sandy clay loam to about 150 cmbs. Shell remains present in very dark gray sandy clay loam for another meter. Below the shell is a more natural pattern of pedogenesis, where dark gray and grayish brown sandy clay loam transitions to gray clay. The limestone is present in Cores 1 and 2 at about 330 cmbs. Additional coring and modeling is necessary to delineate boundary of the lagoonal area with more precision.

Figure 5.7. Recovery of Core 3 in the lagoonal area east of Mound A.
**Mound A (Core 13)**

The sampling of Mound A consisted of a single core (Core 13) comprised of nine sections reaching an approximate depth of 10.5 m. Coring confirms that the shell is constructed of oyster shell and sandy soil that ranges from nearly pure sand to sandy loam. Strata are relatively thin (generally less than 30 cm) although large voids in the first (uppermost) few sections point to the possibility of extensive shell cap.

Examination of color and texture indicate that the mound was built in at least three major stages, not including earlier midden deposits which may be part of the larger Feature B (Figures 5.8-5.11). In contrast with my discussions of previous cores, where I proceeded from the surface downward, for the description of Mound A and other mounds I begin at the bottom and work up. No limestone is present in the Section 9 and only the bottom layer appears to be non-cultural. This stratum consists of a dark grayish brown sandy clay loam.

Shell on the top boundary of this soil horizon makes a transition to a probable cultural horizon at approximately 1030 cmbs (76 to 102 cm in Section 9). This possible cultural horizon consists of a black sandy loam with shell approximately 50 cm in thickness. In terms of color and the presence of shell inclusions, this horizon resembles the midden seen elsewhere on the site. At 980 cmbs (73 to 76 cm in Section 9) a thin layer of very dark clay was observed. The core also recovered a piece of wood at this depth. The wood fragment is circular, possibly as a result of human alteration in the past or maybe because of the coring process. The wood has been submitted for identification, but the results are not yet forthcoming.

The midden material above the clay layer is dark gray sandy loam containing shell. Ending at 922 cmbs (111 to 116 cm in Section 8 and 51 to 73 cm in Section 9), these layers
Figure 5.8. Profiles of Core 13, Sections 1 (left), 2 (center), 3 (right).
Figure 5.9. Profiles of Core 13, Sections 4 (left) and 5 (right).
Figure 5.10. Profiles of Core 13, Sections 6 (left) and 7 (right).
Figure 5.11. Profiles of Core 13, Sections 8 (left) and 9 (right).
become lighter in color and sandier than the deeper midden. The sand accumulation could indicate prolonged surface exposure between depositional events.

At 922 cmbs, the soil dramatically changes, becoming yellowish brown sandy loam with increased shell density. This stratum extends upward to 854 cmbs (88 to 111 cm in Section 8), thus extending roughly from 50 to 120 cm below the present ground surface surrounding the mound.

This layer is overlain by dark brown sandy loam and shell. These colors could represent an oxidized zone associated with a high-water mark. Similar colored soils are present in the lower strata of some of the Feature B cores. Most often these soils are clayey soils bordering the limestone.

The light gray of the final midden deposit is in stark contrast with brown soils below and the "clean" oyster shell above. Like the light gray strata previously mentioned, this may indicate an exposed surface during a hiatus between depositional events.

I use the term "clean shell" cautiously with respect to the monumentality debate briefly discussed in the first chapter. Midden soils associated with Feature B are often black or very dark gray sandy loam in texture and greasy to the touch. In addition to shell, these strata often contain bone albeit in varying quantities. The oyster shell stratum that signifies the first mound construction stage appears more or less white upon visual inspection and does not contain enough soil to even acquire a 15 ml texture sample. This stratum also contains no bone based on the screened samples. In short, this stratum consists almost entirely of shell. Other clean shell strata in this mound contain slightly more bone, but in weights of 0.06 g or less. For reference, higher bone dense strata contain around 0.5 g and one stratum near the bottom of Section 9 contains 2.39 g.
I postulate that these soil-less shell strata represent distinct and rapid mound construction events. These punctuated events were then followed by gradual accumulations of shell associated with the feasting or other food consumption practices operating at the site, as marked by their superposition by more mottled layers with more varied content, including more soil and bone. Alternatively, what I interpret as gradual accumulations on mound surfaces could represent construction using repurposed midden. However, this material is still much lighter in color, contains less organic material, and is more sandy in texture than the Feature B midden strata.

Following this logic, the stratigraphy of the core suggests a pattern of four mound construction stages, alternating between rapid construction and slow deposition associated with mound use (Figure 5.12). The first stage consists of oyster shell from 821 cmbs to 769 cmbs; as noted above, I assume this was deposited in a short time frame. This is followed by gradual accumulation to 701 cmbs. Extrapolating to the mound as a whole, this stage has a total volume of 1637 m$^3$, making up about 25 percent of the total mound volume (6959 m$^3$) (Table 5.1).

The second stage contains a relatively thin layer of oyster shell from 701 cmbs to 692 cmbs. This is overlain by a mottled layer extending to 674 cm that I interpret as a product of gradual accumulation. This stage represents only about 5 percent of the mound composition.

The third stage consists of a slightly thicker oyster shell layer from 674 cmbs to 656 cmbs, with another layer of probable gradual accumulation above this to 589 cmbs. The third stage represents comprises about 14 percent of the total volume of Mound A.

Finally, a layer of oyster shell is followed by mostly homogenous dark grayish brown sand and shell which makes up the remainder of Mound A. The final stage is makes up over half of the mound's volume. In the upper four core sections contained 60 cm or less shell and sand per
tube. There may be more mound construction boundaries obscured by the poor recovery of these sections.

![Figure 5.12. Cross section of Mound A.](image)

Table 5.1. Mound A Construction Stages by Volume

<table>
<thead>
<tr>
<th>Episode</th>
<th>Volume (m$^3$)</th>
<th>Percentage of Total Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1637</td>
<td>23.5</td>
</tr>
<tr>
<td>2</td>
<td>334</td>
<td>4.8</td>
</tr>
<tr>
<td>3</td>
<td>968</td>
<td>13.9</td>
</tr>
<tr>
<td>4</td>
<td>3984</td>
<td>57.3</td>
</tr>
</tbody>
</table>
**Mound H (Core 22)**

A total of four sections were collected from Core 22 in Mound H (Figures 5.13-5.14). Unlike Mound A, this architectural feature contains more sand relative to shell. The shell is primarily concentrated near the bottom and top of the mound. Similar to Mound A, the strata here are generally less than 30 cm thick. Most of the layers are light colored sand, loamy sand, and sandy loam soils.

The lowermost section did not reach the limestone substrate. However, the entire fourth section, as well as some of the third section, consist of non-cultural, sandy soils. These are probably eolian sediments that accumulated on the limestone substrate in the late Pleistocene, as indicated by an OSL date on sand grains (Hodson 2012; Pluckhahn et al. 2014).

Black sandy loam, present from 333 cmbs to 323 cmbs (109 to 113 cm in Section 3), lies on top of this sandy horizon, and probably represents the surface upon which the mound was constructed. This buried A horizon contains no shell or other artifacts and thus appears to represent a natural, rather than anthropogenic, soil layer.

The core stratigraphy suggests that Mound H was built in three major stages (Figure. 5.15). The first stage of mound construction consists of six mixed sand and shell layers with no clean oyster deposits. The initial building event ranges from 323 cmbs to 224 cmbs. There is a difference in 50 cm between the mound height as measured by Pluckhahn and Thompson (2009) and the mound height based on stratigraphy after adjusting for compaction. The first building episode accounts for nearly half of the total volume of the mound (Table 5.2).

The second construction stage of alternating white and light gray sand layers is unique to Mound H. The light gray layers are discolored by small pieces of charcoal which may be the result of ceremonial activities performed on the mound during the construction process, although
Figure 5.13. Profiles of Core 22, Sections 1 (left) and 2 (right).
Figure 5.14. Profiles of Core 22, Sections 3 (left) and 4 (right).
transported soils from elsewhere on the site must be considered as well. Overall, these sand deposits range from 224 to 94 cmbs (108 to 116 cm in section 1 and 69 to 110 cm in Section 2) and make up about 40 percent of the mound's volume.

The final construction phase is a return to mixed sand and shell and represents only 14 percent of the mound by volume. The composition and relatively small volume suggests that this is a capping event, perhaps to prevent erosion. The builders of Mound H showed an entirely different approach to the construction of monumental architecture as seen elsewhere on the site.
Unfortunately, it is impossible to gauge the reasoning behind such dramatic variation of mound construction techniques through coring alone.

Figure 5.16. Coring Mound H.

*Mound J (Core 32)*

Sampling of Mound J required five sections before reaching the limestone substrate around 530 cmbs (68 cm in section section 5) (Figure 5.17-5.18). The non-cultural stratigraphy is limited to approximately 30 cm of gray sandy loam and sandy clay loam at the bottom of Section 5. Above this, from about 497 to 336 cmbs (113 cm in section 3 to 46 cm in Section 5) and the composition is mostly very dark gray shell midden. Color changes of very dark brown (407 cmbs to 396 cmbs) (91 to 95 cm in section 4) and black (353 cmbs to 348 cmbs) (73 to 75 cm in
Figure 5.17. Profiles of Core 32, Sections 1 (left), 2 (center), and 3 (right).
Figure 5.18. Profiles of Core 32, Sections 4 (left) and 5 (right).
Section 4) may indicate subtle and brief changes in midden deposition. The dark midden comprises about 60 percent of the feature (Figure 5.19).

A clearer separation in deposition is apparent where two thin soil-less oyster strata are present at 336 to 328 cmbs (111 to 113 cm in section 3), and 300 to 272 cmbs (97 to 104 cm in section 3). The lower of the two oyster layers, Stratum X, contains no bone while stratum XI and IX contain 0.24 g and 0.45 g, respectively. The upper oyster stratum contains only 0.07 g of bone. The rapid deposition of shell and the absence of bone make this a curious component of this feature. This could represent a distinct midden event or possibly a very early mound that was later covered.

There is however, another oyster-rich stratum around 179 cmbs (105 cm in Section 2), a depth that corresponds much more closely to what could be considered the base of the mound from comparison with the surrounding ground surface. This upper oyster episode makes up a relatively small portion (10 percent) of the mound (Table 5.3). The strata above this point look similar to the gradual accumulation areas of Mound A based on the presence of sandy, relatively lighter colored soil accompanying the shell.

![Figure 5.19. Cross section of Mound J.](image)
Table 5.3. Mound J Construction Stages by Volume

<table>
<thead>
<tr>
<th>Stage</th>
<th>Volume (m³)</th>
<th>Percentage of Total Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>780</td>
<td>60.4</td>
</tr>
<tr>
<td>2</td>
<td>371</td>
<td>28.8</td>
</tr>
<tr>
<td>3</td>
<td>139</td>
<td>10.8</td>
</tr>
</tbody>
</table>

Figure 5.20. Coring Mound J.
**Mound K (Core 21)**

Mounds J and K share some similarities including their locations on the western midden ridge, their heights, and the presence of dense oyster shell. Additionally, both appear to have been constructed on top of midden, which in turn is underlain by the linestone substrate (Figure 5.21).

![Figure 5.21. Cross section of Mound K.](image)

A total of five sections were collected from Mound K (Figures 5.22-5.23). The fifth section encountered the limestone substrate at 550 cmbs (86 cm in Section 5). Non-cultural dark gray clay and grayish brown sandy clay loam rest atop the limestone. This is followed by very dark grayish brown sandy clay loam which contains shell, but does not resemble the midden seen in the following stratum or along the rest of Feature B. This could be a natural accumulation of shell or the product of vertical displacement of shell during the early formation of the midden.

The very dark, organically-rich soils more closely resembling that of cores in the adjacent midden are definitely present at 464 cmbs and continue until 306 cmbs (107 cm in Section 3 to 116 cm in Section 4), where rapidly deposited oyster shell is present. While this appears to be the earliest mound building event there is a 96 cm discrepancy with the surface elevation Pluckhahn
Figure 5.22. Profiles of Core 21, Sections 1 (left), 2 (center), and 3 (right).
Figure 5.23. Profiles of Core 21, Sections 4 (left) and 5 (right).
and Thompson (2009). This would seem to indicate that midden accumulated around the base of the mound.

Another dense oyster stratum is present at 232 cmbs (91 cm in Section 3). These two oyster-rich strata are separated by dark grayish brown and black sandy clay loam midden soil (Strata III and IV) suggesting expedient build up followed by a long hiatus where depositional patterns changed. This break could be the surface of the platform mound that was later capped by additional shell. Alternatively, these strata could be redeposited midden material.

There was limited recovery in the two uppermost sections of this core. Section 2 only had 13 cm of clean oyster and 10 cm of slough leaving the other 103 cm of tube empty. Section 1 contained only 17 cm of soil. These voids are attributable to the high density of shell in the uppermost layers of the mound; as I noted above, whole or mostly whole oyster valves are often pushed out of the way of the tube during the coring process, resulting in a reduced recovery. This could also account for some of the discrepancies between stratigraphic measurements and the external height of the mound; the greater the vacancy in the tube, the more likely there are errors when calculating the actual depths of the strata. These upper shell strata account for approximately forty percent of the total volume (Table 5.4).

Table 5.4 Mound K Construction Stages by Volume.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Volume (m$^3$)</th>
<th>Percentage of Total Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>716</td>
<td>46.1</td>
</tr>
<tr>
<td>2</td>
<td>225</td>
<td>14.5</td>
</tr>
<tr>
<td>3</td>
<td>611</td>
<td>39.3</td>
</tr>
</tbody>
</table>
Marsh and Swamp Stratigraphy (Cores 47-58)

Samples were collected using a vibracore off the limestone landform of the site in the marsh west of Mounds J and K and the swamp to the east and north of Mound H. Figure 5.25 depicts the stratigraphy of Core 48 located south of Mound K.

The vegetation in the western marsh consists primarily of tall, rigid marsh grass with no trees. The black organic-rich sandy clay loam covers very dark grayish brown and very dark gray sandy clay loam. Silt comprises nearly one-third of the soil composition. Shell is present in small and inconsistent concentrations in several cores in this area. This could result from natural deposition, runoff from the midden, or direct deposits of refuse.
Figure 5.25. Profile of Core 48, Section 1.
The northeastern swamp is considerably different as the area is forested and serves as a drainage for the encompassing higher ground. This marsh is impacted by recent modifications associated with road and residential construction. Figure 5.26 depicts Core 56 collected north of Mound H. The top stratum is a very dark brown sandy clay loam that extends approximately 6 cmbs (35 to 41 cm). Below this A horizon, slightly leached soils consisting of shades of gray sandy clay loam (Strata II and III). These layers are followed by brown sandy loam and loamy sand (Strata IV, V, and VI). The muckier soils overlying brown sandy soils may be a product of poor drainage caused by modern development. Around 66 cmbs (107 cm) the soil again becomes clayey. This black sandy clay loam is followed by pale brown sandy clay loam. This pale brown soil likely rests atop the limestone as seen in a few of the cores from the plaza.

GIS Modeling

The cores show a general stratigraphic pattern of limestone substrate, sandy clay, non-anthropogenic sand, and anthropogenic deposits. Interpolation using GIS allows for the mapping of these stratigraphic zones. The following DEMs approximately recreate the terrain at various stages in site formation. Specifically, I recreated four different surfaces, with an additional DEM with corrections for disturbance.

In these DEMs, I have held the water level static, showing the contemporary river bank. This is due to the uncertainties associated with the timing of the recreated surface and associated sea level reconstruction. Elevation is measured in meters from the lowest point on the surface of the limestone. Further investigations into the extent of the river bank and localized sea level reconstruction will greatly improve these visualizations.
Figure 5.26. Profile of Core 56, Section 1.
Figure 5.27. Vibracoring in the marsh.

*Limestone Substrate*

I begin with earliest, basal layer observed in cores, the surface of the limestone substrate (Figure 5.28). This represents the initial outcrop of the site during the Eocene prior to the accumulation of sand. Given the nature of limestone and the karst terrain, the substrate has almost assuredly changed due to exposure of water and acids. However, this still provides a
general picture of why soil accumulated and formed. Additionally, it lends some insight into why prehistoric inhabitants modified some parts of the site.

Two areas of noticeably higher elevation are present in the DEM recreation of the substrate from the coring data. One is the area encompassing the Mounds J and K, and the other is the northeastern part of the site in the areas of the plaza and Mound H. Low lying terrain running southeast to northwest divides the higher ground. East of Mound A is a very low, semicircular depression corresponding with the lagoonal area described by Bullen (1966).

**Basal Sand and Clay**

This DEM recreates the landscape surface after a period of soil formation that probably began after the limestone formed in the Eocene, which ended about 33 million years ago (Figure 5.29). This model is constructed of measurements to the sand, loamy sand, sandy clay, and clay layers that represent the early strata covering the substrate. These early soil deposits show how the outcrop was covered by eolian sand providing the basis for pedogenesis.

In the late Pleistocene the outcrop was covered by eolian sand. In this DEM, the two high areas expand in size, probably because the higher limestone outcrops served as traps for windblown sand. A ridge developed in the southern part of the site on some of the intermediate heights in the limestone substrate, perhaps for the same reason. The northeastern part of the site continues to expand entirely encompassing the location of the plaza. The location of Mound H lies just beyond the plateau of plaza, but above the swamp.

The most apparent change is the formation of a ridge that runs from the southeastern corner of the site northwest toward Mounds J and K. This slightly curved feature matches the
Figure 5.28. Limestone substrate DEM.
angle and location of the Feature B midden. This is the initial indication that these deposits were intentionally built on high ground.

In addition to the high ground, two areas of lower elevation are notable. The eventual location of Mound A is very low, suggesting that it was marshy and possibly even underwater at this time. Also apparent is the semicircular lagoonal area.

Pre-Midden

This DEM illustrates the accumulation of soil during the early and middle Holocene prior to anthropogenic modification (Figure 5.30). This recreates the uppermost surface of the sandy loam and sandy clay loam soils lying below the midden. In cores where no midden is present the strata that best match other pre-occupation layers were used.

In general, the terrain looks more similar to the current configuration of the landscape than the earlier models. The most notable difference over the earlier reconstructed surfaces is the bridging of the previously described higher areas.

This approximates the landscape as it would have been experienced by the first settlers at Crystal River. In this sense, it is interesting to compare with the later anthropogenic modifications. Perhaps not surprising, the residents of Crystal River chose natural elevations for the Feature B midden, as well as Mounds H, J, and K. Strikingly, however, Mound A would eventually be constructed beyond the natural, more elevated portion of the landscape, in an area of low-lying marsh.
Figure 5.29. Basal sand and clay DEM.
Figure 5.30. Pre-Midden DEM.
Post-Midden

The DEM in Figure 5.31 interpolates the uppermost surface of the midden, below the modern A horizon. It thus reflects the landscape at the end of prehistoric human occupation, after the midden was deposited. However, I have omitted the mounds.

The northwest-southeast alignment of the midden is present, but the midden extends farther to the south than mapped by Bullen. In this model, only the soil along the river has been adjusted for disturbed fill. Further corrections were necessary to account for the full extent of modern disturbance.

The final DEM is thus a second version of the post-midden DEM with adjustments to account for the in-filling of the lagoonal area east of Mound A (Figure 5.32). This was created to more accurately represent the landscape and to answer questions related to Bullen's (1966) description of a lagoon and the disturbance related to the trailer park.

The adjustments for disturbance along the river are based on GARI's sea wall report (Ellis 2006). The report estimated that fill and disturbed soil extended to approximately 50 cmbs and possibly deeper in areas to account for natural undulations (Ellis 2006). Results of coring confirm this description.

The elevations were corrected based on these considerations. This noticeably altered the model. With the corrections, the area east of Mound A is much lower, and the shape of the Feature B midden is present. This strongly supports Bullen's description of a lagoonal depression. The difference between the Pre-Midden and Post-Midden models indicates that the size of the depression decreased during the occupation of the site. While midden material was deposited throughout this area, site's residents did not attempt to entirely fill the depression. Instead, the shrinking of the lagoonal area is likely due to the horizontal expansion of the midden.
around the outer edge of the lagoon possibly coupled with lower sea level around the 500s, thus reducing the feature’s size. While coring and modeling reveals that Bullen's description of a lagoonal depression is correct, any use of this feature is unknown.
Figure 5.31. Post-Midden DEM without modern disturbance corrections.
Figure 5.32. Post-Midden DEM with corrections for modern disturbance.
Chapter 6
Discussion

The stratigraphic soil descriptions provide a basic understanding of how the site formed. The results reveal temporal shifts in midden deposition and mound construction. When entered into a GIS, the data may be used to model geomorphological and anthropogenic landscape changes. The relative temporal sequence derived from the stratigraphy is further enhanced with absolute dates. With the addition of calendar dates, landscape modification can be compared with sea level curves, climatic conditions, and other environmental circumstances.

Pluckhahn and colleagues have conducted extensive dating of mound and midden contexts at Crystal River and Roberts Island (2009, 2014; Pluckhahn and Thompson 2009) and the reader is directed to these sources for more information. The tables below summarize the results of midden and mound dating. In lieu of discussing individual dates, I employ the results of the Bayesian statistical modeling using OxCal 4.2 (©Christopher Bronk Ramsey 2013; Bronk Ramsey 2009). As discussed by Pluckhahn and colleagues (2014):

OxCal and other similar Bayesian statistical modeling programs calculate posterior probability densities for radiocarbon dates and other absolute chronological information based on a priori information (Bronk Ramsey 2009; McNutt 2013; Schilling 2013). Bayesian modeling used Bayes' Theorem, a theory that posterior probabilities are proportional to the product of an observed likelihood and prior probabilities. In phase modeling, the proposed phases are used as prior certainties and calibrated radiocarbon dates are observed likelihoods.
The phase based modeling of the midden is based on 24 radiocarbon dates and rates of shell and soil accumulation. Pluckhahn et al. (2014) describe four phases starting with the occupation of Crystal River and ending with the abandonment of Roberts Island. Table 6.1 summarizes the modeled start and end dates for these phases at 68 and 95 percent probabilities. The first phase consisted of limited deposition extending from below Mound J to north of the lagoonal area. The second phase represents a longer term of intensive landscape modification in which the midden expanded to the east. Only two dates from Crystal River and one date from Roberts Island compose the third phase. Both Crystal River dates come from the western portion of the midden. Minimal modification to the midden occurred during the final phase while the focus shifted to Roberts Island (Pluckhahn et al 2014).

Table 6.1. Estimated start and end ranges (at 68% and 95% probabilities) for phases of midden formation at Crystal River and Roberts Island (based on Pluckhahn et al. 2014). All dates are modelled cal A.D.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Start 68%</th>
<th>End 68%</th>
<th>Start 95%</th>
<th>End 95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>125-199</td>
<td>180-242</td>
<td>69-225</td>
<td>144-265</td>
</tr>
<tr>
<td>2</td>
<td>238-292</td>
<td>441-499</td>
<td>221-321</td>
<td>434-544</td>
</tr>
<tr>
<td>3</td>
<td>521-605</td>
<td>671-747</td>
<td>478-634</td>
<td>663-810</td>
</tr>
<tr>
<td>4</td>
<td>779-867</td>
<td>902-982</td>
<td>723-881</td>
<td>891-1060</td>
</tr>
</tbody>
</table>

The collection of soil samples from the mound cores provided a series of at least two radiocarbon dates per mound. Pluckhahn and I applied the same statistical methods as mentioned above to develop estimates for the stages of mound construction. As noted in the previous chapter, the stratigraphy of the mounds, and thus the reconstruction of mound stages, are not always clear. We made conservative estimates of the number of mound stages based on clear breaks in stratigraphy, but this clearly understates the potential complexity in mound
construction. In most cases, the dates from the mounds corresponded with their relative stratigraphic positioning, providing good agreement on the modelled stages of mound construction. Such was not the case, however, with Mound A, where the two dates from the mound—although not far apart chronologically—are inverted stratigraphically, resulting in a relatively poor model. In addition, one date from the uppermost layers in Mound H came back modern and was excluded from the modeling; the other dates from Mound H were more consistent with stratigraphy and the expected period of mound construction. Finally, it is worth noting that because these modelled stages of mound construction are based on fewer radiocarbon samples, the modeled phases have larger probability ranges than the phases of midden construction.

Table 6.2. Estimated start and end ranges (at 68% and 95% probabilities) for stages of stages of mound construction at Crystal River. All dates are modelled.

<table>
<thead>
<tr>
<th>Mound</th>
<th>Stage</th>
<th>68%</th>
<th>95%</th>
</tr>
</thead>
<tbody>
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<td></td>
<td></td>
<td>Start</td>
<td>End</td>
</tr>
<tr>
<td>A</td>
<td>2</td>
<td>cal AD 552-589</td>
<td>cal AD 565-601</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>cal AD 491-582</td>
<td>cal AD 526-586</td>
</tr>
<tr>
<td>H</td>
<td>2</td>
<td>cal AD 427-536</td>
<td>cal AD 451-557</td>
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<tr>
<td></td>
<td>1</td>
<td>cal AD 345-475</td>
<td>cal AD 392-500</td>
</tr>
<tr>
<td>J</td>
<td>2</td>
<td>cal AD 437-636</td>
<td>cal AD 591-755</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>100 cal BC – cal AD 46</td>
<td>cal AD 79-257</td>
</tr>
<tr>
<td>K</td>
<td>2</td>
<td>cal AD 386-490</td>
<td>cal AD 438-568</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>cal AD 229-372</td>
<td>cal AD 298-410</td>
</tr>
</tbody>
</table>

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The dates acquired by Pluckhahn and colleagues represent the first systematic attempt to provide a complete chronology from Crystal River. The earlier dates discussed in the second chapter derive from a variety of sources and often lack stratigraphic context and other provenience. Previous researchers relied on these dates as well as artifacts to establish a rough estimate of the site's occupation. The systematic dating isolates individual features along the site giving a better perspective of both occupation and landscape modification. Dates from previous investigations were included in the tables for Mounds A and H. The dates derived from OSL samples were also excluded from this discussion because the large margin of error produced with the results.

These dates combined with stratigraphic data allow for not only a chronology of the site, but also as a means of comparing individual features with each other. For example, the use of specific building methods changed over time and varied by mound. The resulting patterns indicate how these methods changed over time and what implications these methods may have on mound use.

The dates are also useful for a broader examination of landscape modification at the site with sea level curves, climatic periods, and other environmental information. I test my hypothesis by comparing sea level and climate change with the formation of the midden and the mounds. Since the dates above indicate that all landscape modification occurred in two climate periods, the Roman Warm Period and the Vandal Minimum, I structure the discussion around these episodes. In the first part of each section, I present relevant contextual information about sea level, climate, and other environmental conditions. I then discuss landscape modification at the site with this frame of reference to assess the validity of my hypotheses.
Roman Warm Period (350 B.C. to A.D. 500)

The earliest dates associated with midden formation indicate that the occupation of Crystal River began around the mid-second century A.D. Pluckhahn and colleagues (2014) refer to Phase 1 as beginning between cal A.D. 125 and 199 with a termination between cal A.D. 180 and 242 with a 68 percent probability. This places the site's settlement approximately halfway through the Roman Warm Period, which is described as a period of higher than present sea level.

Tanner's proxy sea level curve projects sea level rise as steadily increasing to a peak around A.D. 200 (Marquardt 2010:257; Tanner 1993:228; Walker et al. 1995:215). Balsillie and Donoghue's (2004:14) curves show a consistent rise reaching approximately 1 m above contemporary MSL. Stapor and colleagues (1993:835) postulate that sea level exceeded modern conditions by 120 cm during the Wulfert High (A.D. 1 to A.D. 400). Walker and colleagues' (1995:215) modified record suggests that sea level was around 30 cm below current MSL in southwestern Florida, projecting a later start to the Wulfert High. This may more closely represent the situation at Crystal River than the global sea level reconstructions. The lower levels of units excavated in 2012 and 2013 were routinely exposed to tidal inundation (Thomas Pluckhahn, personal communication 2013). These earliest deposits are approximately 100 to 150 cm below the modern ground surface. Although some subsidence has likely taken place, it seems likely that sea level was significantly lower than present when Crystal River was first occupied. This is consistent with Sassaman and colleagues (2011) investigations at Little Bradford Island in the Suwannee River Delta.

The earliest dated material comes from Mound G and the Main Burial Complex and ranges from 800 to 420 cal B.C. and 780 to 420 cal B.C., respectively (Pluckhahn et al. 2010).
This may represent an early ceremonial use of the site prior to the Roman Warm Period. Modification to Mound G continued based on a date from 90 cal B.C. to cal A.D. 120 (Pluckhahn et al. 2010). These dates are worth noting, but I do not extensively discuss the burial features due to a lack of systematic dating from reliable contexts and a poor stratigraphic record.

The earliest dates from non-burial features come from Mound J and the northwestern portion of the Feature B midden (Table 6.2). The lowest stratigraphic date from the mound ranges from the late first century to the early third century. The second sample taken from a higher stratigraphic unit indicates a date around the start of the first millennium A.D. If both date ranges are accurate than this shows the redistribution of midden material. However, this sample has a noticeably higher $^{13}$C fractionation, which may represent complications from postdepositional processes.

This further confounds the interpretation of the origins of Mound J. The lowest potentially anthropogenic horizon contains shell without the organically rich dark soil observed throughout the midden. This may represent early midden deposits where the associated soils were transported by alternating water levels. Alternatively, this may represent an early mound construction episode. This would further the support the earlier date seen in the higher stratigraphic layer. In this case Mound J would represent a feature continually modified from the earliest occupation of the site through the later periods of landscape modification.

Stage 1 has a calibrated median range of 27 B.C. to A.D. 168 at 68 percent probability. Mound building episodes are evidenced by the rapidly deposited shell layers containing little soil seen higher in the stratigraphic profile. This interpretation suggests that mound construction occurred much later in the occupation of the site, around the late sixth or early seventh century A.D. Stage 2 is modeled from cal A.D. 537 to 673 with 68 percent probability.
The second stage of midden formation appears to represent a period of intensified use of the site possibly associated with higher population (Pluckhahn et al. 2014). The sampled area of Feature B shows a consistent pattern of deposition to about cal A.D. 400 or 500. A tight grouping of dates suggests that the midden formation was particularly rapid from cal A.D. 250 to 400 (Pluckhahn et al. 2014). At least 41 cm of material accumulated during this span. The formation slowed significantly afterward with only 10 cm of material in one to two hundred years.

The earliest date from Mound K comes from a buried surface below the first predominantly oyster stratum. No dates are currently available for the earliest deposits of midden below this mound although they likely coincide with the earliest formation of the midden of Feature B and below Mound J. A transition from midden accumulation to intentional monument construction is marked by the presence of rapidly deposited oyster shell. Radiocarbon samples indicate that this shift occurred during the fourth century. The two radiocarbon dates suggest that construction of Mound K occurred entirely during the second phase with the final construction episode taking place around the beginning of the sixth century.

Although Mound H appears to have been constructed during a subsequent phase, a radiocarbon date from what is believed to be a pre-mound layer indicates that some activity was taking place in this area in Phase 2. The dated soil layer does not contain the shell or other cultural material observed in the midden, but contains a significant amount of organic material. Instead of mollusk feasting or refuse disposal, other activities may have been performed at this location. This area may have been part of the plaza. Another possibility is that the area was prepared for mound construction at this time.

The stratigraphically and chronologically earliest radiocarbon date from Mound H falls in the range of cal A.D. 430 to 540. This date comes from a sand layer deep in the mound.
However, we cannot rule out a slightly earlier date to the initiation of mound construction, as there was variegated fill representative of mound construction below this dated soil layer. Further, a thin brown stratum below this dated stratum could indicate a buried surface resulting from a significant hiatus in mound construction, thus accounting for the relatively lengthy gap between the pre-mound surface and the second construction phase. Close correspondence between the aforementioned date from lower levels within the mound and a date on bone from a depth of 1-2 feet in Bullen’s trench suggest that the rest of Mound H was constructed in relatively rapid succession, if not as a single episode, between around cal A.D. 420 and 600 (Pluckhahn and Thompson 2010), towards the end of the Roman Warm Period or in the beginning of the Vandal Minimum. This is supported by the modeled ranges which show Stage 1 from cal A.D. 410 to 446 and Stage 2 from cal A.D. 482 to 504.

Around this same time, the residents of Crystal River also began expanding the midden ridge south toward the river, in the area below where Mound A would soon be built. Referring to the pre-occupation DEM, Mound A was constructed on low lying marsh terrain just south and west of the site's raised limestone platform. Around a half a meter of soil and shell accumulated in this low marshy area. This sort of dumping is not present elsewhere in the surrounding marsh or swamp. No other monumental feature was built off the limestone rise, which suggests that this area was intentionally filled. Combined with the declining water level, inhabitants built up this location as it dried making it suitable for mound construction.

This period of increased landscape modification occurred during the general sea level decline in the last few centuries of the Roman Warm Period. Both Tanner's curve and the 7-point floating average curve indicate that sea level declined during the third century, but they differ with regard to the severity of this decline. Tanner's curve shows that sea level declined only to
briefly increase again at the start of the fourth century (Marquardt 2010:257; Tanner 1993:229). Balsillie and Donoghue’s curve simply shows a general decline around the mid-third century that continues into the Vandal Minimum.

While the general curves indicate a decline in sea level, archaeological investigations at several coastal sites suggest instead higher sea level at this time. Walker and colleagues (1995) found evidence of MSL ranging from 70 to 150 cm above current conditions from A.D. 200 to A.D 650. The variation between Tanner’s curve in northwestern Florida and analysis of sites in southwestern Florida led Walker and colleagues (1995) to suggest that the decline in sea level associated with the Vandal Minimum occurred later and in a narrower time span in southwestern Florida.

Discrepancies such as these, as well as the variability that might be expected locally, make it difficult to assess sea level at Crystal River during this time. However, there is no evidence that water levels around Crystal River increased significantly during the Roman Warm Period. This appears consistent with ongoing work in the Suwannee River Delta where sea level rise appears to be much less dramatic than in southwestern Florida (Sassaman et al 2011).

Pollen samples from the midden provide additional insight into environmental conditions of Crystal River during this episode. Arboreal composition is mostly pine with some oak (Cummings and Varney 2013). Weedy plants with particularly high concentrations of what is possibly amaranth or goosefoot grew in the area (Cummings and Varney 2013). The presence of scrub buckwheat which grows in oak-hickory scrub and pinelands at higher elevations and in dryer conditions is the only oddity (Chafin 2000). The nearby marsh contained common or broadleaf cattail (Cummings and Varney 2013). Overall, these species reflect the anticipated
conditions associated with the Roman Warm Period and relatively high sea level, with extensive marsh formation in the immediate environs of Crystal River.

*Vandal Minimum (A.D. 500 to A.D. 850)*

The sixth century marks the start of a roughly 350 year global cooling period known as the Vandal Minimum (Marquardt 2010:257). This coincides with Tanner’s data that shows a start of a dramatic decline in sea level until A.D. 700. Balsillie and Donoghue’s curve exhibits the same general pattern (2004:14). Sea level dropped at least 50 to 60 cm below current conditions and possibly more (Balsillie and Donoghue 2004:14; Walker et al. 1995).

However, investigations at finer scales show variability during the Vandal Minimum. The species distribution of migratory ducks and mollusks points to a period of warmer temperatures and increased precipitation from A.D. 600 to 650 (Wang et al. 2011). This brief warm spell gave way to a second cooling period that lasted until A.D. 700 (Wang et al. 2011). Droughts also plagued southwestern Florida through the mid-eighth century (Walker 2000; Walker et al. 1995; Wang et al. 2011). A gap in the archaeological record of the Calusa from A.D. 750 to 850 has lead researchers to speculate that much of the area was abandoned due to these drastic conditions (Wang et al. 2011).

Many scholars note A.D. 536 as the actual beginning of this climatic episode, based on historical records worldwide that describe a persistent dense fog, reduced sunshine, and snowfall in the tropics (Gunn 2000; Walker 2013). Increased presence of predatory gastropods in southwestern Florida supports cooler temperature and lower sea level around this time (Walker 2000). Investigations into otoliths and duck remains in southwestern Florida indicates not only
cooler winters, but dryer summers (Wang et al. 2011). With these environmental and climatic shifts, the Calusa culture dramatically changed with the use of new technology and the creation of ceremonial mounds (Walker 2000).

Unfortunately, central Florida lacks a well-developed paleoclimate record for this period. A pollen sample from a stratigraphic layer at Crystal River dating to the Vandal Minimum indicates slight changes in flora, but these may be as related to human occupation as climate change. Samples indicate the presence of oak and basswood trees (Cummings and Varney 2013). These trees are more drought resistant and adapted to higher elevations and thus more accustomed to less precipitation and lower sea level (USDA, NRCS 2014). However, the use of the acorn as a source of food leaves the possibility that the growth of oak trees was encouraged by the site's occupants. Non-arboreal plants included the same weedy plants in slightly lower quantities with much higher growth of grasses (Cummings and Varney 2013). Interestingly, no scrub buckwheat appeared in the midden from this time despite the presumably dryer conditions. In the marsh, narrowleaf cattail replaced the broadleaf variety (Cummings and Varney 2013). Since both species have their adaptive advantages, it unclear if this change resulted from climatic conditions or general competition (USDA, NRCS 2014).

Although we currently lack the finely detailed climatic record that has been developed for the Vandal Minimum in southwestern Florida, it is nevertheless apparent that Crystal River experienced dramatic changes in landscape modification during this period. Phase 3 (cal A.D. 521-605 to cal A.D. 671-747) concurs with at least the first half of the Vandal Minimum (Pluckhahn et al. 2014). The accretion of Feature B slowed significantly during this time, with the deposits concentrated on the western end of the shell ridge (Pluckhahn et al. 2014).
However, while the midden data suggest a contraction of settlement and a decline in the resident population, mound construction continued, and possibly even intensified. The construction of the upper two-thirds of Mound K likely occurred during the Vandal Minimum. A buried surface over 2 m below the summit dates to the cal A.D. 400s or early 500s, around the boundary of climatic episodes. Stage 2 of Mound K is modeled at cal A.D. 438 to 503. The upper portion of the mound consists of mostly oyster shell with minimal soil indicating relatively continual and rapid deposition. Radiocarbon dating and the corresponding modeling indicate the completion of the mound sometime after the late cal AD 600s, corresponding with the middle to late Vandal Minimum.

The construction of Mound H through the deposition of sand may have continued into the early sixth century. At some point, construction methods changed again as nearly a meter of shell with some sand was used to complete the mound. This final capping phase was likely performed quickly to preserve the shape of the sand mound. The absence of buried surfaces further supports this interpretation. The end date range (cal A.D. 451 to 557) and the dated bone (cal A.D. 420 to 600) (Pluckhahn and Thompson 2010), provide evidence that the mound was completed during the early Vandal Minimum.

As Mound H neared completion, builders shifted focus toward the construction of Mound A. In the fifth century, the site's occupants deposited a great deal of shell in the marshy area where Mound A was later erected. This may have been the result of passive refuse disposal, intentional expansion of Feature B, or an intentionally prepared surface for mound construction. I support the latter interpretation because there is currently no evidence of other shell deposits in the marsh. This modification also corresponds with the end of the Roman Warm Period during a global decline in sea level. There is little evidence of dramatic sea level change in the area during
the site's occupation, but even a small change in MSL could significantly influence the tractability of the marsh. This may be the case with other heavily modified marsh island sites. The earliest deposits on Roberts Island date to Phase 3 (Pluckhahn et al. 2014).

Regardless of the intent, construction of Mound A began on this artificially raised surface in the early Vandal Minimum. The first act of mound construction consisted of a placing a thin layer of clay and possibly wood over the midden surface. The erection of the mound proceeded with layers of mixed sand and shell during the first episode.

There is a discontinuity in the two later radiocarbon dates from Mound A. The radiocarbon sample from the middle of the mound dates to the early cal A.D. 600s. This strata lies 5 m below the summit, showing that a considerable amount of construction occurred beyond this point. However, the date closer to the summit chronologically conflicts with the lower sample. If the upper date is the more accurate one, then that means all but 3 m of the mound were constructed in less than a century. This is plausible, but I speculate that the lower date is more accurate and older shell and sand were used to construct the final few meters. At the very least, the radiocarbon dates suggest that inhabitants constructed the mound between the mid-fifth and mid-seventh centuries. Modeling projects this stage ranging from cal A.D. 571 to 583.

We can say that the first construction phase fell in a narrower window between the late fifth century and the end of the sixth century. This stage, which was comprised of a combination of shell and dark sandy loam soil, rose approximately a meter and a half above the original midden surface. After this point, mound construction shifted to alternating layers of pure shell with layers of mixed shell and sand. The shell and sand mixture looks very similar to the final construction phase of Mound H, suggesting these constructions were close in time or perhaps even simultaneous.
Landscape modification at Crystal River ceased following the completion of the great platform mound. Beyond this point, it is unclear what role the site held in the region. Evidence suggests that the occupation of Roberts Island began around the mid-seventh century (Gilleland 2013; Pluckhahn et al 2014). The construction of two or three mounds at this site clearly shows that, in contrast with the Calusa area, the practice of monumental architecture was not abandoned during this time. However, it is conspicuous that settlement shifted west at the same time MSL lowered significantly and drought conditions prevailed. At this point, Crystal River may have become a mainly vacant ceremonial center.

*Medieval Warm Period (A.D. 850 to A.D. 1200)*

Sea level stabilized in the late eighth century sea level and began rising around the start of the ninth century (Balsillie and Donoghue 2004:14; Marquardt 2010:257). The Medieval Warm Period is marked by a return to roughly modern sea level and temperatures as warm as or warmer than present (Foster 2012; Walker 2013). The dating of this climatic episode remains a contentious issue, with the beginning placed somewhere between A.D. 800 to 900 and the end around A.D. 1200 to 1300 (Gunn 1994; Marquadt 2010:257; Walker 2013). The correlation between warm temperatures, widespread application of agriculture, and increased monumental construction throughout the Mississippi Valley and southeastern North America have been widely noted, with some researchers going so far as calling this time the Mississippian Optimum (Anderson 2001; Gunn 1997; Walker 2013).

Phase 4 of midden formation corresponds of the end of the Vandal Minimum and the first half of the Medieval Warm Period. A single radiocarbon date from Feature B occurs in this
phase (Pluckhahn et al. 2014). Aside from this one date, this phase is defined by the construction of the dense shell midden and two shell and shell mounds on Roberts Island (Pluckhahn et al. 2014). The modification and intensive use of Roberts Island was relatively short-lived concluding sometime before cal A.D. 1050.

It is unclear why these sites were abandoned and how much climate and sea level influenced these decisions. Crystal River's abandonment coincides with the end of the Vandal Minimum and the associated lower sea level and cooler temperatures. The movement westward to Roberts Island makes sense if brackish and marine resources also retreated westward with a decline in MSL. The departure from Roberts Island during the middle of the Medieval Warm Period is more perplexing. No signs of dramatic sea level rise at Crystal River are present suggesting that Roberts Island was likewise not heavily impacted by higher MSL. If such a transgression affected the island one might expect to see a continued occupation at Crystal River. Instead both sites were abandoned. There is some evidence of a Safety Harbor component elsewhere in the estuary, but little is known about this occupation and it does not appear to have the same scale as Crystal River or Roberts Island (Gary Ellis 2014, personal communication). What happened to the people of this region is unclear. One of the many possibilities is that the population moved inland and adopted agriculture as seen elsewhere in southeastern North America during this time.

*Modeling Landscape Modification and Climatic Conditions*

To briefly summarize, the formation of the midden and mounds at Crystal River corresponds with two major climatic episodes, the Roman Warm Period and the Vandal
Minimum (Figure 6.1). It is unclear exactly how long the region was occupied during the subsequent Medieval Warm Period, but landscape modification at Crystal River during this episode was minimal; more landscape modification took place at Roberts Island.

![Figure 6.1. Landscape modification by volume compared to sea level change.](image)

Pluckhahn and colleagues (2014) suggest that the midden grew rapidly at Crystal River during their first and second phases, corresponding with the Roman Warm Period. The rate of accumulation in Feature B declined significantly during Phase 3 with the last date coming from early in Phase 4 at the very end of the Vandal Minimum (Pluckhahn et al. 2014).

Construction of the non-burial mounds began during the Roman Warm Period. This includes the first building stages of Mounds H, J, and K. Towards the end of this climatic episode a marshy area on the southwest edge of the site was filled with midden material.
Midden deposition waned in the Vandal Minimum, but monumental construction continued as the later stages of Mounds H, J, and K were completed. Mound A was likely constructed entirely during this episode. Radiocarbon dates and similar mound composition indicate that the completion of Mound H and the erection of a large portion of Mound A happened concurrently. By the beginning of the Medieval Warm Period landscape modification at Crystal River ceased and all resources were focused on nearby Roberts Island. Ultimately, these mound centers were abandoned by A.D. 1050 during the middle of the Medieval Warm Period.

Since landscape modification clearly spans at least two major climatic episodes, one ostensibly more favorable for population growth and social complexity than the other, the concept of site formation dependent on climatic conditions alone is rejected. The term "optimum" is often applied to warmer and wetter climatic periods, suggesting that these are spans of time with conditions in which populations around the world prospered. These names can be misleading, as they are often associated with historical events and periods such as the rise and fall of the Roman Empire as depicted by the terms Roman Warm and Vandal Minimum.

The archaeological record at Crystal River shows that warm periods are not necessarily the most opportune times for inhabitants. Based on climate alone, an argument could be made that colder and dryer conditions were more opportune around Crystal River. Cooling episodes correspond with lower sea level. Even a slightly lower sea level around Crystal River could make the marsh islands more suitable for habitation and landscape modification. The sea levels associated with climate episodes are more impactful on coastal Florida than temperature alone. I hesitate to say the same about precipitation given the limited records available at this time.
The occupation of Crystal River continued into the Vandal Minimum, but the comparison of landscape modification with sea level reconstruction exhibits some correlation. Most apparently, use of the site is ceased around the same time as the nadir of the Vandal Minimum. The simplest explanation is that ultimately changes in sea level and ecological conditions forced the population to move farther toward the Gulf. However, such a basic explanation discounts the role of human agency within the environment. The movement to Roberts Island required a tremendous amount of effort to transform a marsh island into a substantial landform bearing two monumental features. This shows that these people were quite capable of actively modifying their environment.

At Crystal River the construction of mounds may show another way that humans responded to environmental change through the manipulation of their landscape. The late Roman Warm Period and early Vandal Minimum marked the transition from intense midden deposition to mound construction. The burial features established the precedence for mound building at Crystal River, but the function of the platform mounds and the more ambiguous mounds J and K is considerably different. A shift in the feature development may signal a reorganization within the society as a response to a changing environment. In other words, these people altered their own cultural-landscape as a means of adapting to their broader environmental-landscape. A remobilization of labor may have proved especially useful at Roberts Island where landscape modification included the construction of a landform suitable for ceremonial or habitation purposes.

The rate at which such a shift in landscape formation occurred is worth an examination because it involves another consideration mentioned in my research design, punctuated sea level change or other climatic events. Such sudden events are more likely to impact ecosystems and
unprepared human populations and thus must considered (Sassaman et al. 2011). At the moment there is no evidence of punctuated events during this time either in the stratigraphic record or the insufficiently low resolution sea level reconstructions currently available.

The limited evidence currently available indicates that the sea level transitions were likely gradual and minimally disruptive to the inhabitants and aquatic ecosystems upon which they relied. There is no evidence of significant declines in the oyster population which might indicate ecological instability. If the move from Crystal River to Roberts Island is related to sea level decline, then occupants had ample time to establish a new complex while finishing architecture on the older one. A shift from midden deposition to mound constructed happened over the course of multiple generations.

Another consideration is the resiliency of the local population and the strategic location in the estuarine system. The diverse faunal assemblage observed at both Crystal River and Roberts Island (see Gilleland 2013) indicates that inhabitants had an abundance of subsistence sources from which to choose. They may have focused on terrestrial and aquatic creatures less impacted by ecological shifts. The rivers also provide greater access to more distant settlements. Cooperation with other populations could mitigate resource inadequacies. Examples of changes in diet and connections with external populations can be seen in southwestern Florida (Marquardt and Walker 2012). Inter-societal interaction is not mutually exclusive of landscape modification either as Widmer (2004) describes mound construction as a form of regional signaling.

This discussion shows that overall landscape modification at Crystal River was not restricted to particularly warm or cool episodes and the corresponding sea level changes. There is, however, a shift in the type of landscape modification from general accumulation to apparent
monumental construction around the time of changing climatic episodes. During the early Medieval Warm Period the site was abandoned in favor of Roberts Island. While this is conspicuous, it unclear if this was precipitated by changing climatic conditions. The earliest midden deposits at Roberts Island suggest that the site was settled during slightly lower sea level, but movement between sites occurred as MSL began to rise to about the modern level. Why would people move towards the gulf when sea level is rising? This may be an indication that sea level change along the Crystal River occurred at a different rate or timeframe than the reconstructions derived from other areas of the Gulf of Mexico.

The reason for the abandonment of Roberts Island and consequently the region is even less clear. If the adoption of agriculture is the reason for the mass exodus in the Medieval Warm Period, then additional factors such as population size, resource management, and the influence of outside cultures must be considered as variables in addition to climatic conditions. In the following chapter I discuss the possibility and necessity for additional research to address the plethora of questions and considerations regarding the people of Crystal River and their interactions with the local and broader environment.
Chapter 7
Conclusion

The interpretations resulting from this research show that landscape modification at Crystal River cannot be modeled on the basis of climatic conditions and the corresponding sea levels alone. A majority of midden accumulation occurred during the Roman Warm Period, while most of the construction monumental architecture coincides with the Vandal Minimum. This shows that a simple change in climate condition did not cause an immediate abandonment of the site, but rather a reorganization of how the landscape was modified. The later stages of mound construction occurred concurrently with the initial development of Roberts Island suggesting that these people were not simply reacting to their environment. The people finally abandoned Crystal River during Medieval Warm Period; a time when many societies throughout the Southeast flourished. This raises questions about local variation in sea level as opposed to the reconstructions from other parts of the Gulf of Mexico. In lieu of a simplistic single variable model, a multitude of variables must be considered such as internal socio-political reorganization, local variation in environmental conditions, the resiliency of people, and external relationships.
Limitations and Future Research

As is the case in nearly all archaeological contexts, more data equal more refined interpretations. More data could derive from the existing collection of soil samples, as well as, the acquisition of additional samples from the site. The stored soil samples should be subjected to additional geoarchaeological methods such as magnetic susceptibility, soil organic matter, carbonates, and especially phosphates. The latter technique could further enhance the analysis of exposed surfaces when describing mound construction.

Additional coring and corresponding excavations would certainly improve the resolution of the soils across the site. This project is based primarily on the analysis of the stratigraphic record as identified and analyzed using soil cores. This method is minimally invasive, but also provides only a small window into an extensive terrain. This is especially the case with the mounds where a single sample was used to defined building episodes and interpolate sub-ground surface strata.

Interpolations require some degree of estimation where performed mathematically or logically. Higher resolution sampling yields higher resolution results. This is especially noticeable in the creation of the DEMs. Additional sampling could further improve the gaps and reduce the amount guesswork applied to mapping process. The burial mounds represent the most obvious holes and exclusions in the DEMs. I understand that invasive methods are unlikely to be applied to the burial features anytime soon, but it must remain at least a consideration.

The work by Pluckhahn and colleagues over the past six years has resulted in a tremendous improvement in the production of radiocarbon and other absolute dates. This project would be essentially impossible without such a high resolution. More dating from the mounds
using existing soil samples and the acquisition of more soil samples can only refine our understanding of the construction episodes of monumental features at Crystal River.

I had the privilege of taking part in the first comprehensive surveying and testing of the Roberts Island site and the results produced by Pluckhahn, Thompson, Weisman, Kassie Kemp, and Sarah Gilleland all greatly aided in the interpretations discussed in this paper. Since my time there, limited shovel testing has occurred on other marsh islands in the estuarine system. Further testing is needed in this area to provide a better understanding of the relationships among occupants of this region and to provide more information about the population movements prior to and after the Woodland Period. Chapter 6 ends on a cliffhanger regarding the abandonment of two mound complexes. What happened to these people? For that matter, where did they come from?

The most important vacancy in my research is the lack of environmental data. In Chapter 3, I mentioned many of the flaws with current sea level curves. Further coring in the marshes and waterways along the entire Crystal River and the adjoining coastline is necessary to establish a localized context for how changes in MSL impacted this particular estuary. Variables such as hydrology, geology, geomorphology, and sedimentation must be incorporated into modeling sea level change on local scale.

Benefits

This research did not produce a clear-cut model for human-environmental interaction at Crystal River, but it took the first steps towards addressing such expansive topics. In the process of examining my research questions an abundance of processed and unprocessed data were
produced. Stratigraphic information is now available for most of the site. Coring the non-burial mounds provided access to the composition and building episodes enhancing future studies of monumentality at the site and throughout the region. Subsurface mapping now exists for the site contributing to the geological, as well as, the anthropological interpretation of site formation. The maps and the other associated geovisualizations that have resulted from the project can greatly enhance the way archaeology is presented to the public in an increasingly technological perspective.

This research also refines the interpretation of the prehistoric people of this area as active agents interacting with their environment. Environmental determinist views depict hunter-gatherers as products of their environment. This perspective completely ignores the other half of the story where human both intentionally and unintentionally modify their environment on multiple scales. By testing my hypothesis I showed that people are not reliant on "optimal" conditions for settlement growth, the construction of monumental architecture, and changes in social complexity. Instead, the history of people in this region is much more complicated and must be presented in such a manner.

These results may provide insight into the impacts of climate change on future generations. By drawing attention to the pitfalls of broad resolution sea level reconstructions and the need for localized data then more attention may be drawn to how specific regions are impacted. The limited evidence from this project supports the assessment that sea level change was less dramatic in Central Florida than Southwest Florida. The timeframe also appears different as signs of sea level change appear slightly later in Central Florida. Sassaman and colleagues (2011) describe similar circumstances in the Suwannee Delta. The compilation of multiple studies in this field can produce a greater perspective of how different parts of Florida
will change with MSL rise. A better understanding of global and local impacts in the past is necessary for interpreting our own human-environmental interactions in the future.
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Appendix 1
Profiles of Core 1, Sections 1 (left), 2 (center), and 3 (right).
Profiles of Core 2, Sections 1 (left), 2 (center), and 3 (right).
Profiles of Core 3, Sections 1 (left), 2 (center), and 3 (right).
Profiles of Core 4, Sections 1 (left), 2 (center), and 3 (right).
Profiles of Core 5, Sections 1 (left), 2 (center), and 3 (right).
Profiles of Core 6, Sections 1 (left) and 2 (right).
Profiles of Core 7, Sections 1 (left), 2 (center), and 3 (right).
Profiles of Core 8, Sections 1 (left), 2 (center), and 3 (right).
Profiles of Core 9, Sections 1 (left), 2 (center), and 3 (right).
Profiles of Core 10, Sections 1 (left), 2 (center), and 3 (right).
Profiles of Core 11, Sections 1 (left), 2 (center), and 3 (right).
Profiles of Core 12, Sections 1 (left), 2 (center), and 3 (right).
Profiles of Core 13, Sections 1 (left), 2 (center), and 3 (right).
Profiles of Core 13, Sections 4 (left) and 5 (right).
Profiles of Core 13, Sections 6 (left), and 7 (right).
Profiles of Core 13, Sections 8 (left) and 9 (right).
Profiles of Core 14, Sections 1 (left), 2 (center), and 3 (right).
Profiles of Core 15, Sections 1 (left) and 2 (right).
Profiles of Core 16, Sections 1 (left) and 2 (right).

1: (A) 10YR2/1 black with 10YR7/3 very pale brown lens (76 cm) sand loam (53.3% sand, 33.3% silt, 13.3% clay)

2: (A2) 10YR2/1 black sandy loam (53.3% sand, 33.3% silt, 13.3% clay)

3: (E) 10YR6/1 light gray mottled with 10YR2/1 black (80-89 cm) sandy loam (66.7% sand, 13.3% silt, 20% clay), rare shell

4: (E2) 10YR4/2 dark grayish brown with 10YR2/2 very dark brown loam (95-100 cm) sandy loam (76.7% sand, 13.3% silt, 10% clay)

5: (E3) 10YR5/1 gray sandy loam (73.3% sand, 20% silt, 6.7% clay)

6: (E4) 10YR4/2 dark grayish brown sandy loam (66.7% sand, 26.7% silt, 6.7% clay)

7: (E) 2.5Y5/4 light olive brown sandy loam (73.3% sand, 3.3% silt, 23.3% clay)

8: (E) 2.5Y4/3 olive brown clay (40% sand, 3.3% silt, 56.7% clay)

9: (C) 2.5Y6/4 light yellowish brown limestone

10: (C2) 2.5Y6/4 light yellowish brown clay (40% sand, 3.3% silt, 46.7% clay)

11: (R) 10YR8/2 white limestone
Profile of Core 17, Section 1.

1: (A) 10YR2/1 black loam (46.7% sand, 33.3% silt, 20% clay), rare shell

2: (AE) 10YR4/1 dark gray sandy loam (60% sand, 26.7% silt, 13.3% clay)

3: (E) 10YR6/2 light brownish gray sandy clay loam (63.3% sand, 10% silt, 26.7% clay)

4: (R) 10YR8/2 white limestone
Profiles of Core 18, Sections 1 (left) and 2 (right).
Profiles of Core 19, Sections 1 (left), 2 (center), and 3 (right).
Profiles of Core 20, Sections 1 (left) and 2 (right).
Profiles of Core 21, Sections 1 (left), 2 (center), and 3 (right).
Profiles of Core 21, Sections 4 (left) and 5 (right).
Profiles of Core 22, Sections 1 (left) and 2 (right).
Profiles of Core 22, Sections 3 (left) and 4 (right).
Profiles of Core 23, Sections 1 (left) and 2 (right).
1: (A) 10YR2/1 black sand loam (56.7% sand, 26.7% silt, 16.7% clay)

2: (AE) 10YR4/1 dark gray sandy clay loam (63.3% sand, 10% silt, 26.7% clay)

3: (E) 10YR7/1 light gray loamy sand (80% sand, 13.3% silt, 6.7% clay)

4: (B1) 10YR5/2 grayish brown loamy sand (86.7% sand, 13.3% silt)

5: (B2) 10YR2/2 very dark brown sandy clay loam (60% sand, 6.7% silt, 26.7% clay)

6: (B3) 10YR3/3 dark brown sandy clay loam (73.3% sand, 3.3% silt, 23.3% clay)

7: (R) 10YR7/2 light gray limestone

Profile of Core 24, Section 1.
Profile of Core 25, Section 1.

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-100</td>
<td>(A1) 10YR2/1 black mottled with gray particles, sand loam (56.7% sand, 26.7% silt, 16.7% clay)</td>
</tr>
<tr>
<td>100-110</td>
<td>(A2) 10YR2/1 block loam (50% sand, 33.3% silt, 16.7% clay)</td>
</tr>
<tr>
<td>110-120</td>
<td>(R) 10YR8/2 10YR8/2 white limestone mottled with 10YR2/1 black</td>
</tr>
</tbody>
</table>
Profile of Core 26, Section 1.

1: (Oa) 10YR2/2 very dark brown sandy loam (50% sand, 33.3% silt, 6.7% clay)

2: (C - Fill) (10YR7/4 very pale brown sandy loam (80% sand, 0% silt, 20% clay)

3: (2Ab) 10YR2/1 black sandy clay loam (53.3% sand, 16.7% silt, 30% clay)

4: (R) 10YR8/3 very pale brown limestone
Profile of Core 27, Section 1.

1: (A) 10YR/2 very dark brown sandy loam (60% sand, 20% silt, 20% clay)

2: (A1) 10YR 5/1 gray sandy clay loam (63.3% sand, 13.3% silt, 23.3% clay)

3: (E) 10YR 8/2 light brownish gray sand loam (66.7% sand, 13.3% silt, 20% clay)

4: (B) 10YR 4/2 dark brownish gray sandy loam (66.7% sand, 13.3% silt, 20% clay)

5: (B2) 10YR/2 very dark brown sandy clay loam (50% sand, 16.7% silt, 33.3% clay)

6: (C) 10YR 6/8 brownish yellow mixed with 10YR 8/2 white limestone, clay (40% sand, 0% silt, 60% clay)
Profiles of Core 28, Sections 1 (left) and 2 (right).
Profiles of Core 29, Sections 1 (left) and 2 (right).
Profiles of Core 30, Sections 1 (left) and 2 (right).
Profiles of Core 31, Sections 1 (left), 2 (center), and 3 (right).
Profiles of Core 32, Sections 1 (left), 2 (center), and 3 (right).
Profiles of Core 32, Sections 4 (left) and 5 (right).
Profiles of Core 33, Sections 1 (left) and 2 (right).
Profile of Core 34, Section 1.

1: (A) 10YR2/1 black sand loam (66.7% sand, 26.7% silt, 6.7% clay), occasional shell

2: (A2) 10YR2/1 black sandy clay loam (53.3% sand, 13.3% silt, 33.3% clay), rare shell
Profiles of Core 35, Sections 1 (left), 2 (center), and 3 (right).
Profiles of Core 36, Sections 1 (left) and 2 (right).

<table>
<thead>
<tr>
<th>Depth</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 cm</td>
<td>void</td>
</tr>
<tr>
<td>10 cm</td>
<td>slough: 10YR2/1 black mottled with yellowish brown</td>
</tr>
<tr>
<td>20 cm</td>
<td>7: (2E3) 10YR7/1 light gray sandy loam (80% sand, 3.3% silt, 16.7% clay)</td>
</tr>
<tr>
<td>30 cm</td>
<td>7: (2E3) 10YR7/1 light gray sandy clay loam (66.7% sand, 3.3% silt, 30% clay)</td>
</tr>
<tr>
<td>40 cm</td>
<td>3: (E) 10YR7/1 light gray loamy sand (86.7% sand, 13.3% silt, 0% clay)</td>
</tr>
<tr>
<td>50 cm</td>
<td>4: (2Ab) 10YR2/1 black sandy clay loam (63.3% sand, 6.7% silt, 30% clay)</td>
</tr>
<tr>
<td>60 cm</td>
<td>7: (2E3) 10YR7/1 light gray sandy clay loam (66.7% sand, 3.3% silt, 30% clay)</td>
</tr>
<tr>
<td>70 cm</td>
<td>8: (2B) 10YR5/2 grayish brown sandy loam (80% sand, 6.7% silt, 13.3% clay)</td>
</tr>
<tr>
<td>80 cm</td>
<td>9: (2B2) 10YR3/2 very dark grayish brown loamy sand (83.3% sand, 6.7% silt, 10% clay)</td>
</tr>
<tr>
<td>90 cm</td>
<td>10: (2B3) 10YR2/1 very dark gray sandy clay (50% sand, 6.7% silt, 43.3% clay)</td>
</tr>
<tr>
<td>100 cm</td>
<td>slough: 10YR2/1 black mottled with yellowish brown</td>
</tr>
<tr>
<td>110 cm</td>
<td>very dark gray sandy clay</td>
</tr>
<tr>
<td>120 cm</td>
<td>void</td>
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</tbody>
</table>

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Profiles of Core 37, Sections 1 (left) and 2 (right).
Profiles of Core 38, Sections 1 (left), 2 (center), and 3 (right).
Profiles of Core 39, Sections 1 (left), 2 (center), and 3 (right).
Profiles of Core 40, Sections 1 (left), 2 (center), and 3 (right).
Profiles of Core 41, Sections 1 (left), 2 (center), and 3 (right).
Profiles of Core 42, Sections 1 (left) and 2 (right).
Profile of Core 43, Section 1.

1: void

2: slough: 2.5Y5/2 grayish brown mottled with 10YR2/1 black

3: void

4: 11: (3Ab) 10YR2/1 black clay (43.3% sand, 13.3% silt, 43.3% clay)

5: 12: (3b) 2.5Y5/2 grayish brown clay (40% sand, 16.7% silt, 43.3% clay), rare shell

6: 13: (3E2) 10YR3/1 very dark gray sandy clay (50% sand, 13.3% silt, 36.7% clay), occasional shell

7: 14: (3E3) 10YR4/1 dark gray sandy clay loam (53.3% sand, 16.7% silt, 30% clay), rare shell

8: 15: (3b) 10YR5/3 brown mottled with 10YR7/3 very pale brown with 5Y 4/1 dark gray lenses, sandy clay (46.7% sand, 13.3% silt, 40% clay), rare shell

9: 16: (3B2) 10YR5/2 grayish brown sandy clay loam (63.3% sand, 3.3% silt, 33.3% clay)

10: 17: (3h3) 10YR4/1 dark gray sandy clay (60% sand, 3.3% silt, 36.7% clay)

11: (R) 10YR8/2 white limestone

12: white limestone
Profiles of Core 44, Sections 1 (left), 2 (center), and 3 (right).

1: (A) 10YR2/1 black mottled with white particles sandy loam (60.7% sand, 26.6% silt, 13.3% clay), occasional shell

2: (A2) 10YR2/1 black sand loam (60% sand, 26.7% silt, 13.3% clay), common shell

3: (AE) 10YR3/2 very dark grayish brown mottled with 10YR2/1 black and 7.5YR4/6 strong brown oxidation sandy loam (56.7% sand, 26.7% silt, 16.7% clay), rare shell

4: (AE2) 10YR3/1 very dark gray with 7.5YR4/6 strong brown oxidation sandy loam (46.7% sand, 13.3% silt, 40% clay), rare shell

5: (E) 10YR6/2 light brownish gray mottled with 10YR4/1 dark gray sandy clay loam (73.3% sand, 33.3% silt, 23.3% clay)

6: (2Ab) 10YR2/1 black sandy clay loam (46.7% sand, 20% silt, 33.3% clay), rare shell

7: (2AE) 10YR4/1 dark gray sandy clay loam (50% sand, 20% silt, 30% clay)

8: (2E) 10YR3/1 gray sandy clay (53.3% sand, 10% silt, 36.7% clay)

9: (3Ah) 10YR2/1 black clay loam (40% sand, 20% silt, 40% clay)

10: (3E) 10YR7/2 light gray with 10YR3/1 dark gray lens loamy sand (80% sand, 13.3% silt, 6.7% clay)

11: (3EB) 10YR6/2 light brownish gray sandy loam (83.3% sand, 3.3% silt, 13.3% clay)

11: (3EB) 10YR6/2 light brownish gray sandy loam (83.3% sand, 3.3% silt, 13.3% clay)

12: (3B) 10YR5/2 grayish brown sandy clay loam (76.7% sand, 0% silt, 23.3% clay)

13: (3C) 2.5YR3/3 light olive brown mottled with 10YR7/8 yellow limestone clay (45.3% sand, 3.3% silt, 53.3% clay)

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Profiles of Core 45, Sections 1 (left), 2 (center), and 3 (right).
Profiles of Core 46, Sections 1 (left) and 2 (right).
Profile of Core 47, Section 1.

1: (A) 10YR2/1 black sandy clay loam (46.7% sand, 20% silt, 33.3% clay), occasional shell

2: (A1b) 10YR3/2 very dark grayish brown sandy clay loam (50% sand, 16.7% silt, 33.3% clay), occasional shell

3: (A1c2) 10YR3/1 very dark gray sandy clay loam (50% sand, 16.7% silt, 33.3% clay), occasional shell
Profile of Core 48, Section 1.

1: (A) 10YR2/1 black clay loam (30% sand, 33.3% silt, 36.7% clay), rare shell

2: (AE) 10YR3/1 very dark gray sandy clay (46.7% sand, 16.7% silt, 36.7% clay), rare shell
Profile of Core 49, Section 1.

1: (A) 10YR2.1 black sandy clay loam (46.7% sand, 20% silt, 33.3% clay)
Profile of Core 50, Section 1.

1: (A) 10YR/2.1 black sandy clay loam (46.7% sand, 23.3% silt, 30% clay), rare shell
Profile of Core 51, Section 1.

1: (A) 10YR2/1 black clay loam (36.7% sand, 30% silt, 33.3% clay)
1: (A) 10YR2/1 black sandy clay loam (53.3% sand, 30% silt, 16.7% clay)

2: (b) 7.5YR7/0 light gray mottled with 10YR5/1 gray (47-57 cm) sandy clay loam (66.7% sand, 3.3% silt, 30% clay)

3: (1/2) 10YR6/1 light gray sand loam (76.7% sand, 6.7% silt, 16.7% clay)

4: (2Ab) 10YR2/1 black sandy clay loam (63.3% sand, 6.7% silt, 30% clay)

5: (B) 10YR2/2 very dark brown sandy loam (66.7% sand, 13.3% silt, 20% clay)

Profile of Core 52, Section 1.
Profile of Core 53, Section 1.

1: (A) 10YR2/1 black clay (26.7% sand, 13.3% silt, 60% clay)

2: 6.~ 7.5YR7/0 light gray mottled with 10YR6/1 gray (70-79 cm) sandy clay loam (63.3% sand, 6.7% silt, 30% clay)

3: (E6) 10YR6/2 light brownish gray sand loam (73.3% sand, 6.7% silt, 13.3% clay)

4: (B) 10YR4/2 dark grayish brown sandy loam (80% sand, 6.7% silt, 13.3% clay)
Profile of Core 54, Section 1.

1: (A) 10YR2/1 black sandy clay loam (50% sand, 20% silt, 30% clay)

2: (AE) 10YR5/2 grayish brown sandy clay (53.3% sand, 10% silt, 36.7% clay)

3: (EB) 10YR7/3 very pale brown mottled with 10YR6/8 brownish yellow sandy loam (76.7% sand, 3.3% silt, 16.7% clay)

4: (2Ab) 10YR2/1 black sandy clay loam (56.7% sand, 20% silt, 23.3% clay)

5: (2E) 10YR6/1 light gray mottled with 10YR3/1 very dark gray (96-99 cm) sand loam (76.7% sand, 3.3% silt, 16.7% clay)

6: (2EB) 10YR6/2 light brownish gray sandy clay loam (66.7% sand, 6.7% silt, 26.7% clay)
### Profile of Core 55, Section 1.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(A) 10YR2/1 black with 7.5YR8/0 white lens sandy clay loam (53.3% sand, 23.3% silt, 23.3% clay)</td>
</tr>
<tr>
<td>2</td>
<td>(AE) 10YR3/1 very dark gray sandy clay loam (73.3% sand, 3.3% silt, 23.3% clay)</td>
</tr>
<tr>
<td>3</td>
<td>(AE2) 10YR3/2 very dark grayish brown mottled with 10YR3/1 very dark gray sandy clay loam (66.7% sand, 6.7% silt, 26.7% clay)</td>
</tr>
<tr>
<td>4</td>
<td>(EB) 10YR5/2 grayish brown sandy loam (73.3% sand, 6.7% silt, 20% clay)</td>
</tr>
<tr>
<td>5</td>
<td>(B) 10YR3/2 very dark grayish brown sandy loam (80% sand, 6.7% silt, 13.3% clay)</td>
</tr>
<tr>
<td>6</td>
<td>(2A) 10YR2/1 black clay loam (40% sand, 20% silt, 40% clay)</td>
</tr>
</tbody>
</table>
Profile of Core 56, Section 1.

1: (A) 10YR2/2 very dark brown sandy clay loam (50% sand, 23.3% silt, 26.7% clay)

2: (AE) 10YR3/1 very dark gray mottled with 10YR6/1 light gray sandy clay loam (53.3% sand, 16.7% silt, 30% clay)

3: A, 10YR6/1 light gray mottled with 10YR3/1 very dark gray sandy clay loam (66.7% sand, 6.7% silt, 26.7% clay)

4: (EB) 10YR6/2 light brownish gray sandy loam (76.7% sand, 6.7% silt, 16.7% clay)

5: (B) 10YR2/2 very dark brown loamy sand (80% sand, 10% silt, 10% clay)

6: (B2) 2.5Y4/3 olive brown loamy sand (80% sand, 10% silt, 10% clay)

7: (2Ab) 10YR2/1 black sandy clay loam (53.3% sand, 16.7% silt, 30% clay)

8: (2EB) 10YR6/3 pale brown mottled with 10YR4/2 dark grayish brown
Profile of Core 57, Section 1.

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
<th>Sand (%)</th>
<th>Silt (%)</th>
<th>Clay (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(A) 10YR2/1 black with 10YR8/2 white lens loam</td>
<td>46.7</td>
<td>30</td>
<td>23.3</td>
</tr>
<tr>
<td>2</td>
<td>(E) 10YR5/4 gray mottled with 10YR2/1 black sandy clay loam</td>
<td>60</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>(2A) 10YR2/1 black mottled with 10YR5/1 gray sandy clay loam</td>
<td>63.3</td>
<td>10</td>
<td>26.7</td>
</tr>
<tr>
<td>4</td>
<td>(2B) 10YR6/1 light gray mottled with 10YR3/1 very dark gray sandy clay loam</td>
<td>70</td>
<td>6.7</td>
<td>23.3</td>
</tr>
</tbody>
</table>
Profile of Core 58, Section 1.

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 20</td>
<td>Void</td>
</tr>
<tr>
<td>20 - 40</td>
<td>O Horizon</td>
</tr>
<tr>
<td>1: (A)</td>
<td>10YR2/1 black mottled with 7.5YR8/0 white and 10YR7/1 light gray sand loam (73.3% sand, 6.7% silt, 20% clay)</td>
</tr>
<tr>
<td>2: (A2)</td>
<td>10YR2/1 black mottled with 10YR5/2 grayish brown sandy clay loam (63.3% sand, 6.7% silt, 30% clay)</td>
</tr>
<tr>
<td>3: (E)</td>
<td>10YR6/1 light gray sandy clay loam (70% sand, 3.3% silt, 26.7% clay)</td>
</tr>
<tr>
<td>4: (H2)</td>
<td>10YR5/1 gray mottled with 10YR2/1 black sandy clay loam (63.3% sand, 10% silt, 26.7% clay)</td>
</tr>
<tr>
<td>5: (EB)</td>
<td>10YR4/1 dark gray sand loam (73.3% sand, 6.7% silt, 20% clay)</td>
</tr>
<tr>
<td>6: (B)</td>
<td>10YR3/2 very dark grayish brown sandy sand loam: 80% sand, 6.7% silt, 13.3% clay</td>
</tr>
</tbody>
</table>